final report

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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 1

Abstract

Bovine respiratory disease (BRD) affects the health and performance of feedlot cattle in the United States as well as Australia. Current diagnostic methods for detecting BRD have a poor specificity and sensitivity. 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 economic impact of BRD on feedlot performance and carcass characteristics. A total of 2,628 steers were allocated to each treatment group for each block of the experiment (6 total). Calves were followed from allocation to slaughter. Results showed no statistical differences between treatment groups for lung lesions, mortalities, rejects, or performance characteristics. A significant difference was found for initial BRD treatment between REDI vs CON (32% vs 8%). A significant difference ($P < 0.05$) was found in treatment costs, with REDI costing an average \$18.58 per head and Control costing \$4.14. The net return per steer was \$164.72 for control and \$152.29 for REDI. 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.

Executive summary

The health, performance, and economic impact of BRD is significant in the feeding and slaughtering of cattle in the United States and Australia. Common diagnostic modalities that are currently available for BRD in the field include visual assessment, rectal temperature, and whisper scores. 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. A Remote Early Disease Identification (REDI) system has been shown to diagnose cattle with BRD based on behavioral changes related to feed, water, distance, and social indices. Previous research has shown 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. The objectives of this project (B.FLT.0242) was 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 economic impact of BRD on feedlot performance and carcass characteristics at two Australian feedlots. This report details the findings on Site 1 and the finding for Site 2 are independent outlined in the second report.

A total of 2,628 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 control 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 112 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 Control) 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, Aumeat Marbling, Ossification, Rib Fat, EMA, weight, bruise, and railers). mixed models were utilized to determine associations of continuous variables (average daily gain, in-weight, final-weight, feed to gain, feed costs, treatment costs, total value, net returns and dry matter intake, hump height, fat depth, pH and MSA index) 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 lung lesions, mortalities, rejects, or performance characteristics. A significant difference was found between initial BRD treatment and BRD relapse between REDI vs CON during the REDI monitoring period (~50 days on feed), with REDI treating 32% of cattle initially for BRD, and a secondary treatment for 44% of initially treated animals compared to 8% and 23% for the control group. Initial BRD treatment in REDI occurred in the first 7 days on feed. A significant difference ($P < 0.05$) was found in treatment costs. The net return per steer on a deads and rejects in basis was $164.72 for control and $152.29 for REDI, with a greater net return per steer for the control by $12.43.

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 testing 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. 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. This trial demonstrated that REDI is comparable to conventional detection for lung lesions, mortality, and carcass performance. The main difference identified was a greater number of initial and second BRD treatments in the REDI group, which can be decreased through algorithm calibration and optimization.

Table of contents

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 proven to have variable 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., 2015). NAHMS reported the cost to treat an animal with respiratory disease within a feedlot $23.6, SE $1.1 (NAHMS, 2011a).

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, 2011b). 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 and diagnosis of feedlot in New South Wales, Australia (Site 1). A second objective was to determine the economic impact of BRD on feedlot performance and carcass characteristics by analysis of treatment records and lung score data at slaughter. The economic analysis was performed in comparison between the two BRD detection methods (REDI vs CON). The trial was approved by the registered Animal Care and Use Committee in the State of New South Wales, Australia.

3   Methodology

3.1 Animal enrolment

Cattle enrolled in the study were procured from saleyards and were comprised of Angus, Angus cross, Bos Indicus cross, British cross, European, Hereford, Murray Grey, and Shorthorn breeds and all cattle were steers. Upon arrival at the feedlot, steers were weighed across the feedlot pen scale for an arrival weight. The arrival weight was kept separate by vendor until treatment allocation at feedlot induction within 48 hours. The cattle were rested overnight, with ad libitum access to clean water and an allocation of cereal hay and Ration 1. The following morning, prior to

feeding, animals were inducted into the feedlot which included scanning of individual National Livestock Identification Scheme RFID tag, identification with plastic visual ID and lot tag, injection with ivermectin for treatment of internal and external parasites (Biomectin, Bayer), a vaccination for clostridial diseases with 5 in 1 vaccine (Tasvax, Coppers Animal Health). A pre-vaccination against respiratory pathogen utilizing one-injection of Bovilis MH + IBR (Coopers Animal Health, Australia) was administered a minimum of 2 weeks prior to feedlot entry and re-vaccinated with Bovilis MH + IBR at feedlot induction. Animals with no history of pre-vaccination for BRD pathogens received a single injection of Bovilis MH (Coopers Animal Health, Australia) and intra-nasal administration of Rhinoguard (Zoetis Animal Health, Animal). All animals were implanted with Revalor S (Coppers Animal Health, Australia). An initial body weight (435.3 ± 5.7 kg) was obtained for all animals at feedlot induction at the processing hydraulic squeeze-chute prior to feeding (Daniels Manufacturing Co, Nebraska).

In each block steers were allocated to either control or REDI pens based on a coin flip as the animals came through the chute to determine sequence of alternate randomization for each block of the experiment. The first blocks were allocated in April, the second and third in May, the fourth in July, the fifth and sixth in August. CON and REDI cattle were allocated randomly to adjacent pens in a grid which contained 4 REDI and 4 CON pens. All individual animals were allocated on the first day of the trial for the first two turns and the last two turns. For the third and fourth turn, animals were allocated over multiple days, the first, third, and fourth day of the trial. 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, which were cleaned prior to the commencement of the experiment. The pens held approximately 220 head and consisted of 50m bunk length and 58m depth (22.7cm per head bunk space; 12.3m^2 / head) and had a 3% slope. All pens had a single strip of shade cloth 11m wide in the middle of the pen. Pen waters were shared along the fence-link with adjoining pens. Water troughs were cleaned out weekly.

3.2   Control configuration

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 control pens. Control pens were checked prior to the REDI pens. Cattle that exhibited at least 2 of the following signs (depression, anorexia or respiratory signs) were removed from the pen and taken to the hospital chute (Moly Manufacturing Inc, Kansas) for further evaluation. Rectal temperature (GLA M700 Digital Thermometer; GLA Agricultural Electronic) and Whisper©; Geissler Corporation, determined the requirement for treatment for BRD. A lung auscultation score was applied by the Whisper© with 1 = normal lung health, 2 = mild acute, 3 = moderate acute, 4 = severe acute, and 5 = chronic. A combination of the rectal temperature and Whisper© score determined the treatment for BRD (**Table 1**).

Table 1. Definitions for treatment for initial BRD therapy during the experiment for Control animals using rectal temperature and Whisper©.

Whisper©	Temperature	Diagnosis	Treatment
1	<40°C	Not Sick	Back to home pen
1	≥40°C	BRD	Draxxin (Tulathromycin; Zoetis Australia), sent back to home pen
2 or 3	Any	BRD	Draxxin, sent back to home pen
4 or 5	any	BRD	Draxxin, placed into 3 pen hospital system

If an animal was detected a second time with BRD visual symptoms in their pen (home or hospital), and at least a 4-day post-treatment interval had lapsed since initial Draxxin treatment, the

animal was removed from the pen and re-assessed with the Whisper© and rectal temperature. A combination of the rectal temperature and Whisper© score determine the second treatment for BRD by a two-course system of oxytetracycline (Engemycin; Coopers Animal Health, Australia) administered 48 hours apart in the hospital system. (**Table 2**).

Table 2. Definitions for treatment for second BRD during the experiment for Control animals using rectal temperature and Whisper©.

Whisper©	Temperature	Diagnosis	Treatment
1	<40°C	Not Sick	Back to home pen
1	≥40°C	BRD	Engemycin (Oxytetracycline, Coopers Animal Health), sent back to home pen
2 or 3	any	BRD	Engemycin, sent back to home pen
4 or 5	any	BRD	Engemycin, remain in hospital for further observation

A minimum of 48 hours after the second Engemycin treatment was allowed for cattle to respond to treatment in their pen (home or hospital), prior to the animal eligible to be pulled a 3rd time for BRD. If an animal was diagnosed with BRD a 3rd time, the body weight was recorded at the hospital chute and animal was retreated based on feedlot veterinary protocol (Nuflor/Meloxicam). An animal that was treated a 3rd time for BRD was removed from the feedlot trial and entered the chronic pen, unable to be returned to the home pen. Any 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.

3.3 REDI configuration

The four 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 were conducted using the REDI system. The REDI pens were equipped with readers surrounding the fence perimeter. A REDI tag was placed on 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 steer in the pen at 4-15 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 (Tulathromycin; Zoetis Australia), and a rectal and Whisper© score were recorded. Cattle with a Whisper© score of 1-3 were immediately sent to their home pen, unless they had a score of 4-5, then they were placed in the hospital pen for treatment and observation. Animals that remained in the hospital pen due to a Whisper© score of 4 or 5 were managed similarly to the CON animals because REDI could not detect re-treatment intervals within hospital systems. REDI is only able to monitor cattle behaviour when

the animal is located within the REDI pens. There was a total of six hospital pens; 3 that were 40m deep, with 34m long of bunk space; 2 convalescence pens that were 40m deep with 77m of bunk space; and 1 chronic pen that was 40m deep with 64m of bunk space. The water troughs in all hospital pens were cleaned daily.

An animal pulled a second time by REDI after the 4-day post-treatment interval with Draxxin, was removed from the pen and re-treated with Engemycin (Oxytetracycline; Coopers Animal Health, Australia) with portions of the treatment course administered at 48-hour intervals in the hospital system. Cattle that enter the hospital system were fed ration 1. Cattle after the second treatment were auscultated with Whisper© and any animals with a score 1-3 were returned to the home pen, and any animals with a score of 4 or 5 remained in the hospital system for further observation, similar to that of the CON animals. A minimum of 48 hours after the second treatment was allowed for cattle to respond to the final treatment in their pen (home or hospital) before qualifying for a 3rd treatment. If REDI called an animal sick a 3rd time, the animal was treated with Nuflor/Meloxicam and returned to the home pen. If the REDI system called that animal sick again after the post-treatment interval, veterinary personal observed those animals to determine if they were truly a chronic. The animal was then taken to the hospital chute to have their body weight recorded and were removed from the feedlot study and ineligible to return to the home pen.

The REDI system only observed animals for BRD diagnosis, any other non-BRD issue an animal 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.

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 were to remain within their pen groups and placed in a separate clean pen adjacent to the other treatment for the remainder of the feeding period. Body weights for both treatment groups, REDI and CON, were recorded at the 60-day REDI tag removal time in the morning prior to feeding. Any cattle that were pulled for BRD greater than 60 DOF in either treatment group were treated with Excenel (Ceftiofur Hydrochloride; Zoetis, Australia).

3.5 Feeding management

Cattle were fed to achieve ad-libitum consumption, with daily feeding starting at 6 am. Cattle were fed twice per day on Ration 1, once per day on Ration 2, once per day on Ration 3, and twice per day on Ration 4. 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 Rotomix feed truck (920-18). 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 estimated with records placed on file, and any feed remaining in the bunk at cattle shipment was also estimated and recorded. All flake weights of grain processed were recorded. Dry matters of rations 1, 2, 3, and 4 were determined daily in a fan-forces oven at 105°C for a minimum of 16 hours. Finisher diets were sampled once weekly throughout the duration of the trial. A monthly composite sample of each finisher treatment diet was analysed for dry matter (DM), protein, non-detergent fibre (NDF), fat, fibre, 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 112 DOF. If there were limitation 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 2-3 days. 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 8 am to 4 pm, and cattle were transported 100 km from the feedlot to the slaughter facility. Cattle were slaughtered the following day around 6 am. At slaughter, a data monitor recorded body number, along with visual ID of the feedlot animals. Carcass grading occurred on all carcasses at approximately 24 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, but a pleurisy score was. Consolidation was recorded based on a scale of 0-100% (Rezac et al., 2014). Consolidations scores were categorized into three categories, 0-1, 2-9% and 10-55%. 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 is severe pleuritic adhesions with the chest requiring "Stripping." An animal where the lungs were adhered to the thoracic wall received a pleurisy score 3, but a consolidation score was not recorded (No Score). 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 3**). If an animal was rejected due to BRD, or necropsy confirmed BRD for an animal that died throughout the trial, these animals were also categorized as severe. Any other animal that was rejected or died for other reasons were not included in the normal, moderate, or severe lung score.

Table 3. Lung categorization table. The rows indicate the categories used for percent lung consolidation and the columns represent the category for pleurisy.

Consolidation	*Pleurisy*						
	0	**1**	**2**	**3**	Normal	N	
0-1%	N	N	M	S	Moderate	M	
2-9%	N	M	M	S	Severe	S	
10-55%	M	M	S	S	BRD_Dead/Reject	S	
No Score	M	M	M	S	Dead/Reject		
					Total		

3.8 Data collection

The REDI system monitored steers equipped with REDI tags for the first approximately 50 days on trial (range 49 – 56 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 (StockAid; Elynx, Australia) 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, whisper recording, body weight, REDI tag identification, and treatment group. All steers were weighed individually at arrival and 50-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 4**. The table describes variables, descriptions, and formulas for animals enrolled and followed through slaughter. The same outcomes variables were used for animals from allocation to behaviour tag removal and animals not treated for BRD from allocation to slaughter.

Table 4. Health outcome variables, descriptions, and formulas for animals enrolled until slaughter. The variables were also analysed for animals enrolled through behaviour tag removal (approximately 50 days on feed) and animals not treated for BRD from allocation to slaughter.

Variable	Descriptions	Formula
Initial BRD treatment	Animals pulled and treated for initial BRD from enrollment to slaughter	$\dfrac{\text{BRD1\_slaughter}}{\text{Total animals enrolled}}$
First BRD relapse	Animals pulled and treated for second BRD from enrollment to slaughter	$\dfrac{\text{BRD2\_slaughter}}{\text{BRD1\_slaughter}}$
Second BRD relapse	Animals pulled and treated for third BRD from enrollment to slaughter	$\dfrac{\text{BRD3\_slaughter}}{\text{BRD2\_slaughter}}$
BRD Trial Rejects	Animals diagnosed and treated 2 times for BRD and determined to be chronic, removed from the trial	$\dfrac{\text{BRD Trial Rejects}}{\text{Total animals enrolled}}$
Trial Rejects	Animals removed from the trial due to Bloat, Buller, Lame, Lost, Polio.	$\dfrac{\text{Trial Rejects}}{\text{Total animals enrolled}}$
BRD Mortality Rate	Mortality due to BRD.	$\dfrac{\text{BRD mortality}}{\text{Total animals enrolled}}$
Mortality Rate	Morality due to Downer, Polio, or unknown.	$\dfrac{\text{Other mortality}}{\text{Total animals enrolled}}$
Lung consolidation	Lung consolidation was categorized and analyzed based on the percent of consolidation. Categories included animals with 0-1%, 2-9%, and 10-55%. All animals enrolled in the trial and were followed through slaughter are included.	$\dfrac{\text{Consolidation category}}{\text{Total animals enrolled}}$
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.	$\dfrac{\text{Pleurisy score}}{\text{Total animals enrolled}}$

Normal	Animals categorized with normal lung lesions at slaughter	$\dfrac{\text{Normal Lung Score}}{\text{Total animals enrolled}}$
Moderate	Animals categorized with moderate lung lesions at slaughter	$\dfrac{\text{Moderate Lung Score}}{\text{Total animals enrolled}}$
Severe	Animals categorized with severe lung lesions at slaughter	$\dfrac{\text{Severe Lung Score}}{\text{Total animals enrolled}}$
BRD_Dead/Reject + Severe	Animals that were categorized as dead and reject and combined with the severe category lung score	$\dfrac{\text{Severe + BRD Dead/Reject}}{\text{Total animals enrolled}}$

Performance data included average daily gain (ADG), dry matter intake (DMI), and feed: gain (F:G). Finisher feed analysis was sampled monthly and analysed dry matter (DM), protein, non-detergent fibre (NDF), fat, fibre, ash, calcium (Ca), and phosphorus (P). Carcass data 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, Aumeat Marbling, Ossification, EMA, pH, Rib Fat, EMA, total hot dressed weight, left side bruising, left side weight, right side bruising, right side weight, and MSA index. All the data were collected for an MSA un-grade except MSA index. Categories were created for meat colour, fat colour, MSA marbling, Aumeat Marbling, Ossification, Rib Fat, EMA, weight, bruise, and railers based on quartiles, distributions, or known categories. Hump height, fat depth, pH and MSA index remained continuous variables. Performance outcome variables and formulas are presented in **Table 5**.

Table 5. 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. 50d weights were also recorded.	$\dfrac{\text{In} - \text{weight per pen total}}{\text{Total animals enrolled}}$
Out-weight	Full body weight taken before feeding over pen scale before dispatch	$\dfrac{\text{Out} - \text{weight per pen total}}{\text{Total animals slaughterd}}$
ADG	Average daily gain	$\dfrac{\text{Total weight gain per pen}}{\text{Total head days}}$
HSCW	Total hot carcass weight at the plant	$\dfrac{\text{Total HSCW}}{\text{Total animals slaughtered}}$
Feed Cost	Average feed cost for delivered per head to cattle slaughtered. Yardage is included in this total.	$\dfrac{\text{Avg. feed cost per pen}}{\text{Total animals slaughtered}}$
Treatment Cost	Average medical cost for animals slaughtered.	$\dfrac{\text{Avg. treatment cost per pen}}{\text{Total animals slaughtered}}$
DMI	Dry matter intake with deads and rejects removed	$\dfrac{\text{Quantity of feed delivered}}{\text{Total animals slaughtered}}$
F:G	Feed to gain (calculated from Initial weight to out-weight on a dry matter basis	
Total Value	Total Value of carcasses obtained at the plant from the grid.	$\dfrac{\text{Total value of carcasses}}{\text{Total animals slaughtered}}$
Net Return per Animal	Total value at slaughter – purchase price[*] – Feed cost – Treatment cost – Interest – Mortality and Railer loss	

[*] Purchase price was calculated from Australia Saleyard feeder steer prices for the month of purchase

3.9   Statistical analysis

The experimental unit for the statistical analysis was the pen, due to the treatment (REDI and Control) 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, Aumeat Marbling, Ossification, Rib Fat, EMA, weight, bruise, and railers). 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, feed to gain, feed costs, treatment costs, total value, net returns and dry matter intake, hump height, fat depth, pH and MSA index) 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

The proposal was originally written to utilize 3,520 steers, but due to conditions in the eastern states for the cattle market, the feedyard was unable to commercially buy the numbers and type of cattle originally designated for the trial. A total of 2,628 steers were enrolled in the trial beginning April 2017.

4.1   Enrolment to slaughter

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 in the first 50 days. 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.

A total of 1,314 animals were allocated for both diagnostic modalities. Lung consolidation for the 0-1% category was statistically different between CON vs REDI, and all other lung consolidation and pleurisy scores were not statistically different between diagnostic modalities for animals followed through slaughter. Lung scores for normal, moderate, severe were similar between the CON and REDI groups for animals followed through slaughter (**Table 6**). A total of 27% of the overall lung score category was normal for the CON and 30% for the REDI group. The severe lung scores were 14% for CON and 13% for REDI. In total, there were 134 animals that did not receive a consolidation score, but did receive a pleurisy score, and these animals were categorized as severe. There were numerically more animals in the dead and reject category in the CON animals than the REDI animals. Initial treatment of BRD was 9.4% in the CON animals compared to 33.30% in the REDI group ($P < 0.05$) (**Table 7 and Fig. 1**). Relapse rates were also higher in the REDI group ($P < 0.05$). The treatment success rate for the CON was 75.6% compared to 57% in the REDI group. Numerically, more animals died from reasons other than BRD in the REDI group, and more animals died from BRD in the CON group, but no statistical difference was found (**Table 6 and 7**). The case fatality rate was 1.6% in the CON vs 0.2% in the REDI group.

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* (1314 per treatment).

	Control	REDI
Total animals enrolled	1314	1314
Other Mortality[*]	0.2% (2)	0.2% (3)
BRD Mortality	0.2% (2)	0.0% (1)
Other Trial Rejects[†]	1.9% (25)	1.6% (21)
BRD Trial Rejects[‡]	0.7% (9)	0.3% (4)
Treatment Success	75.6% (93)	57.0% (247)
Treatment Failure	24.4% (30)	43.0% (186)
Case Fatality Rate[§]	1.6% (2)	0.2% (1)
Initial BRD treatment	9.4% (123)	33.0% (433)
First BRD relapse	24.4% (30)	42.9% (186)
Second BRD relapse	46.7% (14)	55.4% (103)
No BRD	90.1% (1191)	67.0% (881)
Consolidation		
0-1%	33.6% (441)	37.9% (498)
2-9%	46.9% (616)	44.3% (582)
10-55%	11.9% (157)	10.0% (131)
No score[ǁ]	7.6% (100)	7.8% (103)
Pleurisy		
0	4.5% (59)	5.6% (73)
1	49.7% (653)	50.5% (664)
2	37.6% (494)	35.3% (464)
3	5.3% (70)	6.4% (84)
No score[#]	2.9% (38)	2.2% (29)
Animals with Lung Category[**]	1287	1290
Normal	27.3% (351)	30.3% (391)
Moderate	58.0% (747)	56.3% (726)
Severe	13.8% (178)	13.0% (168)
BRD Dead/Reject	0.9% (11)	0.4% (5)
Severe/Dead/Reject	14.7% (189)	13.4% (173)

[*] Mortality due to Downer, Polio, or unknown by necropsy diagnosis.

[†] Animals that were rejects due to the following: Bloat, Buller, Lame, Lost, or Polio.

[‡] 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 3rd time.

[§] 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 50 days.

[ǁ] No score was due to the lungs being retained in the carcass for further inspection at slaughter (n=131), the animals were condemned (n=2), the lungs were adhered to the rumen and could not be scored (n=3), animals that died throughout the trial (n=8) or were true rejects (n=59).

[#] No score were animals that either died or were removed from the trial.

[**] Animals categorized as other reject or dead were not included in the analysis.

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. Rate models used a Poisson distribution and probability models used a binomial distribution using the logit link. Population included all animals enrolled in the trial (CON = 1314, REDI = 1314).

Probability	Control	REDI	*P* value
Initial BRD treatment	0.09 ± 0.01	0.33 ± 0.02	<0.0001
First BRD relapse	0.24 ± 0.04	0.43 ± 0.03	0.0003
Second BRD relapse	0.47 ± 0.09	0.55 ± 0.04	0.376
BRD Mortality	0.002 ± 0.00	0.001 ± 0.00	0.571
BRD Rejects	0.001 ± 0.002	0.003 ± 0.00	0.176
Consolidation			
0-1%	0.32 ± 0.05	0.37 ± 0.05	0.017
2-9%	0.47 ± 0.03	0.44 ± 0.03	0.181
10-55%	0.11 ± 0.02	0.09 ± 0.02	0.1
No score	0.08 ± 0.01	0.08 ± 0.01	0.827
Pleurisy			
0	0.04 ± 0.01	0.05 ± 0.01	0.205
1	0.50 ± 0.03	0.51 ± 0.03	0.663
2	0.37 ± 0.03	0.35 ± 0.03	0.22
3	0.05 ± 0.01	0.06 ± 0.01	0.246
No score	0.03 ± 0.00	0.02 ± 0.00	0.267
Normal	0.26 ± 0.05	0.29 ± 0.05	0.079
Moderate	0.58 ± 0.03	0.56 ± 0.03	0.361
Severe	0.13 ± 0.02	0.13 ± 0.02	0.546
BRD Dead/Reject	0.01 ± 0.002	0.003 ± 0.001	0.141
Severe/Dead/Reject[*]	0.16 ± 0.02	0.15 ± 0.02	0.305
Severe/Dead/Reject_BRD[†]	0.14 ± 0.02	0.13 ± 0.02	0.349

[*] Severe was combined with dead/reject, regardless of reason, denominator equals all animals enrolled

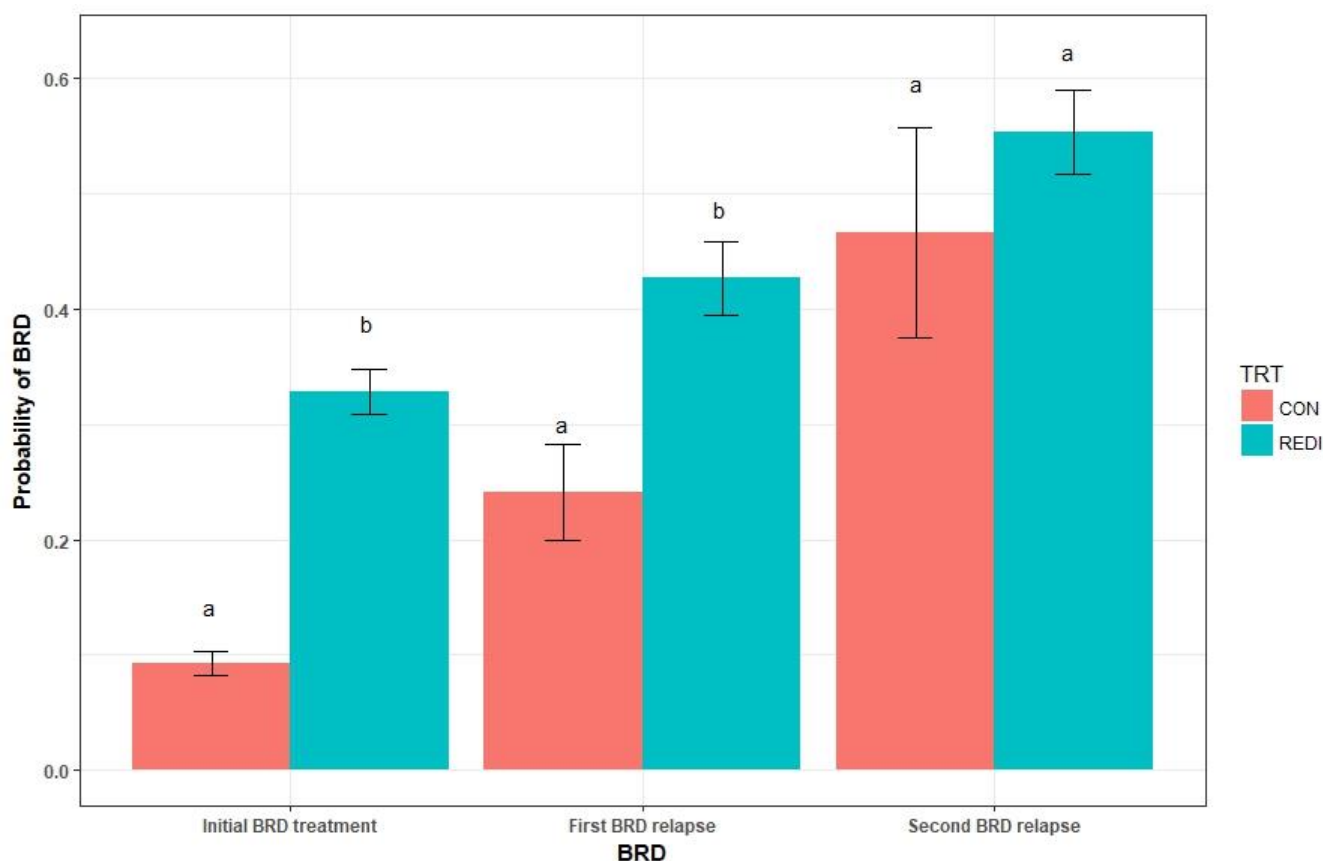[†] Severe was combined with dead/rejects due to BRD

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.

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

REDI tag removal ranged from 49-56 days on feed for each replicate. Of animals initially treated for BRD in the first 50 days, 56.0% were considered a treatment success in the REDI group (i.e. were not treated for BRD a second time), and 76.6% in the Control group (**Table 8**). Peak BRD treatment in the first 50 days occurred around day 5 for the REDI animals (**Fig. 2**). The percent of animals treated each day initially for BRD declines after day 5 but remained greater than the percent of animals treated in the control group throughout the remaining days on feed. Percent of animals treated daily for BRD in the control group remained below 0.5%, and percent of animals treated in the REDI group ranged from 0.3 – 3.6% daily. A significant difference was found between initial BRD treatment and BRD relapse between REDI vs CON, with REDI treating 32% of cattle initially for BRD in the first 50 days, and a secondary treatment for 44% of initially treated animals compared to 8% and 23% for the control group (**Table 9 and Fig. 3**). Control cattle that were considered a reject due to BRD was greater than the REDI group (*P* < 0.05). Of animals initially treated for BRD in the first 50 days, a greater number of control animals did not receive a consolidation score compared to the REDI group. A greater number of animals received a consolidation percentage of 0-1% and a pleurisy score of 1, compared to the control group (*P* <0.05). A greater number of REDI animals that were treated in the first 50 days had a normal lung score compared to control animals (*P* < 0.05). A significant difference was not found between the two groups for animals categorized as severe, but the combination of cattle with a severe lung score and also were a dead/reject in the first 50 days, there were 8% greater animals in the control group compared to the REDI group (*P* < 0.05) (**Fig. 4**).

Table 8. Descriptive statistics for known outcomes between diagnostic modalities during the first 50 days of the trials. Population included animals treated for *BRD in first ~50 days*.

	Control	REDI
Total animals enrolled	1314	1314
Initial BRD treatment	8.1% (107)	32.2% (423)
First BRD relapse	23.3% (25)	44.0% (186)
Second BRD relapse	48.0% (12)	55.4% (103)
No BRD	91.9% (1207)	67.8% (891)
BRD Mortality	1.9% (2)	0.2% (1)
BRD Trial Rejects*	6.5% (7)	0.9% (4)
Other Mortality	(0)	0.2% (1)
Other Trial Reject	8.4% (9)	2.1% (9)
BRD Treatment Success	76.6% (82)	56.0% (237)
BRD Treatment Failure	23.4% (25)	44.0% (186)
BRD Case Fatality Rate†	1.9% (2)	0.2% (1)
Consolidation		
0-1%	29.0% (31)	40.9% (173)
2-9%	38.3% (41)	41.6% (176)
10-55%	10.3% (11)	7.8% (33)
No score‡	22.4% (24)	9.7% (41)
Pleurisy		
0	4.7% (5)	6.4% (27)
1	37.4% (40)	49.9% (211)
2	36.4% (39)	33.1% (140)
3	4.7% (5)	7.1% (30)
No score§	16.8% (18)	3.5% (15)
Animals with Lung Category‖	98	413
Normal	24.5% (24)	32.4% (134)
Moderate	52.0% (51)	53.0% (223)
Severe	14.3% (14)	12.3% (51)
BRD Dead/Reject	9.2% (9)	1.2% (5)
Severe/Dead/Reject BRD	23.5% (23)	16.0% (66)

* 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 3rd time.

† 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 50 days.

‡ No score was due to the lungs being retained in the carcass for further inspection at slaughter (n=131), the animals were condemned (n=2), the lungs were adhered to the rumen and could not be scored (n=3), animals that died throughout the trial (n=8) or were true rejects (n=59) of animals initially treated for BRD in the first 50 days.

§ No score were animals that either died or were removed from the trial of the animals initially treated for BRD in the first 50 days.

‖ Animals categorized as other reject or dead were not included in the analysis.

Table 9. Model-adjusted least square mean probability differences ± SE for various outcomes for each diagnostic modality during the first 50 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 50 days (CONT = 107 and REDI = 423).

Probability	Control	REDI	*P* value
Initial BRD treatment	0.08 ± 0.01	0.32 ± 0.02	<0.0001
First BRD relapse	0.23 ± 0.04	0.44 ± 0.03	<0.0001
Second BRD relapse	0.48 ± 0.10	0.55 ± 0.04	0.488
BRD Mortality	0.02 ± 0.01	0.002 ± 0.002	0.0901
BRD Rejects	0.07 ± 0.02	0.01 ± 0.005	0.00175
Consolidation			
0-1%	0.26 ± 0.06	0.40 ± 0.05	0.006
2-9%	0.39 ± 0.05	0.42 ± 0.03	0.64
10-55%	0.10 ± 0.03	0.07 ± 0.02	0.37
No score	0.22 ± 0.04	0.10 ± 0.01	0.0005
Pleurisy			
0	0.04 ± 0.02	0.05 ± 0.02	0.645
1	0.37 ± 0.05	0.50 ± 0.03	0.02
2	0.34 ± 0.06	0.32 ± 0.04	0.69
3	0.05 ± 0.02	0.07 ± 0.02	0.43
No score	0.17 ± 0.04	0.03 ± 0.01	<0.0001
Normal	0.23 ± 0.05	0.33 ± 0.05	0.0782
Moderate	0.52 ± 0.06	0.54 ± 0.03	0.761
Severe	0.14 ± 0.04	0.12 ± 0.02	0.533
BRD Dead/Reject	0.09 ± 0.03	0.01 ± 0.01	0.00021
Severe/Dead/Reject[*]	0.30 ± 0.05	0.16 ± 0.02	0.001
Severe/Dead/Reject BRD[†]	0.24 ± 0.05	0.13 ± 0.02	0.011

[*] The severe was combined with dead/reject, regardless of reason, denominator equals all animals treated

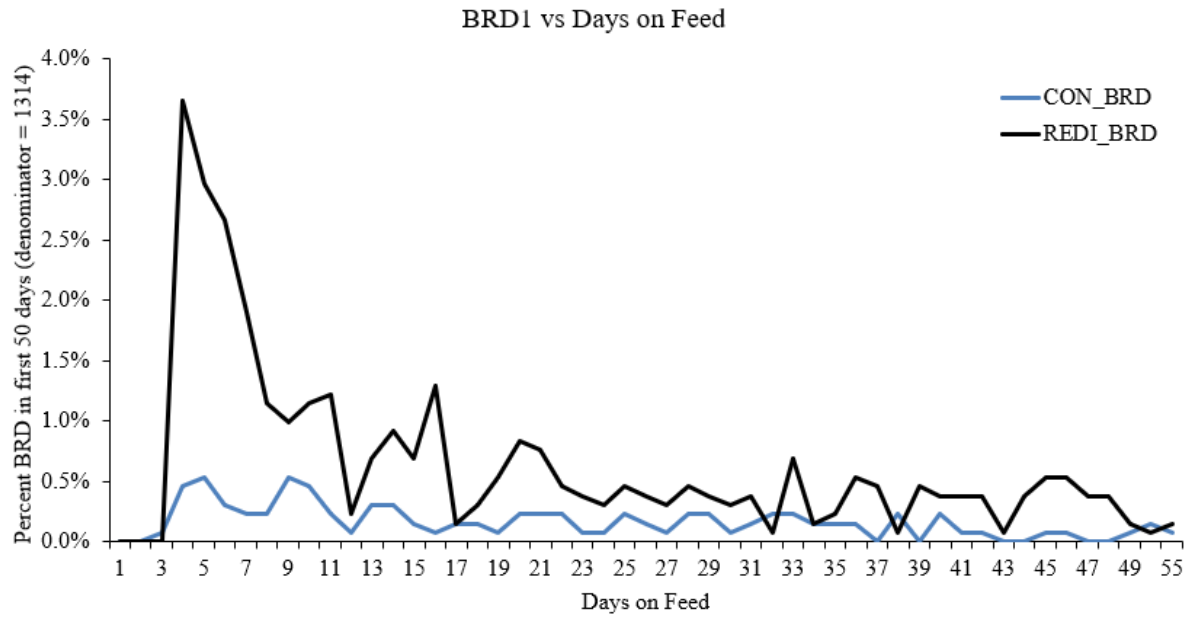[†] The severe was combined with dead/rejects due to BRD

Figure 2. Percent of animals treated initially for BRD prior to behaviour monitoring tag removal by diagnostic modality.
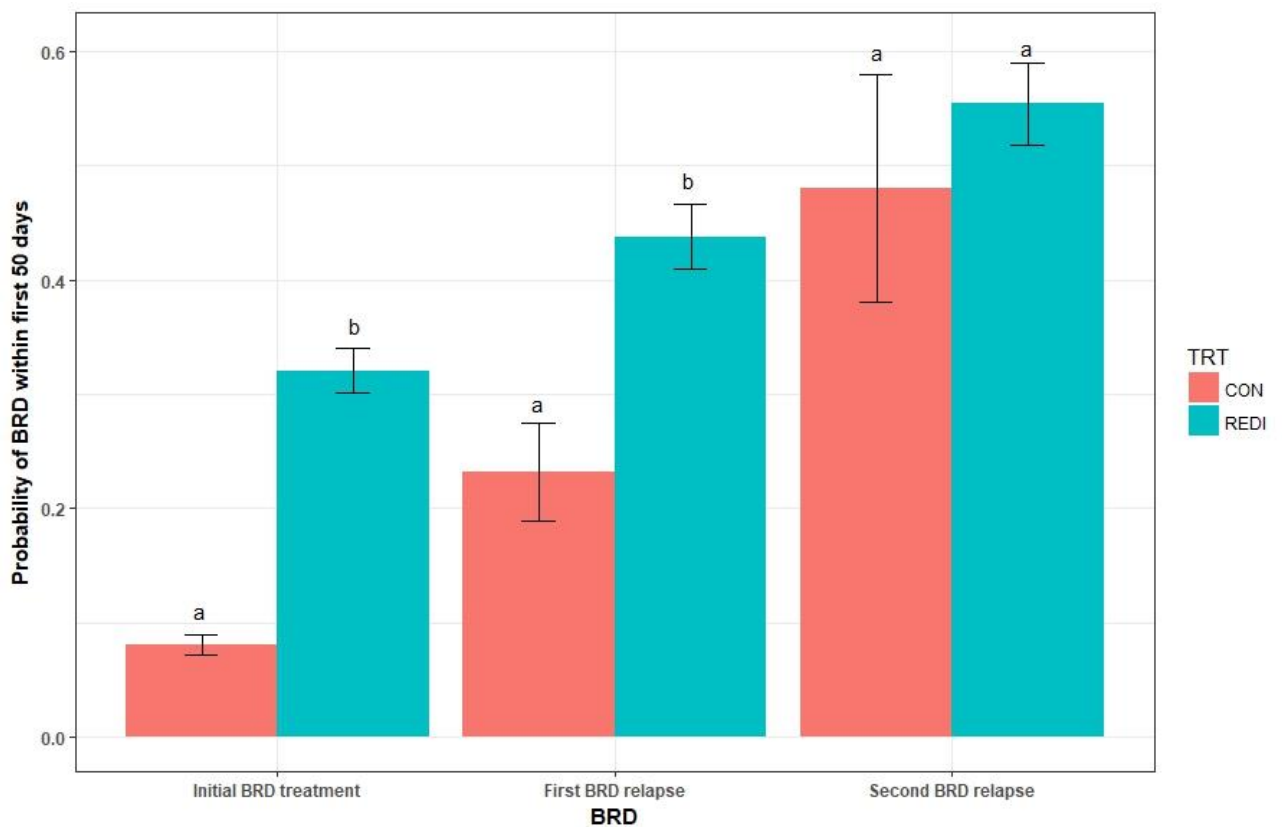

Figure 3. Probability of BRD treatment within the first 50 days by diagnostic modality. Error bars indicate the standard error of the probability. Rates sharing a letter are not significantly different
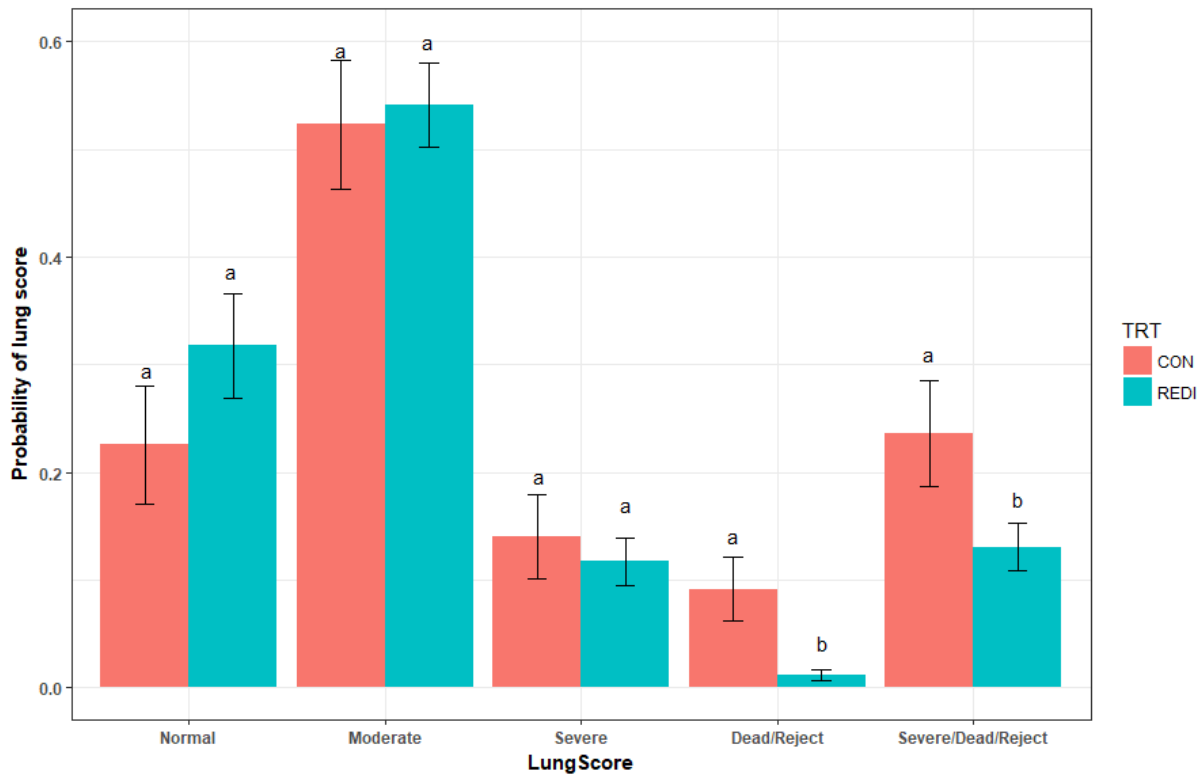
Figure 4. Probability of lung score of animals treated for BRD in the first 50 days by diagnostic modality. Error bars indicate the standard error of the probability. Probabilities sharing a letter are not significantly different.

4.3 Enrolment to slaughter for animals not treated for BRD

In the control group, 90.6% of the animals enrolled were not treated for BRD, and 67.0% of the REDI animals were not initially treated for BRD (**Table 10**). The difference between the two diagnostic modalities was not statistically different (**Table 11**). All other parameters tested were shown to not be statistically different between either treatment group at $P < 0.05$.

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=1191, REDI = 881)

Outcome	Control	REDI
Total animals enrolled	1314	1314
No initial BRD treatment	90.6% (1191)	67.0% (881)
Other Mortality[*]	0.2% (2)	0.2% (2)
Other Trial Rejects[†]	1.3% (16)	1.2% (11)
Consolidation		
0-1%	34.2% (407)	36.2% (319)
2-9%	47.9% (570)	46.0% (405)
10-55%	11.9% (142)	10.9% (96)
No score[‡]	6.4% (72)	6.9% (61)
Pleurisy		
0	4.5% (54)	5.2% (46)
1	51.0% (608)	50.7% (447)
2	37.6% (448)	36.4% (321)
3	5.3% (63)	6.1% (54)
No score[§]	1.5% (18)	1.5% (13)
Normal	27.2% (324)	28.7% (253)
Moderate	57.9% (689)	56.6% (499)
Severe	13.4% (160)	13.2% (116)
Dead/Reject	1.5% (18)	1.5% (13)
Severe/Dead/Reject	14.9% (178)	14.6% (129)

[*] Mortality due to Downer, Polio, or unknown by necropsy diagnosis. No animals died that were not previously treated for BRD.

[†] Animals that were rejects due to the following: Bloat, Buller, Lame, Lost, or Polio. No animals were reject for BRD that were not previously treated (i.e. an animal rejected for BRD had to be treated for BRD to become a chronic)

[‡] No score was due to the lungs being retained in the carcass for further inspection at slaughter, the animals were condemned, the lungs were adhered to the rumen and could not be scored, animals that died throughout the trial, or were true rejects of animals not initially treated for BRD.

[§] No score were animals that either died or were removed from the trial of the animals not initially treated for BRD.

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	0.91 ± 0.01	0.67 ± 0.02	<0.0001
Non-BRD Mortality	0.001 ± 0.001	0.002 ± 0.001	1.00
Non-BRD Rejects	0.01 ± 0.003	0.008 ±0.0.003	0.336
Consolidation			
0-1%	0.33 ± 0.05	0.35 ± 0.06	0.346
2-9%	0.48 ± 0.03	0.46 ± 0.03	0.415
10-55%	0.11 ± 0.02	0.10 ± 0.02	0.475
No score	0.06 ± 0.01	0.07 ± 0.01	0.427
Pleurisy			
0	0.04 ± 0.01	0.05 ± 0.01	0.443
1	0.51 ± 0.03	0.51 ± 0.03	0.861
2	0.37 ± 0.03	0.36 ± 0.03	0.609
3	0.05 ± 0.01	0.06 ± 0.01	0.426
No score	0.02 ± 0.00	0.01 ± 0.00	0.947
Normal	0.25 ± 0.05	0.27 ± 0.05	0.457
Moderate	0.58 ± 0.03	0.57 ± 0.03	0.598
Severe	0.13 ± 0.02	0.13 ± 0.02	0.865
Dead/Reject	0.02 ± 0.00	0.01 ± 0.00	0.947
Severe/Dead/Reject	0.15 ± 0.02	0.14 ± 0.02	0.85

4.4 Performance outcomes from enrolment to slaughter

A total of 1,276 animals were slaughtered from the Control group, and 1,285 animals from the REDI group. There was an average of 213 animals in the Control pens and 214 animals in the REDI pens, with an average of 115 days on feed per pen. No statistical differences were found between diagnostic modalities of animals' slaughter between in-weight, out-weight, HSCW, F:G, DMI, ADG, or total value at slaughter (**Table 12**). A significant difference (*P* < 0.05) was found in treatment costs, with REDI animals costing an average of $18.58 per head and Control animals costing $4.14. No significant difference was found between purchase price, feed cost, gross revenue, or net return. The net return per steer on a deads and rejects out basis was $183.38 for control and $169.72 for REDI, with a greater net return per steer for the control by $13.66. The net return per steer on a deads and rejects in basis was $164.72 for control and $152.29 for REDI, with a greater net return per steer for the control by $12.43. Carcass characteristic models demonstrated a significant difference (*P* < 0.05) between both groups with a greater P8Fat for REDI, greater Rib Fat 0-8 mm for control, and 9-35mm for REDI (**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	114.64	114.67	1.22	0.254
In-weight (kg)	434.4	436.2	5.7	0.18
Out-weight (kg)	690.4	690.2	8.8	0.957
F:G*	5.17	5.25	0.1	0.244
DMI	11.5	11.6	0.3	0.114
ADG (kg)	2.2	2.2	0.1	0.55
ADG_50days	2.4	2.3	0.1	0.471
Total Value per hd	$2214.44	$2217.67	$26.50	0.793

* Feed to Gain was calculated from In-weight to Out-weight on a dry matter basis

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	*P* value
HSCW (kg)	366.9 ± 4.4	367.0 ± 4.4	0.97
P8Fat	17.05 ± 0.67	17.51 ± 0.67	0.0166
Fat Color, %			
0	0.34 ± 0.06	0.37 ± 0.06	0.1579
1	0.63 ± 0.06	0.60 ± 0.06	0.1950
2	0.02 ± 0.01	0.02 ± 0.01	0.786
Meat Color, %			
1B, 1C	0.11 ± 0.04	0.11 ± 0.04	0.732
2-7	0.89 ± 0.04	0.89 ± 0.04	
Hump Height	76.63 ± 0.97	77.19 ± 0.97	0.565
MSA Marble, %			
140-360	0.48 ± 0.05	0.47 ± 0.05	0.367
370-690	0.52 ± 0.05	0.53 ± 0.05	
AUS Marble, %			
0	0.04 ± 0.02	0.04 ± 0.02	0.863
1	0.53 ± 0.04	0.54 ± 0.04	0.871
2	0.34 ± 0.04	0.33 ± 0.04	0.409
3	0.04 ± 0.01	0.05 ± 0.01	0.25
Ossification, %			
110-180	0.50 ± 0.05	0.51 ± 0.05	0.627
190-500	0.50 ± 0.05	0.49 ± 0.05	
pH	5.53 ± 0.01	5.53 ± 0.01	0.74
Rib Fat, mm			
0-8	0.56 ± 0.04	0.52 ± 0.04	0.0169
9-35	0.43 ± 0.04	0.48 ± 0.04	
EMA			
55-83	0.50 ± 0.04	0.50 ± 0.04	0.956
84-125	0.50 ± 0.04	0.50 ± 0.04	
LGrade, %			
PR (Prime Beef)	0.003 ± 0.002	0.004 ± 0.002	0.801
YG (Young Beef)	0.93 ± 0.01	0.93 ± 0.01	0.83

YP (Young Prime Beef)	0.06 ± 0.01	0.06 ± 0.01	0.763
LBruise			
0	0.99 ± 0.003	1.00 ± 0.002	0.127
3	0.01 ± 0.003	0.004 ± 0.002	0.246
RBruise			
0	0.99 ± 0.003	0.99 ± 0.003	0.821
3	0.008 ± 0.002	0.008 ± 0.002	0.987
RGrade, %			
PR (Prime Beef)	0.004 ± 0.002	0.004 ± 0.002	0.801
YG (Young Beef)	0.93 ± 0.01	0.93 ± 0.01	0.83
YP (Young Prime Beef)	0.06 ± 0.01	0.06 ± 0.01	0.763
MSA Index	54.71 ± 0.50	54.63 ± 0.50	0.806
Retain Rail, %	0.01 ± 0.01	0.003 ± 0.003	0.301

4.5 Breed outcomes

Nine different breeds were enrolled in the trial (Angus, Red Angus, Angus cross, Bos Indicus cross, British cross, European, Hereford, Murray Grey, and Shorthorn). Of the nine breeds within each treatment group, the control animals numerically treated more Angus and European compared to the other breeds and REDI treated more Angus, Bos Indicus cross, and European compared to the other breeds. Overall, there were no difference between breeds for the treatment groups at allocation (**Table 14**). Of animals treated in the first 50 days, there was a statistical difference between the treatment groups for the European breed ($P < 0.05$), with the probability of European breed being treated initially for BRD 4% higher in the control cattle compared to the REDI cattle. All other breeds were not statistically different for effect on diagnostic modality in the first 50 days.

Table 14. Model-adjusted least square means ± SE of the effect of breed on diagnostic modality. 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	*P* value
Allocation to Slaughter			
Angus	0.65 ± 0.17	0.64 ± 0.17	0.806
Red Angus	0.00 ± 0.00	0.00 ± 0.00	0.214
Angus cross	0.06 ± 0.02	0.06 ± 0.02	0.939
Bos Indicus cross	0.03 ± 0.04	0.02 ± 0.04	0.27
British cross	0.03 ± 0.01	0.03 ± 0.01	0.919
European	0.04 ± 0.04	0.04 ± 0.04	0.457
Hereford	0.01 ± 0.01	0.01 ± 0.01	0.742
Murray Grey[*]			
Shorthorn	0.00 ± 0.00	0.00 ± 0.00	0.423
Initial BRD treatment in 50 days			
Angus	0.56 ± 0.21	0.65 ± 0.18	0.190
Red Angus[*]			
Angus cross	0.06 ± 0.02	0.06 ± 0.02	0.788
Bos Indicus cross	0.03 ± 0.03	0.05 ± 0.06	0.189
British cross	0.04 ± 0.03	0.03 ± 0.02	0.527
European	0.09 ± 0.09	0.05 ± 0.05	0.0207
Hereford	0.03 ± 0.02	0.02 ± 0.01	0.325
Murray Grey	0.01 ± 0.01	0.01 ± 0.01	0.551
Shorthorn[*]			

*Model failed to converge

4.6 Tag retention rates

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 (~50 days). The first and third induction did not have records for tags missing at tag removal. The first two 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 3-6. Tag loss per induction group ranged from (5.9 – 19.3%) (**Table 15**). Total tag loss for all animals inducted was 10.9%.

Table 15. REDI tag loss for each induction group.

Induction group	Head inducted	Tags not retained throughout trial	Tag loss (%)
1*	220	37	16.8%
2*	223	43	19.3%
3	215	22	10.2%
4	216	15	6.7%
5	220	13	5.9%
6	220	13	5.9%
Total	1314	143	10.9%

*Old tag backs used in the first two inductions, groups 3-6 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 a large-scale feeding operation in Australia to the authors' knowledge. Previous research evaluating the REDI system has occurred in the United State 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 generated lung categorizations (Table 3) provide novel information to further quantify BRD disease detection.

The first objective of the project was to evaluate both systems (REDI vs CON) for BRD detection and diagnosis. A significant difference in animals initially treated for BRD from allocation to slaughter provided interesting results. Previous research has demonstrated REDI to diagnose BRD up to three days 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 greater number of calves were treated initially for BRD in the REDI group compared to the control group, which differs from previous research results. REDI treated 23% greater cattle for BRD compared to CON, although most of these animals were treated in the first 5 days on feed. Further calibration of the REDI system in the first week animals are on feed could optimize the accuracy of the REDI system. Recalibration and optimization of the REDI system would also help decrease the number of animals treated a second time for BRD.

The ability to associate BRD treatment with lung lesion category in cattle remotely monitored for BRD versus conventional detection is the first of the authors' knowledge. A greater number of animals treated from the REDI group were categorized as normal at a greater probability compared to the CON animals, and further analysis of BRD detection by days on feed is warranted to calibrate the disease detection methods not only by individual groups, but also to specific times during the monitoring period.

A significant difference between the diagnostic modalities for BRD trial rejects in the first 50 days on feed may have been due to a greater number of animals treated for initial BRD in the REDI group compared to CON earlier in the disease process. No difference in BRD mortality was found, which may be due to the decreased number of animals that were categorized as a BRD mortality throughout the trial for both diagnostic modalities.

The second objective of the trial was to determine the economic impact of BRD on feedlot performance and carcass characteristics by analysis of treatment records and lung score data at slaughter. The difference in net returns from the two diagnostic modalities is associated with the greater difference in treatment costs. The significant difference in treatment cost is due to the greater number of initial BRD and second BRD treatments in the REDI group compared to the control. Decreasing the cost of treatments could be accomplished by decreasing the number of initial BRD treatments in the REDI group, which could also increase the net returns. No difference found in performance characteristics is consistent with previous research comparing REDI to conventional detection (White et al., 2017).

6 Conclusions/recommendations

Results from the trial showed no statistical differences between treatment groups for lung lesions, mortalities, rejects, or performance characteristics. A significant difference was found between initial BRD treatment and BRD relapse between REDI vs CON during the REDI monitoring period (~50 days on feed), with REDI treating 32% of cattle initially for BRD, and a secondary treatment for 44% of initially treated animals compared to 8% and 23% for the control group. Initial BRD treatment in REDI occurred in the first 7 days on feed. The percent of animals treated each day initially for BRD declines after day 5 but remained greater than the percent of animals treated in the control group throughout the remaining days on feed. Decreasing the number of pulls in the first 7 days on feed in the REDI group would have resulted in lesser initial BRD treatment percentage differences between both modalities.

A significant difference ($P < 0.05$) was found in treatment costs, with REDI animals costing an average of $18.58 per head and Control animals costing $4.14. The net return per steer on a deads and rejects in basis was $164.72 for control and $152.29 for REDI, with a greater net return per steer for the control by $12.43.

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. It is believed that the algorithms could be calibrated to result in less initial BRD pulls in the REDI groups compared to the controls, resulting in decreased treatment costs and greater net returns.

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 testing 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 7 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. This trial demonstrated that REDI is comparable to conventional detection for lung lesions, mortality, and carcass performance. The main difference identified was a greater number of initial and second BRD treatments in the REDI group, which can be decreased through algorithm calibration and optimization.

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