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Evaluation of a Remote Early Disease Identification system to detect bovine respiratory disease in beef cattle in commercial Australian feeding operations – Site 2

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Abstract

The objective of this project was to evaluate a remote early disease identification (REDI) system to diagnose BRD versus conventional (CON) disease detection and diagnosis of feedlot cattle at an Australian feedyard (Site 2). Six replicates of cattle were enrolled in the trial. Calves were randomly assigned to one diagnostic modality (REDI vs CON) with 300 steers per pen. Health and performance outcomes between the two diagnostic modalities were compared. The REDI system monitored calves for the first 55 days on trial. Calves initially treated for BRD were greater ($P < 0.05$) in CON (44% ± 0.07) compared to REDI (27% ± 0.05). Second BRD treatments were greater ($P < 0.05$) in REDI compared to CON. Calves initially treated for BRD had greater ($P < 0.05$) normal lung scores (75% ± 0.04) in CON compared to REDI (70% ± 0.04) and REDI had greater moderate lung scores (26% ± 0.05) compared to CON (21% ± 0.04) during the REDI monitoring period. Calves not treated for BRD had greater ($P < 0.05$) normal lung scores (75% ± 0.04) in CON compared to REDI (70% ± 0.04), and REDI had greater ($P < 0.05$) moderate lung scores (28% ± 0.05) compared to CON (24% ± 0.04). There were no differences in severe lung scores, mortalities, rejects, or performance between modalities. The results indicate that REDI can detect more calves with moderate lung scores compared to CON with a lesser treatment rate.

Executive summary

The objectives of this project were to evaluate a remote early disease identification (REDI) system to diagnose BRD versus conventional (CON) disease detection and diagnosis of feedlot cattle and determine the impact of BRD on feedlot performance and carcass characteristics. This final report outlines findings for Site 2 where research was conducted independently of Site 1 (See MLA Final Report B.FLT.0242 – Site 1).

A total of 3,599 steers were allocated to REDI pens and CON pens based on a coin flip as the animals came through the chute to determine sequence of alternate randomization for each block (n=6) of the experiment. Pens were checked each morning in the same order each day. The same pen riders for a given day of the trial were used to detect and diagnose sick cattle from the CON pens. Control pens were checked prior to the REDI pens. All BRD identification in the REDI pens were conducted using the REDI system. All data collected from the REDI tags were transferred to the readers, which were then transferred to an on-site server where calculations of movements, proximity, and social indices are performed prior to uploading of aggregated data to the cloud server. The cloud server then applied the REDI disease classification engine to generate the BRD status of an individual steer and the reports then replayed to a digital platform for personnel to determine which steers needed to be pulled by pen riders for daily treatments. Monitoring for BRD using the REDI system can only occur when the animal is within the REDI pens, given this limitation, at approximately 60 days on feed (DOF), REDI cattle were removed from their home pens and the REDI tags were removed. Animals in the CON or REDI pens were slaughtered based on blocks on the same DOF endpoint, approximately 187 DOF. Lung scores, in the form of lung consolidation, pleurisy, and abscesses were recorded at the slaughter plant for every animal eligible to be scored. Lung scores were categorized as normal, moderate, and severe. The experimental unit for the statistical analysis was the pen, due to the treatment (REDI and CON) being applied to individual pens. Individual animal data were aggregated on a pen level. Generalized logistic regression models with a logit link were utilized to calculate the probability of binomial outcomes of interest (morbidity, mortality, lung consolidation, pleurisy, lung score, meat colour, fat colour, MSA marbling, Ossification, Rib Fat, EMA, and weight). Linear mixed models were utilized to determine associations of continuous variables (average daily gain, in-weight, final weight, and pH) with the treatment applied. Random effects were included in each model for replicate. Main effects were considered significant at $P \leq 0.05$.

Results from the trial showed no statistical differences between treatment groups for mortalities, rejects, or carcass / performance characteristics. A significant difference was found between initial BRD treatment and BRD relapse between REDI vs CON during the REDI monitoring period (~60 days on feed), with REDI treating 29% of cattle initially for BRD, and a secondary treatment for 51% of initially treated animals compared to 44% and 31% for the CON group. Initial BRD treatment in REDI occurred in the first 6 days on feed. Of animals treated for BRD, there were significantly more normal lung scores in the CON group compared to the REDI group.

The reported trial demonstrated that REDI is comparable to conventional detection for lung lesions, mortality, and carcass performance with greater accuracy of BRD detection in animals with moderate lung lesions. Further research is required to calibrate the REDI system to Australian conditions as there was no productivity advantages to using the system.

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1 Background

Bovine respiratory disease (BRD) affects the health and performance of feedlot cattle in the United States as well as Australia (Sackett D, 2006). The economic impact of BRD is significant in the feeding and slaughtering of cattle in both regions (Galyean et al., 1999; Lechtenberg et al., 2011). Common diagnostic modalities that are currently available for BRD in the field include visual assessment, rectal temperature, and Whisper scores (Mang et al., 2015; Wolfger et al., 2015). The methods have been shown to have a poor specificity and sensitivity (Nickell and White, 2010; Theurer et al., 2013a; Theurer et al., 2013b; Timsit et al., 2016). A poor diagnostic sensitivity can result in cattle who are truly diseased, but not treated, and a poor specificity can result in cattle who are not diseased yet were treated for BRD (White and Renter, 2009; Amrine et al., 2013; Theurer et al., 2015a).

A report from the 2011 US Department of Agriculture survey, reported the percent of feedyards with pen-riding or walking procedures conducted on animals more than twice a day less than 15 days after arrival were 20.3%, twice a day were 44.5%, once a day was 32.1%, less than once a day was 1.1%, and no standard procedure was 2% (NAHMS, 2011). Thirty days after feedlot arrival, these numbers dropped to 5.5%, 13.5%, 70.2%, 7.4%, and 3.4% respectively. The results demonstrate that after 30 days of arrival, most animals (70.2%) on feed in the United States are only being visually assessed once a day. Visual assessment may take a pen rider approximately 5 mins per pen, which results in about 1 second per animal in a pen of 300.

Behaviour monitoring is now being investigated for a more accurate diagnostic modality of BRD. Previous research has reported changes in feeding, water, distance travelled, and social behaviour on individual animals affected with BRD compared to the rest of the pen. A Remote Early Disease Identification (REDI) system has been reported to diagnose cattle with BRD based on behavioral changes related to feed, water, distance, and social indices (White et al., 2014; White et al., 2015b). Previous research has reported REDI to diagnose animals three days before visual assessment. REDI continuously monitors cattle behaviour 24 hours each day, whereas conventional methods might include visual assessment of cattle once or twice a day.

2 Project objectives

The first objective of the project was to evaluate a remote early disease identification (REDI) system to diagnose Bovine Respiratory Disease (BRD) versus conventional (CON) disease detection used in diagnosis of feedlot in New South Wales, Australia (Site 2). A second objective was to determine the impact of BRD on feedlot performance and carcass characteristics by analysis of treatment records and lung score data at slaughter. The trial was approved by the Secretaries Animal Care and Ethics Committee in the State of New South Wales, Australia.

3 Methodology

3.1 Animal Enrolment

Cattle enrolled in the study were procured from vendors and were comprised of Angus cross, Hereford cross, and shorthorn cross breed and all cattle were steers. Upon arrival at the feedlot, steers were kept separate by vendor overnight with free access to clean water, prior to induction the following morning. Once enough cattle were accrued, they were inducted and randomly split into trial lots. It took 3-9 days to fill 2 treatment pens with 300 head each. The arrival processing included scanning of individual National Livestock Identification Scheme RFID tag, identification with plastic lot tag and individual animal barcode identification, administration of an oral Benzimidazole drench for treatment of internal and external parasites, and vaccination again

respiratory pathogens with Bovilis MH + IBR (Coopers Animal Health, Australia) and Rhinogard (Zoetis Animal Health, Australia). All steers were implanted at induction (Component S and Compudose 200, Elanco Animal Health, Australia). An initial body weight (day 0; 365.01 ± 3.36 kg) was obtained for all animals at feedlot induction at the processing hydraulic squeeze-chute prior to feeding (Warwick Cattle Crush Co). The chute operator ensured that stable body weights were recorded. The chute was calibrated prior to the start of allocation by a certified technician, across the expected range of body weight in the experiment (i.e. 250 to 750 kg), with certification records placed on file.

Steers were randomly allocated to REDI or CON pens within cattle source, alternately, as they passed through the processing chute during feedlot induction. A flip of a coin was used to determine the sequence of alternate randomization for each block of the experiment, with heads = CON first, and tails = REDI first. REDI and CON cattle in each block were randomly placed in adjacent pens of a grid of 8 REDI pens and 8 CON pens. The 1st four blocks were allocated in the Autumn and the last two blocks were allocated in Spring. All individual animals were allocated over 3 – 9 days, with the first and third block allocated over the first 3 days, the second block allocated over the first and fourth days, the fourth allocated over the first and seventh days, the fifth block allocated over the first, third, sixth, and ninth days, and the sixth block allocated over the first and third days.

Animals in the REDI treatment received a wi-fi real-time locational system tag (Precision Animal Solutions, Kansas) applied in the opposite ear to the NLIS RFID tag. After treatment allocation, steers were placed in dirt floored pens. Manure depth was approximately the same in REDI and CON pens with cleaning records placed on file. Pens held approximately 300 head and were 80m long and 50m depth (13.3m^2 / head) and had <2% slope. Each pen had 73.5m of bunk space (24.5cm / head). All pens had slatted corrugated shade with steel post supports that were 4m high and iron sheets that were 8m in width. Pen waters were shared along the fence-line with adjoining pens 31m from the feedbunk and 14.5m from the back fence. Water troughs were cleaned out twice weekly with cleaning records placed on file.

3.2 Control Configuration

Pens were checked early each morning in the same order each day. The same roster of pen riders was utilized to detect and diagnose sick cattle from the CON pens. Control pens were checked prior to the REDI pens. Cattle that exhibited visual signs of BRD (depression score: mild (1), moderate (2), or severe (3)) were removed from the pen and taken to the hospital chute (Warwick Cattle Crush Co) for primary treatment with Draxxin (Zoetis Animal Health, Australia) (**Table 1**). The BRD depression scores relate to generalized listless, lethargy, dull, and lack of purpose. BRD depression score (3) involves profound depression, low head carriage, slow moving, sleepy / dull eyes, markedly reduced prey animal awareness, or lack of maintenance. Respiratory scores were applied to upper respiratory cases and severe (3) depression scores. Respiratory scores are (0) for normal respiratory rate and action, (1) for increased respiratory rate, and (2) for increased respiratory rate and / or labored breathing. Rectal temperature was not used for case definition of BRD for treatment, but rectal data were recorded of animals treated.

Table 1. Definitions for treatment for initial BRD therapy during the experiment for CON animals using depression scores.

Depression Score	Diagnosis	Treatment
1	BRD	Draxxin, sent back to home pen
2	BRD	Draxxin, sent back to home pen
3	BRD	Draxxin, placed in hospital pen

If an animal was detected a second time with BRD visual symptoms in their pen (home or hospital), and at least a 5-day post-treatment interval had lapsed since initial Draxxin treatment,

then retreatment occurred with Oxytetracycline (Engemycin 100; Merck MSD). All animals treated a second time were returned to the home pen. Animals were only allowed two antibiotics, if an animal was pulled a third time for BRD it was treated according to feedlot veterinary protocol, had a body weight recorded, classified as a reject, and removed from the trial pen. The animals were not to re-enter the trial pen again after being classified as a reject. All other health conditions or ailments that an animal was diagnosed with were treated according to the feedlot standard protocol and recorded by the feedlot system's software. If an animal was classified as a buller throughout the trial it was also removed and placed in a separate pen and was not allowed to re-enter the home pen.

3.3 REDI Configuration

The eight REDI pens were equipped with real-time locational system technology. The equipment and data management were performed as in previous research. All BRD identification in the REDI pens was conducted using the REDI system. The REDI pens were equipped with readers surrounding the fence perimeter. A REDI tag was placed in the ear of each individual steer and the location engine software calculated the time of arrival of signals between sensors and tags to calculate the location of each calf in the pen at 4 second intervals. All data collected from the REDI tags were transferred to the readers, which were then transferred to an on-site server where calculations of movements, proximity, and social indices are performed prior to uploading of aggregated data to the cloud server. The cloud server then applied the REDI disease classification engine to generate the BRD status of an individual steer and the reports then replayed to a digital platform for personnel to determine which steers needed to be pulled by pen riders for daily treatments.

REDI pens were checked daily by the same pen riders that checked the CON pens. CON pens were checked prior to the REDI pens to not bias the decision of the pen riders entering the CON pens. Pen riders received the list of BRD pulls that the system called as sick. The animal's tags were illuminated prior to the riders entering the pen, signalling that they were required to be a pull. A check list of the pulls was taken to cross-reference with visual tags to ensure the correct animals were removed from the pen and treated. Any animal pulled by REDI was treated, with no exceptions. Once an animal entered the REDI pen after induction, it was not eligible to be pulled for 36 hours, after this time was elapsed, all animals were eligible to be called sick. All animals pulled and treated for the first BRD diagnosis were treated with Draxxin (Zoetis Animal Health, Australia), and a rectal temperature was recorded. After Draxxin treatment, cattle were immediately returned to their home pen, unless animals were severely affected by BRD (BRD depression score 3) and were placed in the hospital pen. A minimum of 5 days post-treatment interval after primary Draxxin treatment were required before an animal qualified for re-treatment. If an animal was called sick a second time by REDI it was treated with oxytetracycline and was returned to the home pen unless they were severely affected with BRD. Once treated a second time, an indefinite PTI was labelled, and REDI was no longer able to determine health status of the animal. After the second treatment, pen riders determined the criteria for animals being pulled a third time. If pen riders pulled an animal for BRD a third time, the animal had a body weight recorded and was classified as a reject, placed in the hospital pen and not allowed to re-enter the home pen. REDI is only able to monitor cattle behaviour when the animal was located within the REDI pens.

The REDI system only observed animals for BRD diagnosis, any other non-BRD issue an animal had that was observed by the pen riders were removed and treated through the standard feedlot convalescence and hospital system. Animals that were observed with BRD by the pen riders and not pulled by the REDI system were determined to be overrides. The feedyard manager made the final decision to determine if a calf in the REDI pen was truly an override (n=20).

3.4 Behaviour Monitoring Period

Monitoring for BRD using the REDI system can only occur when the animal is within the REDI pens, given this limitation, at approximately 60 days on feed (DOF), REDI cattle were removed from their home pens and the REDI tags were removed. All cattle returned to the same pen after the REDI tag was removed. Cattle in REDI and CON treatments for Blocks 1 & 2 were moved to new adjacent pens for the remainder of the feeding, before Blocks 5 and 6 were inducted. Body weights for both treatment groups, REDI and CON, were recorded at the 60-day REDI tag removal time. Cattle were weighed before the morning feeding. Any cattle that were pulled for BRD greater than 60 DOF in either treatment group were treated with Oxytetracycline (Engemycin 100, Merck, MSD).

3.5 Feeding Management

Cattle were fed to achieve ad-libitum consumption. Cattle on starter rations are transitioned to the finisher diet over a 21-day period. Cattle for blocks 1 to 3 had six days on ration 1, ration 2, ration 3, and a 3 day transition to the finisher ration. Cattle for blocks 4 to 6 were adapted via a titration method of combining ration 1 and finisher ration (ration 4). Cattle on the finisher ration (ration 4) were fed twice a day with a 7kg drop in the morning feeding. Within a source block both the CON and REDI pens were transitioned to rations at the same days on feed. Diets were delivered in a feed truck (Rotomix 920; Rotomix, Kansas). All feed trucks were calibrated prior to the experiments initiation by a certified technician with records placed on file. Feedlot scale checks occurred twice a week. Any food that was removed from the bunk due to spoilage was weighed in a loader bucket with records placed on file, and any feed remaining in the bunk at cattle shipment was estimated and recorded. All flake weights of grain processed were recorded. Dry matters of rations 4 were determined daily from 100g sub-samples of diets obtained from the CON and REDI pens in a fan-forced oven at 105°C for a minimum of 16 hours. Finisher diets were sampled once weekly on Monday throughout the duration of the trial. A monthly composite sample of each finisher treatment diet was analyzed for dry matter (DM), protein, non-detergent fiber (NDF), fat, fiber, ash, calcium (Ca), and phosphorus (P). Analysis was performed by Symbio Labs in Queensland, Australia. If a diet was changed during the trial, both the CON and REDI treatments were changed to the diet at the same time and the change was recorded.

3.6 Slaughter

Animals in the CON or REDI pens were slaughtered based on blocks on the same DOF endpoint, approximately 170 DOF. If there were limitations in slaughter capacity at the processing plant, an equal number of REDI and CON animals were shipped and slaughtered. All animals within each block were slaughtered within a 7-day period. Any cattle that were determined to be a chronic and were located within the chronic pen were classified as ‘Rejects’ and had their body weights recorded and removed from the experiment and marketed as either grass-fed, Pet-food, or salvaged for marketing at a later date into alternative Grain-fed programs. If chronic cattle were marketed earlier to this date, then their body weights were recorded at feedlot exit. On the morning of exit from the feedlot, prior to feeding, animals in both treatment groups were weighed on the cattle weighbridge. Prior to shipment, the weighbridge was certified. Time of cattle shipment varied from 6 am to 7 pm, and cattle were transported 1.5 hours from the feedlot to the slaughter facility. Cattle were slaughtered the following day around 6 am. At slaughter, the barcode ID and NLIS tag were scanned by a trained operator and matched to body number. Carcass grading occurred on all carcasses at approximately 18 hours after slaughter at (0-2°C).

3.7 Lung Scores

Lung scores, in the form of lung consolidation, pleurisy, and abscesses were recorded at the slaughter plant for every animal eligible to be scored. Scoring was performed by the same three people, who were trained prior to initial scoring. Animals that died or were rejected from the trial did not have a lung score recorded. Animals that were condemned also did not have a lung score recorded. If an animal's lungs were stuck to the thoracic wall, a consolidation score was not recorded (No score), but the animal did receive a pleurisy score. Consolidation was recorded based on a scale of 0-100%. Consolidation scores were categorized into four categories, 0%, 1-10% and 11-49%, and greater than 50%. Pleurisy scores ranged from 0-3. Score 0 is no pleurisy, score 1 is pleuritic tags between lung lobes, or on the lung surface with no adhesion on the pleura of the thorax, a score 2 was pleuritic lesions with localized adhesion to the thoracic wall, and a score 3 was severe pleuritic adhesions with the chest requiring "Stripping". An animal where the lungs were adhered to the thoracic wall received a pleurisy score 3, and a consolidation score was not recorded. An overall lung score was created based on the combination of consolidation and pleurisy scores. Lung scores were categorized as normal, moderate, or severe (**Table 2**). If an animal was rejected due to BRD, or necropsy confirmed BRD for an animal that died throughout the trial, these animals were categorized as severe. Any other animal that was rejected or died for other reasons was not included in the normal, moderate, or severe lung score. Any animal that was missing from the pen when blocks were taken to slaughter, missing a lung score based on human error, or were slaughtered out of order were not included in the lung score analysis.

T**able 2.** Lung categorization table. The rows indicate the categories used for percent lung consolidation and the columns represent the category for pleurisy.

	Pleurisy				
Consolidation	**0**	**1**	**2**	**3**	**No Score**
0%	N	N	M	S	M
1-10%	N	M	M	S	M
11-49%	M	M	S	S	M
>50%	S	S	S	S	M
No Score	M	M	M	S	M

Normal	N
Moderate	M
Severe	S
BRD Dead/Reject	S
Dead/Reject	N/A
Total	

3.8 Data collection

The REDI system monitored steers equipped with REDI tags for the first approximately 60 days on trial (range 53 – 65 days). After tag removal, steers were monitored daily by pen riders and feedlot personnel until trial conclusion (slaughter). Health events and treatments were recorded for all animals by feedlot software and hand-written data sheets. Health records included individual animal identification, replication number, induction date, event type (first, second, or third treatment for BRD; treatment for any other reasons), rectal temperature, body weight, REDI tag identification, and treatment group. All steers were weighed individually at arrival and 60-day tag removal to determine changes in body weight. Animals were weighed as a group before slaughter. Any animals that died during the trial had a necropsy performed by veterinarian or feedlot staff personnel and diagnosis was recorded. Health outcome variables and formulas are presented in **Table 3**. The table describes variables, descriptions, and formulas for animals enrolled and followed through slaughter. The same outcomes variables were used for animals treated for BRD from allocation to behavior tag removal and animals not treated for BRD from allocation to slaughter.

Table 3. Health outcome variables, descriptions, and formulas for animals from allocation through slaughter. The variables were also analysed for animals treated for BRD from allocation through behaviour tag removal (approximately 60 days on feed) and animals not treated for BRD from allocation to slaughter. Denominators for allocation to slaughter, BRD1 and non-BRD will be different for health outcomes.

Variable	Descriptions	Formula
Initial BRD treatment	Animals pulled and treated for initial BRD from enrollment to slaughter	$\frac{\text{BRD1}}{\text{Total animals enrolled}}$
First BRD relapse	Animals pulled and treated for second BRD from enrollment to slaughter	$\frac{\text{BRD2}}{\text{BRD1}}$
Second BRD relapse	Animals pulled and treated for third BRD from enrollment to slaughter	$\frac{\text{BRD3}}{\text{BRD2}}$
BRD Trial Rejects	Animals diagnosed and treated 2 times for BRD and determined to be chronic, removed from the trial	$\frac{\text{BRD Trial Rejects}}{\text{Total animals enrolled}}$
Trial Rejects	Animals removed from the trial due to Bloat, Buller, Lame, Lost, Polio	$\frac{\text{Trial Rejects}}{\text{Total animals enrolled}}$
BRD Mortality Rate	Mortality due to BRD	$\frac{\text{BRD mortality}}{\text{Total animals enrolled}}$
Mortality Rate	Morality due to Downer, Polio, or unknown	$\frac{\text{Other mortality}}{\text{Total animals enrolled}}$
Lung consolidation	Lung consolidation was categorized and analyzed based on the percent of consolidation. Categories included animals with 0%, 1-9%, 10-49%, and >50%. All animals enrolled in the trial and were followed through slaughter are included	$\frac{\text{Consolidation category}}{\text{Total animals with lung scores}}$
Pleurisy score	Pleurisy score from 0-3 were assigned to all animals at slaughter. 0, No pleurisy; 1, Pleuritic tags between lung lobes, or on the lung surface. No adhesions on the pleura of the thorax; 2, Pleuritic lesions with localized adhesions to the thoracic wall; 3, Severe pleuritic adhesions with the chest requiring “stripping”. All animals enrolled in the trial and were followed through slaughter are included	$\frac{\text{Pleurisy score}}{\text{Total animals with lung scores}}$
Normal	Animals categorized with normal lung lesions at slaughter	$\frac{\text{Normal Lung Score}}{\text{Total animals with lung scores}}$
Moderate	Animals categorized with moderate lung lesions at slaughter	$\frac{\text{Moderate Lung Score}}{\text{Total animals with lung scores}}$
Severe	Animals categorized with severe lung lesions at slaughter	$\frac{\text{Severe Lung Score}}{\text{Total animals with lung scores}}$
BRD_Dead/Reject + Severe	Animals that were categorized as dead and reject and combined with the severe category lung score	$\frac{\text{Severe} + \text{BRD Dead/Reject}}{\text{Total animals with lung scores}}$

Performance data included average daily gain (ADG) from allocation to slaughter and allocation to behavior tag removal. Finisher feed analysis was sampled monthly and analyzed dry matter (DM), protein, non-detergent fiber (NDF), fat, fiber, ash, calcium (Ca), and phosphorus (P). Carcass data included kill date, body number, sex, dentition, butt shape, fat depth (P8), fat colour, meat colour, hump height, MSA Marbling, Ossification, pH, Rib Fat, EMA, and total hot dressed weight. All the data were collected for an MSA un-grade. Categories were created for meat colour, fat colour, MSA marbling, MSA Marbling, Ossification, Rib Fat, EMA, and weight based on quartiles, distributions, or known categories. Fat depth and pH remained continuous variables. Performance outcome variables and formulas are presented in **Table 4**.

Table 4. Performance outcome variables, descriptions, and formulas for animals enrolled until slaughter. Each outcome was evaluated by diagnostic modality (Control vs REDI).

Variable	Descriptions	Formula
In-weight	Individual animal initial weight. 60d weights were also recorded	$\frac{\text{In} - \text{weight per pen total}}{\text{Total animals enrolled}}$
Out-weight	Full body weight taken before feeding over pen scale before dispatch	$\frac{\text{Out} - \text{weight per pen total}}{\text{Total animals slaughterd}}$
ADG	Average daily gain	$\frac{\text{Total weight gain per pen}}{\text{Total Head Days}}$
HDW	Total hot carcass weight at the plant	$\frac{\text{Total HDW}}{\text{Total animals slaughtered}}$

3.9 Statistical Analysis

The experimental unit for the statistical analysis was the pen, due to the treatment (REDI and CON) being applied to individual pens. Individual animal data were aggregated on a pen level. Data were imported in R Core Team 2016. Generalized logistic regression models with a logit link were utilized to calculate the probability of binomial outcomes of interest (morbidity, mortality, lung consolidation, pleurisy, lung score, meat colour, fat colour, MSA marbling, Ossification, Rib Fat, EMA, and weight). Model results were converted to least square means. Linear mixed models were utilized to determine associations of continuous variables (average daily gain, in-weight, final-weight, and pH) with the treatment applied. Random effects were included in each model for replicate. Main effects were considered significant at $P \leq 0.05$.

4 Results

A total of 3,599 steers were enrolled in the trial beginning in the Autumn of 2017. Animals that were not able to be verified as remaining in the pen throughout the entire trial were removed for certain outcomes. Total animals removed and included in each analysis are displayed in **Table 5**.

Table 5. Animals included for each outcome analysis.

Outcome	Control	REDI	Total Included	Total Removed
Inducted	1,799	1,800	3,599	0
60d BW[a]	1,690	1,700	3,390	209
Health Outcomes	1,799	1,800	3,599	0
Lung Scores[b]	1,691	1,697	3,385	214
Lung Scores (BRD1)[c]	758	509	1,267	55
Lung Scores (non-BRD)[d]	927	1,168	2,095	154
Carcass/Performance[e]	1,677	1,681	3,358	241

[a] Removed due to dead = 27, lost = 5, missing = 70 (no data recorded at time of 60-day weight collection or in hospital at time of weight collection), and reject = 107

[b] Removed due to other dead = 39, other reject = 142, missing = 33 (28 not slaughtered with cohort, 5 from human error)

[c] Lung scores of animals treated for BRD during the REDI monitoring period. Animals were removed due to other dead = 14, other reject = 37, missing = 4 (3 not slaughtered with cohort, 1 from human error)

[d] Removed due to other dead = 25, other reject = 103, missing = 26 (22 not slaughtered with cohort, 4 from human error)

[e] There was a total of 3,501 slaughtered animals, 143 were rejects which were not included in the carcass / performance analysis. Of the total animals allocated (3,599), those not included in the carcass analysis include reject = 147 (143 with carcass, 4 without), dead = 47, rejects which also died = 14, and animals missing = 33 (28 not slaughtered with cohort, 5 from human error). Animals included in this analysis were for dead and rejects out for both performance and economics. Dead and rejects in analysis will only include those that were accurately categorized in the trial sheet data as dead or reject. Missing animals will not be included in either analysis.

The results are presented in three formats based on the sub-grouped animal populations within the dataset. The first format is based on the population of animals enrolled in the trial from allocation to slaughter. The second format is only analysing the population of animals that were treated for BRD during the REDI monitoring period. The last format is analysing the population of animals not treated for BRD from allocation to slaughter. The denominators should be considered when analysing the results from the three different formats.

4.1 Enrolment to Slaughter

A total of 3,599 animals were allocated for both diagnostic modalities. Lung scores for moderate and severe were similar between the CON and REDI groups for animals followed through slaughter (**Table 6**). Initial treatment of BRD was 44% in the CON animals compared to 30% in the REDI group ($P < 0.05$) (**Table 6 and Fig. 1**). A total of 20 overrides were treated from the REDI pens. Relapse rates were higher in the REDI group ($P < 0.05$). There were numerically more animals in the BRD dead category in the REDI animals compared to CON, and numerically more BRD rejects in the CON category compared to REDI. The case fatality rate was 0.1% in the CON vs 1.3% in the REDI group. A total of 73.5% of the overall lung score category was normal for the CON and 68.8% for the

REDI group. The severe lung scores were similar between CON and REDI at 1.5%. In total, there were 137 animals that did not receive a consolidation score, and 115 animals that did not receive a pleurisy score. Numerically, more animals died from reasons other than BRD in the CON group, and more animals died from BRD in the REDI group, but no statistical differences were found (**Table 6 and 7)**. Lung consolidation for the 0 and 1-9% category and pleurisy score 0 and 2 were statistically different between CON vs REDI, and all other categories were not statistically different between diagnostic modalities for animals followed through slaughter. The CON group had statistically greater normal lung category compared to REDI, and REDI had statistically greater moderate lung category compared to CON. No statistical differences were found in the severe, BRD dead/reject and combined severe with BRD dead/reject category (**Table 7 and Fig. 2**).

Table 6. Descriptive statistics for known outcomes between diagnostic modalities from induction to slaughter. Population included *all animals enrolled at the start of the trial*.

	Control	**REDI**
Total animals enrolled	1799	1800
Other Mortality[a]	1.3% (23)	0.9% (16)
BRD Mortality	0.0% (1)	0.4% (7)
Other Trial Rejects[b]	3.7% (67)	4.2% (75)
BRD Trial Rejects[c]	0.7% (13)	0.3% (6)
Treatment Success	68.7% (552)	45.2% (247)
Treatment Failure	31.3% (252)	51.5% (281)
Case Fatality Rate[d]	0.1% (1)	1.3% (7)
Initial BRD treatment	44.7% (804)	30.3% (546)
First BRD relapse	31.3% (252)	51.5% (281)
Second BRD relapse	(0)	0.4% (1)
No BRD	55.3% (995)	69.7 % (1254)
Total animals with lung category	1691	1697
Consolidation		
0%	42.5% (718)	37.6% (638)
1-10%	49.4% (836)	54.2% (916)
11-49%	3.5% (60)	2.9% (49)
>50%	0.0% (3)	0.0% (1)
No score[e]	3.5% (60)	4.5% (77)
BRD Dead/Reject	0.8% (14)	0.9% (16)
Pleurisy		
0	64.6% (1093)	61.2% (1038)
1	27.9% (472)	29.2% (495)
2	2.5% (43)	3.8% (64)
3	1.1% (19)	1.1% (19)
No score[f]	3.0% (50)	3.8% (65)
BRD Dead/Reject	0.8% (14)	0.9% (16)
Normal	73.5% (1243)	68.8% (1168)
Moderate	24.1% (408)	28.8% (488)
Severe	1.5% (26)	1.5% (25)
BRD Dead/Reject	0.8% (14)	0.9% (16)
Severe/Dead/Reject	2.4% (40)	2.4% (41)

[a] Mortality due to Digestive, Musculoskeletal, Buller, Peritonitis, Pericarditis, and Unknown

[b] Animals that were rejects due to the following: Digestive, Musculoskeletal, Buller, Unknown

[c] BRD trial rejects are animals that were removed from the trial due to being diagnosed as a chronic or were treated 2 times for BRD.

[d] BRD case fatality rate calculated as the number of BRD deaths that were treated for BRD out of all BRD treated animals.
[e] No score was due to the lungs having severe pleurisy (n=16), the animal being slaughtered out of sequence (n=42), missed due to human error at the plant (n= 73), lungs were dropped by plant staff (n=6).
[f] No score were animals that were slaughtered out of sequence (n=42), missed due to human error at the plant (n = 73).

Table 7. Model-adjusted least square probability differences ± SE for various outcomes for each diagnostic modality from allocation to slaughter. The model included a fixed effect for treatment group and a random effect accounting for arrival date were included in each model. Probability models used a Binomial distribution and probability models used a binomial distribution using the logit link. Population included all animals enrolled in the trial (CON = 1799, REDI = 1800).

Probability	**Control**	**REDI**	***P* value**
Initial BRD treatment	0.44 ± 0.07	0.29 ± 0.06	0.0001
First BRD relapse	0.30 ± 0.03	0.50 ± 0.04	0.0001
BRD Mortality	0.00 ± 0.00	0.003 ± 0.001	0.0658
BRD Rejects	0.01 ± 0.002	0.003 ± 0.002	0.116
Consolidation			
0%	0.42 ± 0.05	0.37 ± 0.05	0.002
1-10%	0.49 ± 0.05	0.54 ± 0.05	0.005
11-49%	0.03 ± 0.005	0.03 ± 0.005	0.274
>50%	0.002 ± 0.001	0.00 ± 0.00	0.34
No score[e]	0.03 ± 0.01	0.04 ± 0.01	0.13
BRD Dead/Reject	0.01 ± 0.002	0.01 ± 0.002	0.837
Pleurisy			
0	0.66 ± 0.05	0.62 ± 0.05	0.029
1	0.25 ± 0.06	0.27 ± 0.06	0.3956
2	0.03 ± 0.004	0.04 ± 0.005	0.0413
3	0.01 ± 0.003	0.01 ± 0.003	0.986
No score[f]	0.02 ± 0.008	0.03 ± 0.01	0.141
BRD Dead/Reject	0.01 ± 0.002	0.01 ± 0.002	0.837
Normal	0.75 ± 0.04	0.70 ± 0.04	0.002
Moderate	0.23 ± 0.04	0.27 ± 0.04	0.002
Severe	0.01 ± 0.003	0.01 ± 0.003	0.871
BRD Dead/Reject	0.01 ± 0.002	0.01 ± 0.002	0.837
Severe/Dead/Reject_BRD[a]	0.02 ± 0.004	0.02 ± 0.004	0.796

[a] Severe combined with dead/rejects due to BRD

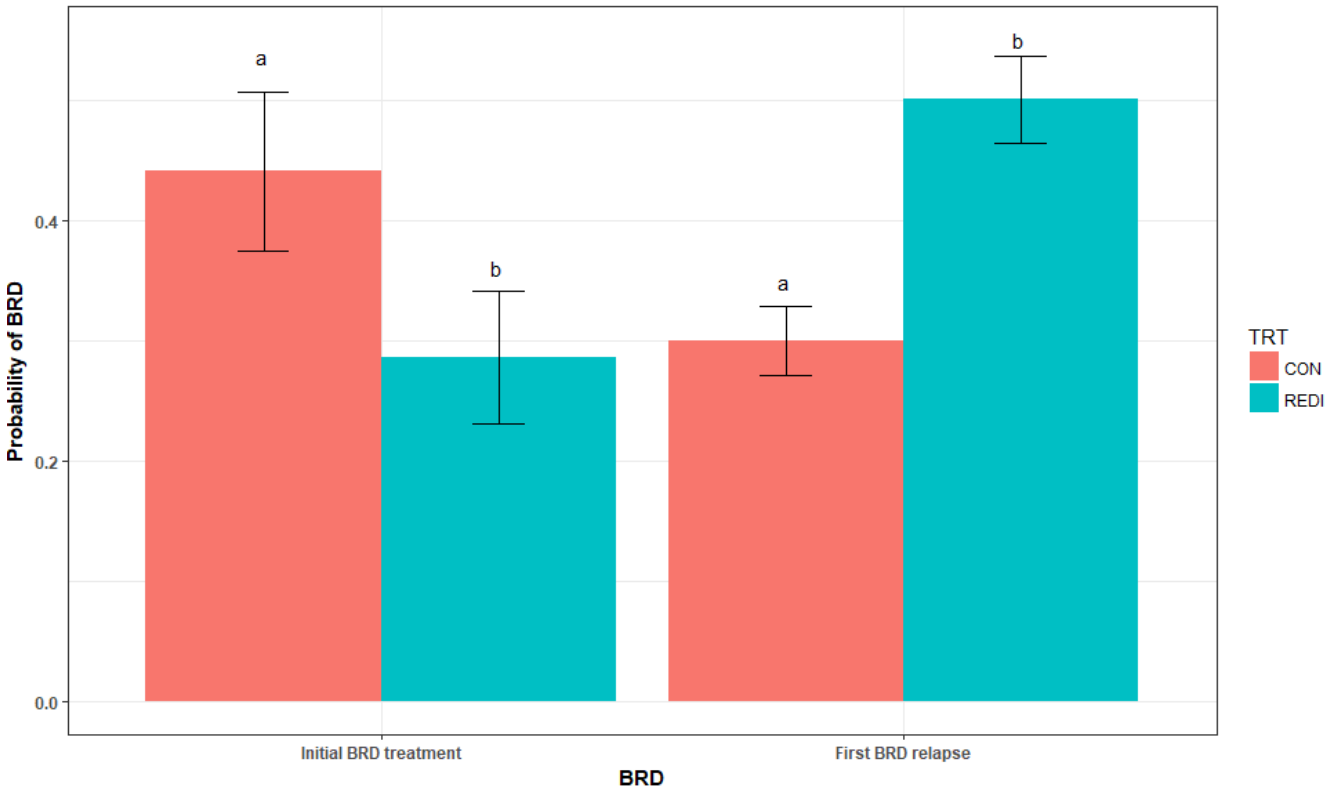

Figure 1. Probability of BRD treatment by diagnostic modality. Error bars indicate the standard error of the probability. Probabilities sharing a letter are not significantly different. Probability of BRD relapse was calculated as BRD relapse / Initial BRD treatment.

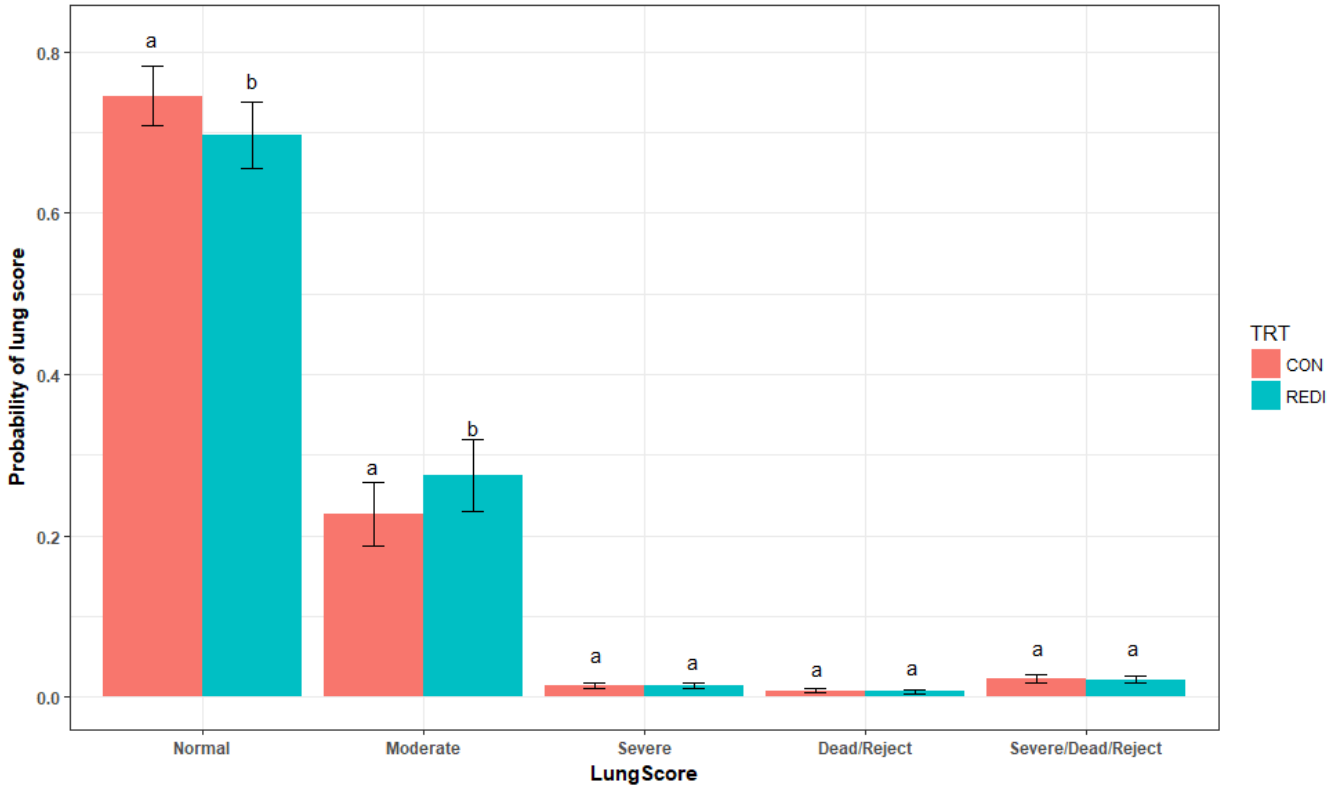

Figure 2. Probability of lung score by diagnostic modality. Error bars indicate the standard error of the probability. Probabilities sharing a letter are not significantlydifferent.

4.2 Enrolment to behaviour tag removal of animals initially treated for BRD

REDI tag removal ranged from 53 – 65 days on feed for each replicate. A total of 44.2% of CON animals were treated during the REDI monitoring period and 29.2% of REDI (**Table 8**). Peak BRD treatment during the REDI monitoring period occurred around day 5 for the REDI animals (**Figure 3**). The percent of animals treated each day initially for BRD continues to decline after day 5 and remained less than the percent of animals treated in the CON group throughout the remaining days on feed. Peak BRD relapse treatment during the REDI monitoring period occurred around day 17 for the REDI animals and around day 32 for CON animals. A significant difference was found between initial BRD treatment and BRD relapse between REDI vs CON, with REDI treating 27% of cattle initially for BRD in the first 60 days, and a secondary treatment for 49% of initially treated animals compared to 44% and 29% for the CON group (**Table 9 and Fig. 4**). Control cattle that were considered a reject due to BRD were greater than the REDI group but was not statistically significant. A greater number of CON animals that were treated in the first 60 days had a normal lung score compared to REDI animals ($P < 0.05$). A significant difference was not found between the two groups for animals categorized as severe, or the combination of cattle with a severe lung score and also were a dead/reject in the first 60 days (**Fig. 5**).

Table 8. Descriptive statistics for known outcomes between diagnostic modalities during the first 60 days of the trials. Population included animals treated for *BRD in first ~60 days*.

	Control	**REDI**
Total animals enrolled	1799	1800
Initial BRD treatment	44.2% (796)	29.2% (526)
First BRD relapse	30.7% (244)	51.3% (270)
Second BRD relapse	(0)	(0)
No BRD	55.8% (1003)	70.8% (1274)
BRD Mortality	(0)	0.95% (5)
BRD Trial Rejects[a]	1.4% (11)	1.1% (6)
Other Mortality	0.6% (5)	0.4% (2)
Other Trial Reject	1.5% (12)	0.7% (4)
BRD Treatment Success	69.3% (552)	48.7% (256)
BRD Treatment Failure	30.7% (244)	51.3% (270)
BRD Case Fatality Rate[b]	(0)	0.95% (5)
Total animals with lung category[c]	756	509
Consolidation		
0%	45.2% (342)	41.7% (212)
1-10%	46.1% (348)	48.5% (247)
11-49%	3.3% (25)	2.8% (14)
>50%	0.1% (1)	0.2% (1)
No score[d]	3.8% (29)	4.7% (24)
BRD Dead/Reject	1.5% (11)	2.2% (11)
Pleurisy		
0	67.9% (513)	65.0% (331)
1	23.8% (180)	24.2% (123)
2	2.6% (20)	3.7% (19)
3	1.2% (9)	1.2% (6)
No score[e]	3.0% (23)	3.7% (19)
BRD Dead/Reject	1.5% (11)	2.2% (11)
Normal	75.9% (574)	70.7% (360)
Moderate	21.0% (159)	25.1% (128)
Severe	1.6% (12)	2.0% (10)

BRD Dead/Reject	1.5% (11)	2.2% (11)
Severe/Dead/Reject BRD	3.0% (23)	4.1% (21)

[a] BRD trial rejects are animals that were removed from the trial due to being diagnosed as a chronic or were treated 2 times for BRD. The REDI system called animals as a chronic if they were called by the system a 2nd time.

[b] BRD case fatality rate calculated as the number of BRD deaths that were treated for BRD out of all BRD treated animals in the first 60 days.

[c] A total of 1,265 animals were included in the lung score analysis (removed n=57) due being classified as a non-BRD reject (n=16), rejected after the REDI monitoring period (n=22), non-BRD dead (n=7), dead after the REDI monitoring period (n=8), and missing animals (n=4).

[d] No score was due to animals that were slaughtered out of sequence (n=15), missed due to human error (n=27), had severe pleurisy (n=7), lungs dropped by plant staff (n=4).

[e] No score were animals that were slaughtered out of sequence (n=15), missed due to human error at the plant (n = 27).

Table 9. Model-adjusted least square mean probability differences ± SE for various outcomes for each diagnostic modality during the first 60 days of the trial. The model included a fixed effect for treatment group and a random effect accounting for arrival date were included in each model. Probability models used a binomial distribution using the logit link. Population only included animals that were initially treated for BRD in the first 60 days (CONT = 796 and REDI = 526).

Probability	**Control**	**REDI**	***P* value**
Initial BRD treatment	0.44 ± 0.07	0.27 ± 0.05	0.0001
First BRD relapse	0.29 ± 0.03	0.49 ± 0.04	0.0001
BRD Mortality	0.0 ± 0.0	0.01 ± 0.01	0.983
BRD Rejects	0.01 ± 0.005	0.01 ± 0.005	0.697
Consolidation			
0%	0.43 ± 0.05	0.38 ± 0.05	0.076
1-10%	0.48 ± 0.05	0.52 ± 0.05	0.185
11-49%	0.03 ± 0.01	0.03 ± 0.01	0.558
>50%	0.001 ± 0.001	0.002 ± 0.002	0.78
No score	0.04 ± 0.01	0.05 ± 0.01	0.376
BRD Dead/Reject	0.01 ± 0.004	0.02 ± 0.01	0.351
Pleurisy			
0	0.67 ± 0.05	0.63 ± 0.06	0.201
1	0.24 ± 0.06	0.25 ± 0.06	0.805
2	0.03 ± 0.01	0.05 ± 0.01	0.063
3	0.02 ± 0.01	0.02 ± 0.01	0.801
No score	FTC[a]		
BRD Dead/Reject	0.02 ± 0.004	0.02 ± 0.01	0.351
Normal	0.75 ± 0.04	0.70 ± 0.04	0.04
Moderate	0.21 ± 0.04	0.26 ± 0.05	0.074
Severe	0.02 ± 0.01	0.02 ± 0.01	0.615
BRD Dead/Reject	0.02 ± 0.004	0.02 ± 0.01	0.351
Severe/Dead/Reject BRD[b]	0.03 ± 0.01	0.04 ± 0.01	0.304

[a] FTC = Failed to Converge

[b] The severe was combined with dead/rejects due to BRD

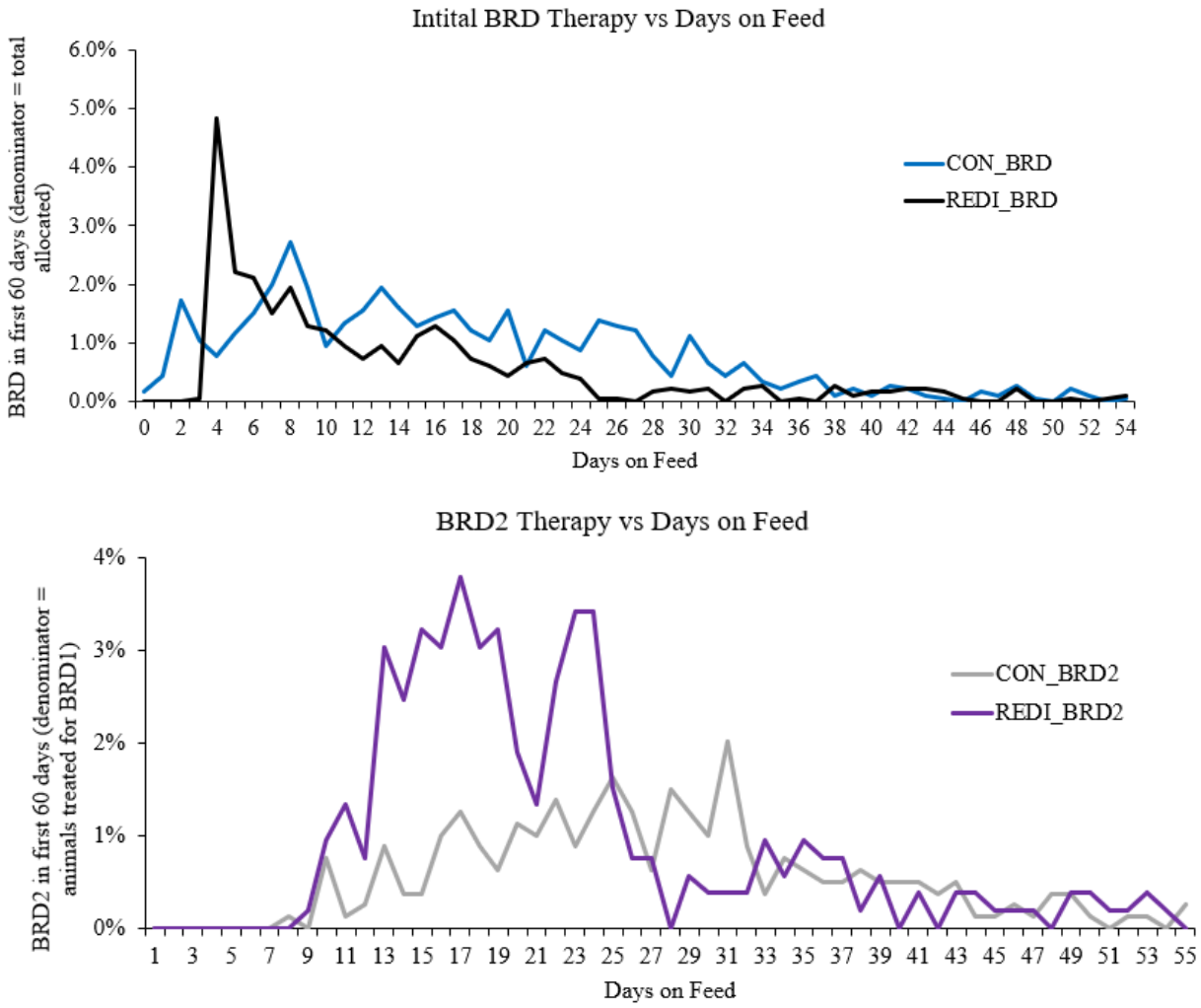

Figure 3. Percent of animals treated for initial BRD and first BRD relapse prior to behaviour monitoring tag removal by diagnostic modality.

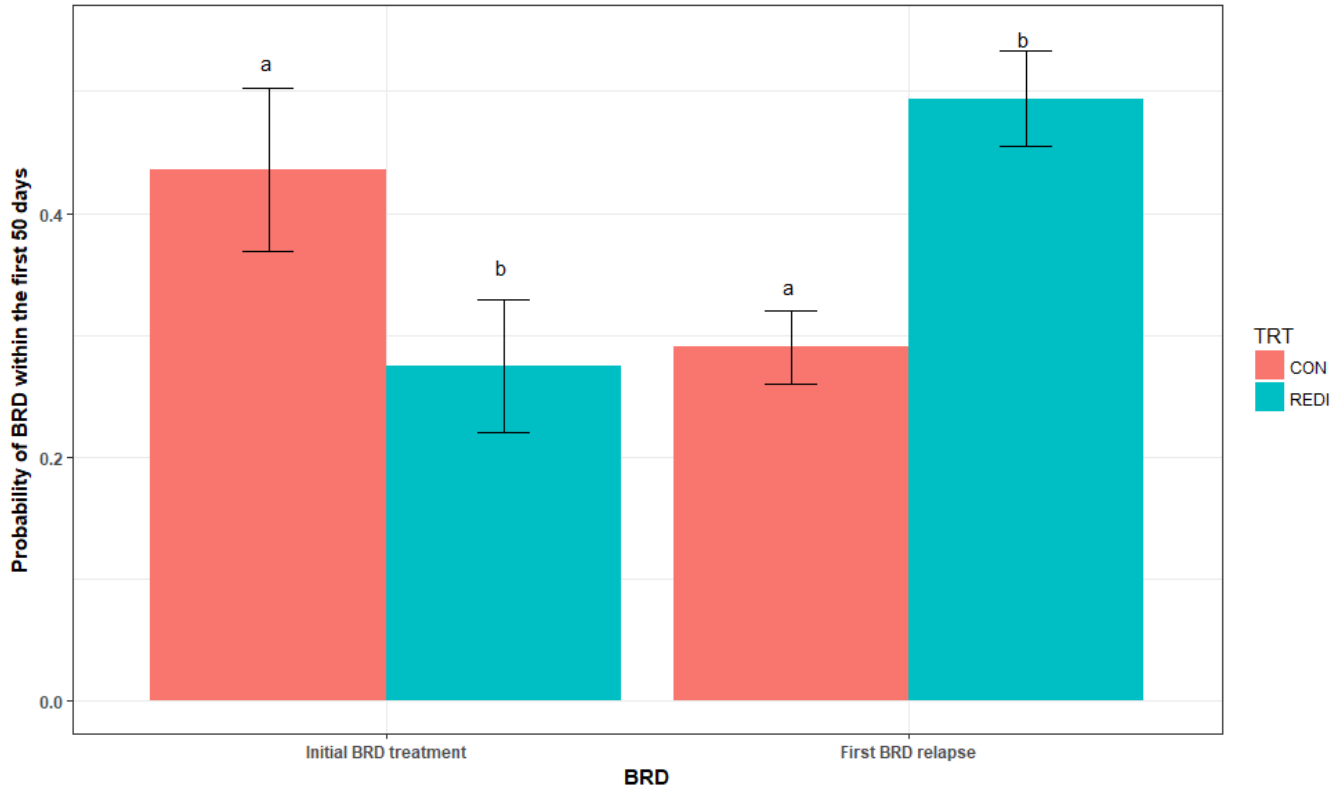

Figure 4. Probability of BRD treatment within the first 50 day by diagnostic modality. Error bars indicate the standard error of the probability. Probabilities sharing a letter are not significantly different. Probability of BRD relapse was calculated as BRD relapse / Initial BRD treatment.

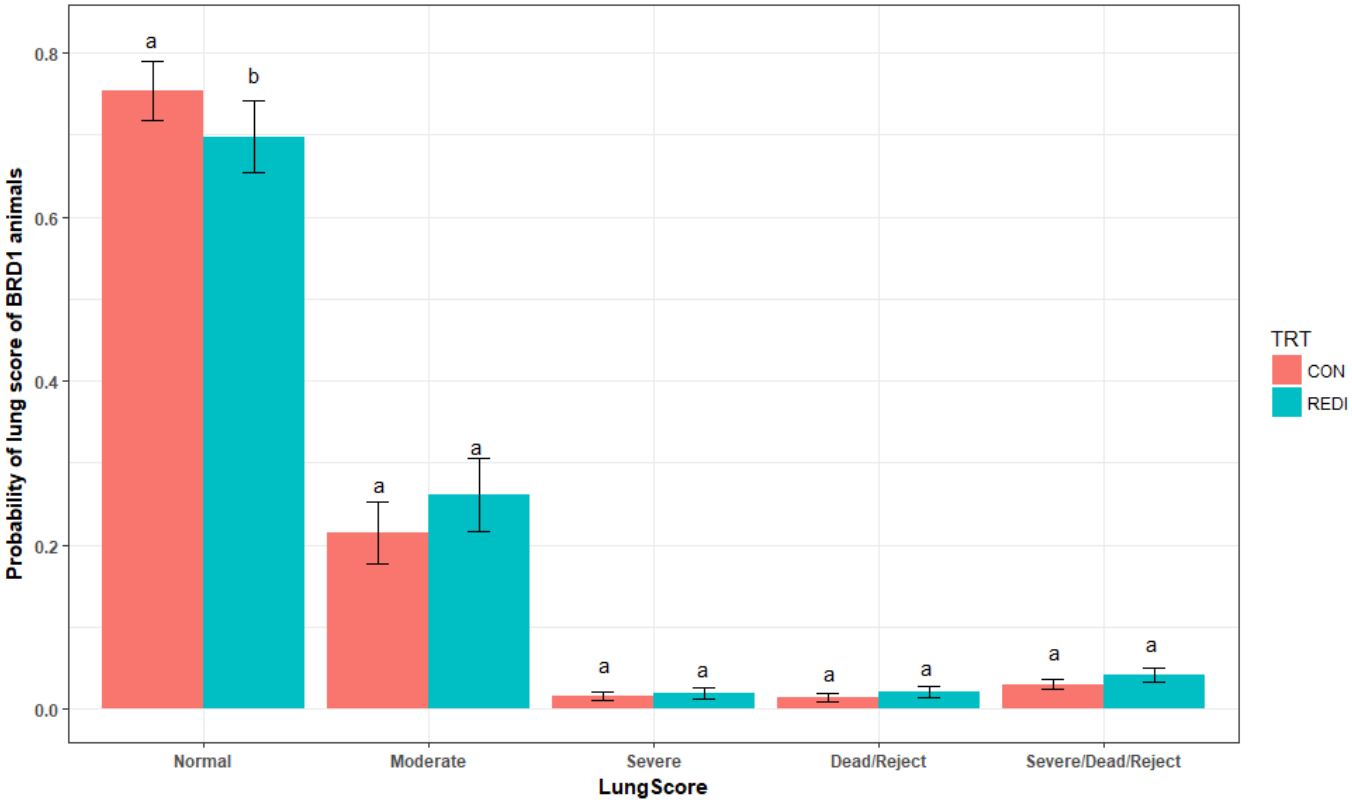

Figure 5. Probability of lung score of animals treated for BRD within the first 50 days by diagnostic modality. Error bars indicate the standard error of the probability. Probabilities sharing a letter are not significantly different.

4.3 Enrolment to slaughter for animals not treated for BRD

In the CON group, 55.3% of the animals enrolled were not initially treated for BRD, and 69.70% of the REDI animals were not initially treated for BRD (**Table 10**). The difference between the two diagnostic modalities for animals not treated was statistically different, with CON animals 14% less likely to not be treated initially for BRD (**Table 11**). Lung category normal was statistically higher in the CON group compared to REDI, and moderate was statistically lower in the CON group compared to REDI ($P < 0.05$) for animals not initially treated for BRD from allocation to slaughter (**Table 11 and Fig. 6**).

Table 10. Descriptive statistics for known outcomes between diagnostic modalities for animals not treated for BRD. The population *includes animals not treated for BRD* (Con=995, REDI = 1254)

Outcome	Control	REDI
Total animals enrolled	1799	1800
No initial BRD treatment	55.3% (995)	69.7% (1254)
Other Mortality[a]	1.3% (13)	0.95% (12)
Other Trial Rejects[b]	4.1% (41)	4.9% (62)
Total animals with lung category[c]	927	1168
Consolidation		
0%	40.3% (374)	35.9% (419)
1-10%	52.4% (486)	56.8% (664)
11-49%	3.8% (35)	2.9% (34)
>50%	0.2% (2)	(0)
No score[d]	3.2% (30)	4.4% (51)
Pleurisy		
0	62.4% (578)	59.8% (698)
1	31.3% (290)	31.6% (369)
2	2.5% (23)	3.9% (45)
3	1.1% (10)	1.0% (12)
No score[e]	2.8% (26)	3.8% (44)
Normal	71.8% (666)	68.2% (797)
Moderate	26.6% (247)	22.0% (257)
Severe	1.5% (14)	1.2% (14)

[a] Mortality due to Digestive, Musculoskeletal, Buller, Peritonitis, Pericarditis, and Unknown
[b] Animals that were rejects due to the following: Digestive, Musculoskeletal, Buller, Unknown
[c] 154 animals were not included in the lung score analysis due to non-BRD death (n=25), non-BRD rejects (n=103), and missing animals (n=26).
[d] No score was due to animals that were slaughtered out of sequence (n=25), missed due to human error (n=45), had severe pleurisy (n=9), lungs dropped by plant staff (n=2).
[e] No score were animals that were slaughtered out of sequence (n=25), missed due to human error at the plant (n = 45).

Table 11. Model adjusted least square probability ± SE of animals not treated for BRD. The model included a fixed effect for treatment group and a random effect accounting for arrival date were included in each model. Population included animals enrolled in the trial that were not treated (Control = 1191, REDI = 881)

Probability	Control	REDI	*P* value
No initial BRD treatment	0.56 ± 0.07	0.71 ± 0.06	0.0001
Non-BRD Mortality	0.01 ± 0.004	0.01 ± 0.003	0.428
Non-BRD Rejects	0.04 ± 0.01	0.04 ± 0.01	0.433
Consolidation			
0%	0.42 ± 0.05	0.37 ± 0.05	0.018
1-10%	0.50 ± 0.05	0.55 ± 0.05	0.0203
11-49%	0.04 ± 0.01	0.03 ± 0.004	0.272
>50%	FTC[a]		
No score[d]	0.03 ± 0.01	0.04 ± 0.01	0.202
Pleurisy			
0	0.65 ± 0.05	0.62 ± 0.06	0.0729
1	0.27 ± 0.06	0.29 ± 0.06	0.41
2	0.24 ± 0.01	0.04 ± 0.01	0.0839
3	0.01 ± 0.00	0.01 ± 0.00	0.908
No score	0.02 ± 0.01	0.03 ± 0.01	0.262
Normal	0.75 ± 0.04	0.70 ± 0.04	0.0211
Moderate	0.24 ± 0.04	0.28 ± 0.05	0.0122
Severe	0.02 ± 0.00	0.01 ± 0.00	0.538

[a] FTC = Failed to Converge

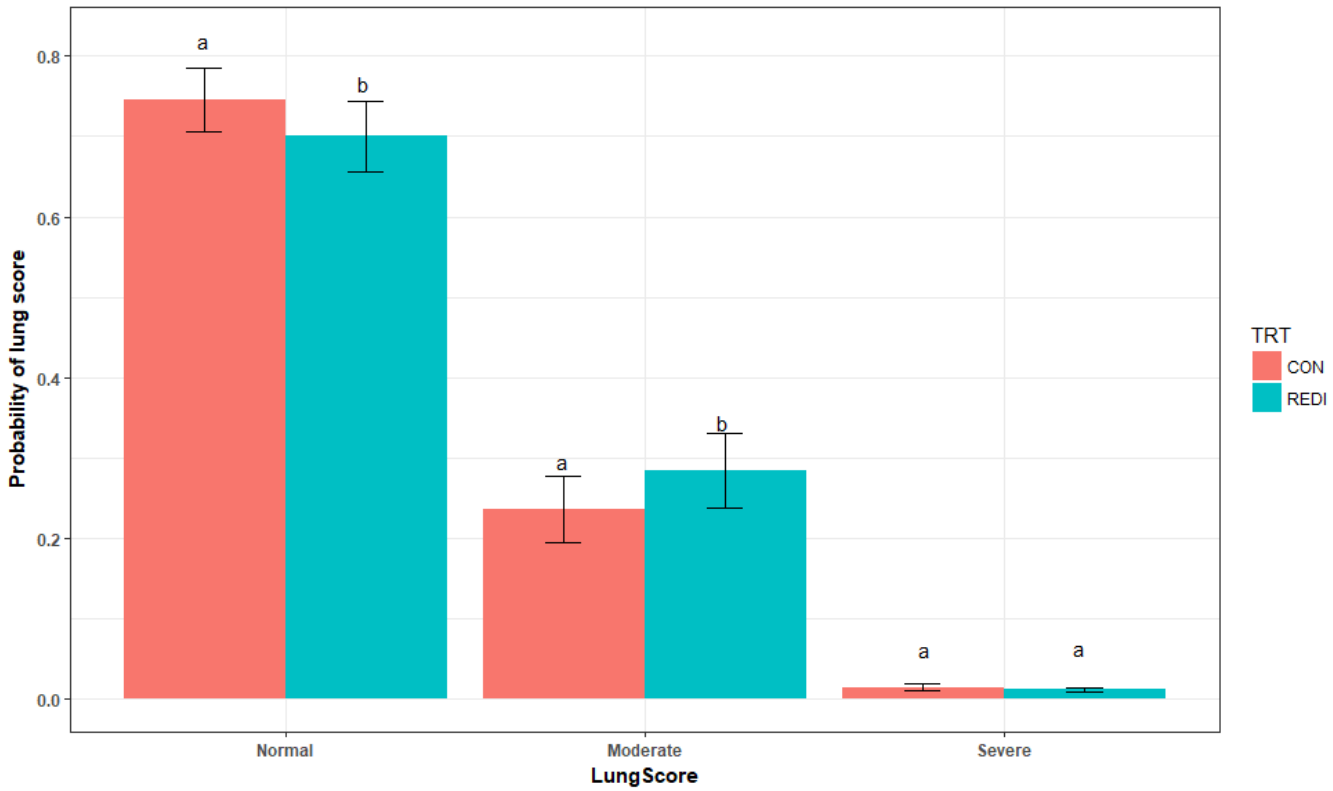

Figure 6. Probability of lung score of animals not treated for BRD by diagnostic modality. Error bars indicate the standard error of the probability. Probabilities sharing a letter are not significantly different.

4.4 Performance outcomes from enrolment to slaughter

A total of 3,358 animals were included in the slaughter analysis, CON = 1,677 and REDI = 1,681. The average days on feed (DOF) for both pens was 187 days with an average of 280 head slaughtered per pen. No statistical differences were found between diagnostic modalities of animals slaughtered between in-weight, out-weight, or ADG (**Table 12**). Carcass characteristic models demonstrated a significant difference ($P < 0.05$) between both groups with a slightly greater P8Fat for CON, greater 1B, 1C and 0-5 Meat Color for REDI, greater 560 – 860 MSA Marble for CON, greater 40 -83 EMA for REDI, and a greater 84-106 EMA for CON. (**Table 13**). All other carcass characteristics did not show a significant difference.

Table 12. Model-adjusted least square means ± SE of performance outcomes for animals slaughtered in the trial between diagnostic modalities on a DEADS and REJECTS OUT basis. The model included a fixed effect for treatment group and a random effect accounting for arrival date were included in each model.

Variable	Control	REDI	SE	*P* value
DOF	187.3	187.5	11.7	0.522
In-weight (kg)	364.65	365.37	23.36	0.461
Out-weight (kg)	668.26	678.14	6.57	0.312
ADG (kg)	1.61	1.66	0.05	0.432
ADG 60days[a]	2.05	2.05	0.05	0.821

Table 13. Model-adjusted least square means ± SE of carcass characteristics for animals slaughtered between diagnostic modalities. The model included a fixed effect for treatment group and a random effect accounting for arrival date were included in each model.

Variable	Control	REDI	SE	*P* value
HDW (kg)	396.18	395.67	3.68	0.77
P8Fat	20.36	20.07	0.72	0.0311
Fat Color, %				
1	1.0	1.0	0.00	0.983
Meat Color, %				
1B, 1C	0.50	0.53	0.04	0.0543
0-5	0.50	0.53	0.04	
MSA Marble, %				
0	0.07	0.07	0.01	0.703
340-550	0.78	0.80	0.01	0.129
560-860	0.15	0.13	0.01	0.0381
Ossification, %				
0	0.07	0.07	0.01	0.703
140-180	0.83	0.81	0.01	0.339
190-230	0.10	0.11	0.01	0.386
pH	5.17	5.15	0.04	0.794
Rib Fat, mm				
0	0.07	0.07	0.01	0.703
9-28	0.93	0.93	0.01	
EMA				
40-83	0.23	0.28	0.01	0.001
84-106	0.77	0.72	0.01	0.001

4.5 Tag retention

Tag loss counts included tags that were replaced at any point in the trial due to falling / ripped out of the ear, tag malfunctioning (going offline), or missing at REDI tag removal. Tag loss counts included tags that went offline and were replaced, but not tags that went offline due to the animals no longer being in the coverage area; differentiating between a tag needing to be replaced or not due to a tag going offline was determined by analysed the raw data. Tag loss counts also included tags missing from animals at tag removal (~60 days). The fourth induction did not have records for tags missing at tag removal. The first three inductions had the highest percent tag loss compared to the remaining induction groups, this is most likely due to new tag backs being deployed for inductions 4-6. Tag loss per induction group ranged from (9 – 45%) (**Table 14**). Total tag loss for all animals inducted was 21.4%.

Table 14. REDI tag retention for each induction group.

Induction group	Head inducted	Tags not retained throughout trial	Tag Retention (%)
1[a]	300	72	76
2[a]	300	59	80.3
3 [a]	300	135	55
4	300	40	86.7
5	300	53	82.3
6	300	27	91
Total	1800	386	78.6

[a] Old tag backs used in the first three inductions, groups 4-6 used new tag backs at induction

5 Discussion

The results obtained from this project are the first to evaluate the REDI system versus conventional detection in one of two large-scale feeding operations in Australia to the authors' knowledge. Previous research evaluating the REDI system has occurred in the United States and Canada. The outcomes of the project created a novel dataset including individual and pen-level information on disease occurrence and magnitude of lung lesions at harvest.

The first objective of the project was to evaluate both diagnostic modalities (REDI vs CON) for BRD detection and diagnosis. Previous research has demonstrated REDI to diagnose BRD 0.75 earlier compared to CON as well as fewer treated (White et al., 2015a). REDI has shown greater sensitivity at detecting BRD in calves and identifies BRD earlier in the disease process with the continuous monitoring of cattle behaviour using changes over time for levels of activity, location within the pen, and social patterns (White B, et al., 2015). A significant difference in animals initially treated for BRD during the behaviour monitoring period provided interesting results. A greater number of calves were treated initially for BRD in the CON group compared to the REDI group, which is similar to previous research results. A greater number of animals treated for BRD in the CON group had normal lung scores compared to REDI, and REDI has been shown to have a greater diagnostic specificity and sensitivity values compared to conventional BRD visual detection (Theurer et al., 2015b; White et al., 2016). Greater sensitivity and specificity values result in a greater percentage of calves being correctly classified with BRD. The results presented are the first to the author's knowledge to describe the association between lung scores and BRD treatment for animals monitored with remote location technology versus conventional visual detection. Further research is warranted to determine if long-term studies in a variety of environments would result in similar results between diagnostic modalities and lung scores. In the presented trial, REDI retreated a greater number of steers compared to the CON group, and it is believed that recalibration and

optimization of the REDI system would increase the accuracy of the system for animals being treated a second time for BRD.

Initial BRD cases have been shown to occur in the first 45 days of the feeding period for incoming calves classified as high risk in the United States (Babcock et al., 2010). The presented results demonstrated most treatments for BRD occurred in the first two weeks of the feeding period, with peak treatments occurring around day 5 for REDI and day 8 for CON. Detecting calves earlier in the feeding period can prove to be advantageous for both performance (Babcock et al., 2009) and labour resource allocation. Peak relapse for BRD appeared to occur 1-2 weeks after initial BRD therapy for most of the animals treated for secondary BRD in the REDI system. Utilizing the REDI system earlier in the feeding period can allow for greater management of high risk calves during known peak times of BRD. The REDI system is only able to monitor for BRD, and pen riders would still need to be utilized to monitor for other disease conditions.

The second objective of the trial was to determine the impact of BRD on feedlot performance and carcass characteristics by analysis of treatment records and lung score data at slaughter. In the reported trial, calves were followed from allocation to slaughter and a significant difference in ADG was not found. Lack of significant differences in performance outcomes has been reported in a similar trial where calves were followed in the first 30 days on feed (White et al., 2017). Other performance outcomes (feed to gain and dry matter intake) were not able to be analysed in this trial. Animals missing from trial outcomes for performance data may have been due to the animal located within the hospital system at the time of data collection. Further research is warranted to determine if differences exist between diagnostic modalities for performance outcomes.

A limitation to this study includes the loss of records that occurred throughout the trial and affected the number of animals included in each outcome analysis. Tag retention rates demonstrated greater losses than usual from previous trials. A new tag back was deployed after the third block was allocated which appeared to improve the retention rates. An added identification tag was inserted along with the REDI tag for the first three blocks which also may have contributed to the greater tag loss rates. It is believed that the loss of records and decreased retention rates would not have significantly changed the results described in this report although further research is warranted to validate the results presented.

6 Conclusions/recommendations

The REDI system demonstrated advantageous results which could benefit long-term values in animal welfare. A significant difference was found between initial BRD treatment and BRD relapse between REDI vs CON during the REDI monitoring period (~60 days on feed), with REDI treating 29% of cattle initially for BRD, and a secondary treatment for 50% of initially treated animals compared to 44% and 31% for the CON group. Initial BRD treatment in REDI occurred greatest in the first 6 days on feed. The percent of animals treated each day initially for BRD declines after day 5 and remained lesser compared to the percent of animals treated in the CON group throughout the remaining days on feed. The CON group had significantly greater animals with a normal lung category compared to REDI (75% vs 70%) for animals initially treated for BRD during the REDI monitoring period, and REDI treated numerically more moderate lung category animals compared to CON. No major performance or carcass characteristics were found.

The REDI algorithms were generated for U.S. cattle and further research to calibrate and optimize these algorithms for greater accuracy of detecting BRD in the Australian environment is warranted.

7 Key messages

The remote early disease identification (REDI) system provides objective continuous behavioural monitoring and applies classification engines to determine changes in wellness status and has now been tested in the United States, Australia, and Canada. Further research into calibrating and optimizing the detection classification engines specific to cattle type, location, and other risk factors can allow for greater accuracy of detecting BRD in multiple environments. No statistical differences between treatment groups for lung lesions, mortalities, rejects or performance characteristics has been noted. Initial BRD treatment for the REDI system occurs in the first 5 days on feed. Further research into the association with remote BRD detection and days on feed will improve the fundamental understanding of behaviours associated with BRD and offer value to Australian production systems using conventional diagnostic methods as well as identify areas to prioritize when evaluating new disease detection technologies. Utilization of a remote disease detection system can allow for rapid behaviour result generation on both individual and group level data. Platforms for data dissemination have been created to provide real-time information from raw behavioral data that are transformed into classification animal wellness status. The reported trial demonstrated that REDI is comparable to conventional detection for lung lesions, mortality, and carcass performance with greater accuracy of BRD detection in animals with moderate lung lesions.

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