Final report

Evaluation of partial pen coverage with shelter in a commercial feedlot

Project code: B.FLT.4020

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Abstract

The effects of partial covered shelter and bedding on animal productivity, health, wellbeing, and carcase characteristics were evaluated in a large commercial feedlot. Partial covered housing is a potential solution to protect cattle from solar radiation and heat in summer, and rainfall and wet conditions in winter. Bedding may provide drier and more comfortable pen floors. Partial covered housing provides cattle with the opportunity to express choice over their environment to spend time under cover or outdoors. A randomised block design including 8 pen replicates per treatment with a total of 5,178 Angus steers housed in 24 pens was completed across two seasons, winter and summer. Three treatments were compared including: 1) conventional outdoor feedlot pen with no shade and hardwood wood chipped bedding at a depth of 150 mm (OUT-BED), 2) partial covered housing feedlot pen with 7.5 m^2 of cover per individual and conventional manure pack pen floor with no bedding (SHED-NOBED), and 3) partial covered housing feedlot pen with 7.5 m^2 of cover per individual and hardwood wood chip bedding at a depth of 150 mm (SHED-BED). Cattle under partial covered housing with bedding had increased feed intake, average daily gain, exit weight, and hot carcase weight. Cattle under partial covered housing with no bedding had increased musculoskeletal morbidity and removals, demonstrating bedding is beneficial to musculoskeletal health in long-fed Angus cattle. In the situation where carcase weight value of 900c/kg HSCW could be achieved, the SHED-BED treatment returned a positive NPV and IRR, suggesting that it would be a profitable investment, and have a payback period of 12 years.

Executive summary

Background

This project evaluated the effects of partial covered housing and woodchip bedding in long-fed Angus cattle in the final 110 days of their feeding period. These data are essential to provide feedlot managers, owners, and operators with clear information regarding the advantages of partial covered housing and bedding for feedlot cattle and to quantify the costs of such interventions. The results of this research will help producers to make informed decisions regarding installation and adoption of strategies to improve animal comfort, welfare, performance, and health.

Objectives

This project determined the effect of partial covered shelter and bedding on animal productivity, health, wellbeing, environment, and carcase characteristics of feedlot cattle. This project was completed in a large commercial feedlot with the objective to evaluate the benefits of bedding and partial covered housing, a potential solution to protect cattle from solar radiation and heat in summer and rainfall and wet conditions in winter.

Methodology

A randomised block design including eight pen replicates per treatment with a total of 5,178 Angus steers housed in 24 pens was completed across two seasons, winter and summer. Three treatments were compared including:

1. conventional outdoor feedlot pen with no shade and hardwood wood chipped bedding at a depth of 150 mm (OUT-BED)
2. partial Covered housing feedlot pen with 7.5 m^2 of cover per individual and conventional manure packed pen floor with no bedding (SHED-NOBED), and
3. partial covered housing feedlot pen with 7.5 m^2 of cover per individual and hardwood wood chipped bedding at a depth of 150 mm (SHED-BED).

The project evaluated key parameters including:

- Animal performance (feed intake, average daily gain, gain:feed).
- Animal health (morbidity, removals, mortality).
- Carcase characteristics (hot carcase weight, dressing percentage, meat quality and yield including full MSA grading parameters).
- Pen conditions (mud depth).
- Environmental impact (manure compositional analysis, manure yield, water intake).
- Cattle cleanliness (dag scores).
- Pen temperature and humidity.
- Ex-ante Cost Benefit Analysis.

Results/key findings

- Cattle under partial covered housing with bedding had increased feed intake (0.45 kg DM/hd/d), average daily gain (0.09 kg/d), and exit weight (11.1 kg).
- Cattle under partial covered housing with bedding had increased hot carcase weight (6.3 kg HSCW).
- Bedding has a significantly positive impact on musculoskeletal health in long-fed Angus cattle, reducing morbidity and cull rates.
- Pen floor contents removed from pens with bedding had increased carbon: nitrogen ratio, total carbon, and moisture content.
- Where the MAX carcase weight value (900c/kg HSCW) could be achieved, the SHED-BED treatment returned a positive NPV and IRR, suggesting that it would be a profitable investment, and have a payback period of 12 years.

Benefits to industry

Partial covered housing and bedding were clearly evaluated as potential interventions to improve animal performance and welfare. These results demonstrate cattle have increased feed intake, average daily gain, and hot carcase weight under partial covered housing and bedded conditions. Where a premium carcase weight value could be obtained, for this class of cattle, the partial covered shelter with bedding returned a positive Net Present Value and a payback period of 12 years.

Future research and recommendations

Future research should continue to evaluate the effects of the same parameters over sequential year-round conditions as annual weather conditions including rainfall and temperature are variable and hence have a significant impact on the effects of partial covered housing and bedding. Future research could also be directed towards different market categories of cattle.

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1. Background

The increasing global demand for animal protein is driving the intensification of livestock production systems, and at the same time, societal concerns about the animal products origin, their environmental impact, and animal welfare are growing. There is some philosophical debate about how welfare should be defined and managed (Fraser, 2008). Animals' physical health and productive responses have traditionally been the primary focus when assessing welfare conditions. However, there is a growing recognition of the importance of providing animals with opportunities to exercise control over their environment and live 'natural lives'. This shift in mentality underscores the crucial role of humans in enhancing the psychological well-being and overall welfare of animals in captivity. (Englund and Cronin, 2023). Some researchers suggest that perceiving control over one's environment is evolutionarily beneficial, enhancing an animal's chances of survival as animals when presented with options are likely to choose those that maximize benefits and avoid those that pose risks (Leotti et al., 2010). In many countries, cattle feeding occurs in covered indoor housing systems or barns where animals are hand-fed. Since 1970, the construction of large feedlot operations has shifted towards low-rainfall areas, particularly in major beef-producing countries such as the U.S., Mexico, Australia, and South America (Grandin, 2016). Modern feedlots are intensive beef production systems designed to maximise growth and development while ensuring animal welfare, well-being, and health. Therefore, promoting cattle welfare in modern feedlot facilities can enhance consumers' perception of beef production and improve cattle growth performance, potentially leading to greater financial sustainability.

Generally, increased animal growth and development are brought about by enhanced availability of energy utilized for tissue growth and synthesis (i.e. Net Energy for gain [NEg] and Net Energy for Lactation [NEl]) (Lofgreen and Garrett, 1968). In other words, the increased energy available for tissue growth is largely due to 1) increased feed energy intake and 2) reduced energy requirements for maintenance, which incorporates heat energy associated with basal metabolism (HeE), digestive enzyme activity (HdE), fermentation (HfE), metabolic processes of product formation and absorption (HrE), thermal regulation (HcE), and waste formation and excretion (HwE) (NRC, 1984). In some cases, both factors may occur concurrently (Tedeschi and Fox, 2020). Like all homeothermic animals, cattle have a thermoneutral zone, which is a thermal environment that supports their optimal health and productivity (Ames, 1980) by reducing heat energy associated with thermal regulation (Baumgard and Rhoads, 2012). As the environmental temperature goes above or below the cattle thermoneutral zone, heat accumulation might occur, resulting in a decrease in energy intake, or the generation of heat might be necessary to maintain core body temperature (Fox and Tylutki, 1998). When cattle are exposed to temperatures outside their thermoneutral zone, their growth performance and welfare are impaired. This is due to reduced feed energy intake or increased heat production for thermal regulation, consequently reducing the energy available for tissue growth. Several research studies have widely supported the implementation of shade to alleviate heat load in feedlot cattle and improve their growth and welfare (Gaughan et al., 2008; Grandin, 2016; Edwards-Callaway et al., 2021). The beneficial responses of shade for feedlot cattle include improved immune function (Mitlöhner et al., 2002; Aengwanich et al., 2011), lowered cattle respiration rate and body temperature (Brown-Brandl et al., 2013), and many positive responses on animal behaviour (Titto et al., 2011; Baliscei et al., 2012; Lees et al., 2020). Some of the benefits of providing shade to feedlot cattle include increased finishing and carcass weights by 8.9 kg and 5.8 kg, respectively, improved marbling scores (by 3.55%), and enhancements in average daily gain (ADG) and feed conversion ratio (F:G) by 4.96% and 2.95%, respectively (Edwards-Callaway et al., 2021). Different studies have shown that cattle will utilise shade if available and use of shade increases as heat-load intensity increases (Sullivan et al., 2011; Lees et al., 2020), which emphasises that providing animals with opportunities to exercise control over their environment can improve both growth and development parameters as well as animal welfare.

Exposure to cold, wet, or windy conditions during winter can also compromise animal comfort and productivity (Mader and Griffin, 2015). Wagner et al. (2008) indicated that the energy requirement for maintenance can increase up to 2.5-fold when cattle are exposed to severe winter weather conditions. Additionally, uncomfortable surface conditions, such as mud, can breach the skin barrier, elevating the risk of infectious diseases like digital dermatitis and foot rot, thus increasing the incidence of lameness (Davis-Unger et al., 2019). When given a choice, cattle clearly have a preference for avoiding lying on wet surfaces (Fregonesi et al., 2007; Johnson et al., 2011). Exposure to wet conditions and/or deprivation of lying time can trigger a cascade of physiological responses, including elevated cortisol levels and decreased white blood cell counts (Tucker et al., 2007; Webster et al., 2008). The negative impacts of muddy pens can be further mitigated by utilising bedding materials to absorb excess moisture from pen surfaces, creating a drier and more comfortable area for cattle to lie (Grandin, 2016). Tait et al. (2023) observed improvements in feed intake, ADG, and F:G, with increases of 4.42%, 8.41%, and 3.67%, respectively, when pens were bedded with woodchips at 15 cm and 30 cm depth over a 109-day feeding period. The authors also observed an additional 26.1 kg of live weight by the end of the feeding period and estimated that woodchip bedding can improve energy utilization efficiency for tissue growth. Additionally, the adrenal gland weight relative to carcass weight tended to be greater in animals without bedding, suggesting that woodchip bedding may reduce chronic stress in confined cattle, especially in cold environments. Using woodchips to alleviate muddy conditions in feedlot pens has garnered significant interest due to their durability, porosity, and high water-absorption capacity (Kumar and Flynn, 2006). Wilkes et al. (2022) noted a linear decrease in soil moisture content and penetration depth in pens bedded with woodchips at 0, 15, or 30 cm, suggesting that avoiding muddy conditions through bedding enhances animal locomotion and contributes to improved animal welfare (Grandin, 2016). It is likely that the benefits of bedding could be even more significant during extended feeding periods, as heavier animals could experience reduced locomotion due to muddy conditions and increased penetration depth. In summary, the provision of drier surface through bedding pens is of great interest to long-fed cattle in feedlot conditions as it can reduce the energy required for maintenance (Smerchek and Smith, 2021) and improve animal welfare conditions in Australia (Salvin et al., 2020). Furthermore, there is an interest in evaluating the potential benefits in animal welfare and growth performance parameters by providing partially covered housing alone or combined with woodchip bedding in long-fed animals. It is anticipated that offering animals the option to seek shade during high-heat events and access drier surfaces can enhance animal welfare (Rust et al., 2024) and enable better utilisation of energy intake for tissue growth (Fox and Tylutki, 1998).

The research outcomes of this study will empower feedlot owners and managers to make informed decisions regarding potential capital investments in covered housing and partial covered housing as well as bedding investments.

2. Objectives

The objective of the present study was to examine the effects of pen cover (0 vs. 7.5m^2 shelter per head) retrofitted to an open feedlot pen compared to conventional open pen management and bedding (150 mm woodchip bedding) on:

- Animal performance (feed intake, average daily gain, gain:feed).
- Animal health (morbidity, removals, mortality).
- Carcase characteristics (hot carcase weight, dressing percentage, meat quality and yield including full MSA grading parameters).
- Pen conditions (mud depth).
- Environmental impact (manure compositional analysis, manure yield, water intake).
- Cattle cleanliness (dag scores).
- Pen temperature and humidity.
- Ex-ante Cost Benefit Analysis.

3. Methodology

3.1 Animal Ethics

This project was completed under the approval of the NSW DPI (Animal Ethics Committee Reference Number: RVF23/344) by the establishment number 80454.

3.2 Experimental Design

A randomised block design including eight pen replicates per treatment with a total of 5,178 Angus steers housed in 24 pens was completed across two seasons, winter and summer.

The experimental treatments were:

1) Control- unshaded pens with woodchip bedding (150 mm). Referred to in this final report as OUT-BED.
2) Partial covered housing (7.5 m^2/head) without woodchip bedding. Referred to in this final report as SHED-NOBED.
3) Partial covered housing (7.5 m^2/head) with woodchip bedding (150mm). Referred to in this final report as SHED-BED.

Three original home pens of 220 individual cattle of similar days on feed were included per replicate, for a total of 660 individuals per replicate. Individual animals were blocked by vendor and original home pen and sequentially allocated to one of three treatment groups with approximately 220 individuals per group. A random number generator was used to allocate treatment group to one of three treatment pens.

This study was completed using cattle in the final 100 days of a 280 day long-fed Angus program. Cattle were therefore inducted into the feedlot 180 days prior to the commencement of the study. There were no additional animal health or processing treatments applied to the cattle at the commencement of the study. As the animals were placed into the study at 180 days on feed, they were only fed one ration (finisher ration) for the duration of the study.

3.3 Pen Designs

Three pen designs were used for the study. The pen designs are listed below. A covered housing system design retrofittable to the existing feedlot pens was selected and designed for the feedlot by Entegra Signature Structures. The housing system was 440m long x 30 m wide x 6 m high with ridgeback roof.

1) Unshaded pens E11-E18 (OUT-BED treatment).
   Pen dimensions: 55 x 60 m
   Head in pen: 220 animals
   Outdoor Pen – Industry Standard
   Bedding: Hardwood Wood Chipped at a depth of 150 mm
   Stocking density of 15 m2 per head
   Water trough: 2900 m x 790 mm
   Bunk Space: 55m – 25 cm per head

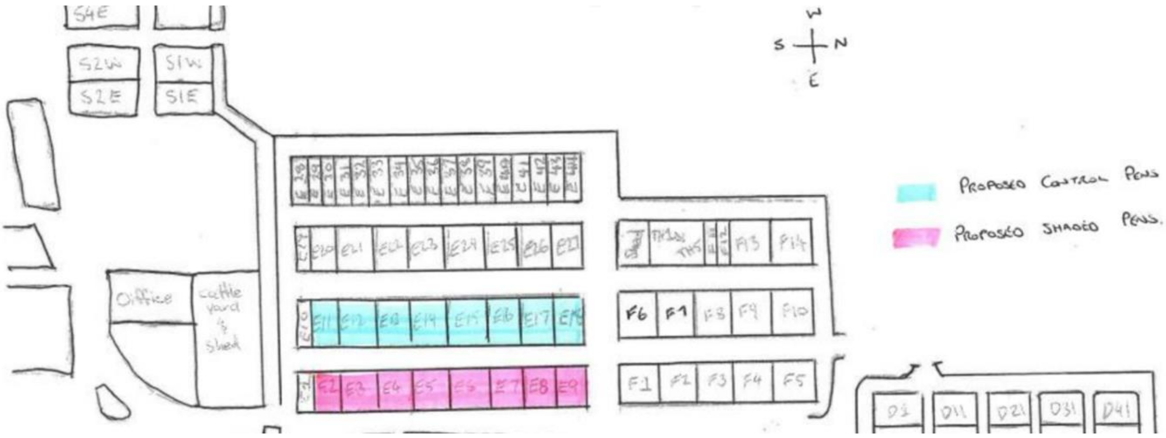
2) Partial shelter pens E2-E9 (SHED-NOBED treatment).
   Pen dimensions: 55 x 60 m
   Head in pen: 220 animals
   Covered Pen- 7.5 m^2 per head covered housing
   Bedding: Hard Packed Soil – No Wood Chip
   Stocking density of 15 m2 per head
   Water trough: 2900 m x 790 mm
   Bunk Space: 55 m – 25 cm per head

3) Partial shelter pens E2-E9 (SHED-BED treatment).
   Pen dimensions: 55 x 60 m
   Head in pen: 220 animals
   Covered Pen- 7.5 m^2 per head covered housing
   Bedding: Hardwood Wood Chipped at a depth of 150 mm
   Stocking density of 15 m2 per head
   Water trough: 2900 m x 790 mm
   Bunk Space: 55 m – 25 cm per head

All control and treatment pens were located in the same region of the feedlot with similar orientation.

The partial shelter structure covered pens E2-E9 as shown in the partial site map below. The control pens consisted of pens E11-E18.

Figure 1. Partial site map depicting where study was completed



Pens were cleaned prior to the enrolment of cattle into pens for each block. New woodchip was applied to the pens requiring woodchip prior to the commencement of the feeding period for each of those pens (150 mm depth).

3.4 Animal Health

Animal health was monitored daily by trained pen riders. Animals expressing clinical signs of morbidity were taken to the hospital for further evaluation, and treatment was performed according to the feedlot health protocol designed by a veterinarian. Morbidities, mortalities, and removals were classified into four categories including respiratory, digestive, musculoskeletal, and other.

Respiratory ailments included Bovine Respiratory Disease Complex and Diphtheria. Digestive ailments included bloat. Musculoskeletal ailments included infected joint, abscess, cast, cellulitis, footrot, laminitis, lameness, and open wounds. Treatment protocols are confidential and thus not discussed in this report.

Electronic records were maintained for all individual animal treatments including date, individual weight, visual ID, RFID, diagnosis, and treatment.

All mortalities in the experimental pens had a necropsy performed by feedlot staff, with information entered into the necropsy template and reported as part of the project.

3.5 Ration Formulations, Bunk Management, and Feeding

The cattle were 180 days on feed at the commencement of the trial, and therefore established on full feed (finisher ration). Cattle had ad libitum water from arrival to trial commencement. Cattle were fed a steam flaked wheat and barley diet with a vitamin and trace mineral supplement that exceeded recommended requirements (NASEM, 2016). The ingredient and nutrient composition of the finishing ration are provided below.

Table 1. Composition and analyzed nutrient content of diet

Item		
Finisher ration ingredient, % (as-fed basis)		
	Steam-flaked wheat	42.50
	Steam-flaked barley	18.00
	Corn silage	19.00
	Whole cottonseed	6.00
	Finisher supplement[2]	4.90
	Biscuit meal	3.00
	Molasses	2.50
	Vegetable oil	1.60
	Wheat straw	1.50
	Cereal hay	1.00
	Dry matter	72.37
Finisher ration formulated composition, % (DM)		
	Ne_m, Mcal/kg	2.08
	Neg, Mcal/kg	1.41
	Metabolizable energy (MJ/kg)	12.86
	Crude protein, %	13.74
Finisher ration analyzed composition, % (DM)		
	Dry matter, % (as-fed basis)	72.70
	Neutral detergent fibre, %	15.80
	Crude protein, %	14.70
	Fat, %	5.20
	Ash, %	4.30
	Crude fiber, %	7.00

Metabolizable energy, MJ/kg	13.40

[1]Finisher supplement contained vitamins, minerals, and monensin at 26.33 PPM.

The feedlot used a modified 'Clean Bunk at Midday' program. Feed bunks were evaluated visually at approximately 0600 hours and a residual feed estimate was made and cattle were adjusted using the standard bunk procedure to maintain ad libitum feed intake.

The first round of finisher (40% allocation) was delivered between 6:30 AM- 9:00 AM. The second round of finisher (60%) was fed between 1:30-3:30 PM.

Feed trucks were calibrated at the commencement of the trial by a certified technician with records kept on file. Scale checks on feed trucks occurred once weekly during the duration of the experiment with records kept on file.

Samples of steam-flaked finisher ration were collected daily from the feed bunk, and subsamples of the ration were dried at 100 °C to determine the daily dry matter of the ration.

Electronic records of daily pen as-fed feed deliveries including head counts, feeding time, and kg delivered were recorded.

3.6 Scale calibrations and checks

Individual trial induction crush scale, two hospital scales, six feed trucks, cattle pen scale, and weigh bridge were calibrated prior to the commencement of the project. All scales passed calibration requirements. Feed truck scales were checked weekly using empty full empty methodology. Feed trucks had 10 kg scale breaks. The feed trucks were also checked continuously with the batch box system.

Standard Operating Procedure for Feed Trucks using Empty Full Empty Method:

1. Ensure truck is empty.
2. Drive truck across tared weigh bridge
3. Tare weigh bridge
4. Load truck with batch from batch box
5. Weigh on weigh bridge
6. Discharge feed
7. Weigh truck empty
8. Scales must be within 50 kg. Repeat if out of specification. If continued to be out of specification, immediate calibration.

Individual induction crush scale was checked with 200 kg of test weights prior to the commencement of each induction session. All scales were within acceptable limits at check points. Calibration records are included as Appendix 9.1.

The induction crush used was a Warwick Cattle Crush – Rustler Model. The hospital crush used was a Warwick Cattle Crush – Exotic Model. The pen weigh bridge is a Rinstrum 5000. The weighing equipment had the following scale accuracies:

- Induction Crush: 2 kg break
- Hospital crush: 2 kg break
- Pen weigh bridge: 20 kg break
- Truck weigh bridge: 50 kg break

3.7 DAG Scoring

The coverage of dags on cattle at d0, d50, d115 was scored according to the dags scoring chart (B.FLT.0244, Watts et al., 2015). Thirty individuals per pen were scored at each time point.

Table 2. Dag Scoring Chart

Score	Description
1	No dag, clean hide
2	Small lumps of manure attached to the hide in limited areas of the legs and underbelly
3	Small and large lumps of manure attached to the hide, covering larger areas of the legs, side and underbelly
4	Small and large lumps of manure attached to the hide, in even larger areas along the hind quarter, stomach and front shoulder
5	Lumps of manure attached to the hide continuously on the underbelly and side of the animal from brisket to rear quarter

3.8 Mud depth and pen pictures

Photos of pen surface and mud depth were taken a d 0, d 50 and exit. Seven photos were taken per pen per day of assessment including pen sign, back right, mid right, front right, front left, mid left, and back left. Two representative replicates were selected to demonstrate pen conditions at the commencement of the replicates and at d 50. Photos of all eight replicates were shown for the d100 photos.

Mud depth was measured using two systems, objective and subjective, as described below at d0, d50, and exit.

Subjective mud depth on animal leg depth was measured on 30 animals in the pen evenly across the pen:

a. No depth
b. Mid hoof wall
c. Coronary band
d. Pastern
e. Fetlock
f. Mid metacapus
g. Carpal Joint
h. Mid radius
i. Elbow
j. Higher than elbow

Objective mud depth was recorded by digging down to the floor base and measuring the depth on a ruler at 30 locations across the pen (10 near bunk, 10 middle, 10 back) using a 30 cm metal ruler.

3.9 Carcase Data

Cattle exited the feedlot at equivalent days on feeds and times. Cattle remained on full feed until the time of exit. Cattle were transported 380 km (5 hours) to the processing plant. Cattle remained on water in shaded lairage pens until the time of slaughter. Carcase data were collected by trained personnel from Bovine Dynamics Pty Ltd (Kenmore, Queensland, Australia). Individual animal visual identification tag was recorded and affixed to the harvest sequence number for each carcase. Time of stun was recorded manually. Electronic RFID tags were recorded at the time of stun.

Carcasses were dressed to AUS-MEAT carcass standards and hot standard carcass weight (kg) was measured after evisceration and trimming (AUS-MEAT, 2005). Dressing percent (%) was calculated as hot standard carcass weight/ live weight at exit. Carcasses were chilled overnight for approximately 22 hours, ribbed between the 12th and 13th ribs, and then graded by a single qualified Meat Standards Australia grader (Polkinghorne et al., 2008). Carcass characteristics measured include eye muscle area of the *longissimus thoracic et lumborum* at the carcass quartering site (cm^2), rib fat depth (mm) of subcutaneous fat of the *longissimus thoracic et lumborum* at the carcass quartering site, P8 fat depth (mm) of subcutaneous fat aligned with the crest of the third sacral vertebra, Meat Standards Australia marbling score which is the amount of fat between muscle fibres within the muscle of the *longissimus thoracic et lumborum* at the carcass quartering site (cm^2), Aus-Meat meat colour of the *longissimus thoracic et lumborum* at the carcass quartering site, Aus-meat fat colour of intermuscular fat lateral to the *longissimus thoracic et lumborum* at the carcass quartering site, Meat Standards Australia Index calculated using a predictive model of eating quality, and ultimate pH of the *longissimus thoracic et lumborum* (AUS-MEAT, 2005; Polkinghorne et al., 2008). Aus-Meat meat colour was scored as 1A=1.00, 1B=1.33, 1C=1.67, 2=2.00, 3=3.00, 4=4.00, 5=5.00, and 6=6.00.

3.10 Temperature and Humidity Sensors

Temperature and humidity sensors were used to obtain measurements on an hourly basis. The sensors were installed in the same location for every pen. Data was downloaded every 50 days. A minimum of two loggers per pen were mounted.

3.11 Water troughs and intake

A total of 18 water flow meters (MT-EX 40, HR Products, Install Solutions, Toowoomba, Queensland, Australia) were installed on water troughs to measure water intake of cattle inside and outside of the sheds. The water troughs (n=2) were located on the dividing fence lines of each pen. Water troughs were cleaned on a weekly basis.

3.12 Manure analysis

At the conclusion of the feeding period, manure was sampled at 30 locations across the pen and mixed into a composite sample. Duplicate samples of manure were obtained from each pen. Samples were analyzed at Southern Cross University under CA-PACK-019: Compost Total and Available Nutrients: Includes Moisture, pH, EC; TC, TN, TC/TN Ratio, Organic Matter; Total (Ca, Mg, K, Na, S, P, Zn, Mn, Fe, Cu, B, Si, Al, Mo, Co, Se); Soluble (Ca, Mg, K, P), Dissolved (NH4, NO3, S); Exchangeable (Ca, Mg, Na, K, H, Al, ECEC); Bray I and II Phosphorus; Colwell Phosphorus; Available Micronutrients (Fe, Cu, Mg, Zn, B, Si); TC, TN, TC/TN Ratio, Organic Matter.

3.13 Statistical Analyses

The experimental unit was defined as the pen. The experiment was analysed with dead cattle removed. The experiment was analysed as an analysis of variance using the PROC MIXED, PROC GLM, and PROC GLIMMEX procedures of SAS (SAS Institute Inc., Cary, North Carolina, USA). Treatment, block, and season were included in the model as fixed effects. Statistical significance of interactions and main effects were defined at $P < 0.05$ and a trend at $P < 0.10$ levels.

3.14 Capital and bedding costs

Initial value (construction cost) of the covered housing (shed) was $2,862,550 at the time of commencement of this project. The rental rates for shed for the project was agreed at 3.6% per annum. Hence, the rental fee was $8,600 per month to rent the shed for the project, by arrangement between the research service provider and Rangers Valley Feedlot.

An ad-hoc survey of Australian feedlot managers determined an average woodchip landed cost of $80 per tonne landed. Most woodchip was purchased by cubic metre at prices from $22-$26 per cubic metre. The price per tonne was multiplied by the number of tonnes used to fill a pen (155 tonnes) which equalled $12,400. This price was divided by 216 head to result in $57.41 per head. The woodchip can be used for two rounds of feeding per woodchip load and hence this price was divided by two to result in a woodchip price her head for 110.6 day of $28.70.

Bedding labour was valued at $30 per hour. To apply woodchip to a pen, 10 labour hours were required for a total cost of $300. To clean a woodchipped feedlot pen and cart the manure and woodchip away, 12 labour hours were required resulting in a total cost of $360. To clean a non-bedded pen, 8 labour hours were required resulting in a total cost of $240. Machinery wet hourly rates were $120 per hour including carting trucks, loader, and excavator. A woodchipped pen required 22 hours of wet machinery hire for raking, cleaning, and carting for a total cost of $2,640. An unbedded pen required 8 hours of wet machinery hire for cleaning and carting for a total cost of $960.

3.15 Economic analysis

An ex-ante private cost-benefit analysis (CBA) was completed for the three experimental treatments: OUT-BED, SHED-NO BED, and BED-SHED. For this analysis, the OUT-BED scenario was defined as the control scenario. The CBA was completed using project data (e.g., inputs, labour, and production data), and supplemented where needed with assumptions collected from key stakeholders. Costs associated with capital, operations, and inputs were all accounted for in the analysis. Key inventory data used in the analysis are outlined in Table 3. No finance or insurance costs were included in this assessment. Cattle purchase costs, and costs associated with day-to-day operations of the feedlot (labour, machinery etc) not related to the treatments were not included in the assessment as these were assumed to be the same across the three treatments.

Table 3. Key inventory data used in the economic analysis

	OUT-BED	SHED-NO BED	SHED-BED	Reference
Pen number	8	8	8	
Drinking water (L/head.day)	41.88	36.69	36.69	Table 8
Individuals (n)	1694	1660	1699	Table 4
Trial days on feed	110.6	110.6	110.6	Table 4
Feed intake, as-fed (kg)	14.53	14.80	15.15	Table 4
Hot carcase weight (kg)	483.2	485.3	489.5	Table 4
Total first pull (n)	39	70	42	Table 5
Mortality (n)	11	20	8	Table 5
Woodchip (t/pen)	155.58	N/A	154.69	Table 6
Labour - bedding application (hrs/pen)	10	N/A	10	Section 3.14
Labour - bedding removal (hrs/pen)	12	8	12	Section 3.14
Wet machinery hire (hrs/pen)	22	8	22	Section 3.14
Manure harvested (t/pen)	291.64	113.94	335.19	Table 6
Moisture content of manure harvested (%)	47.43%	35.13%	41.42%	Table 7
Total solids harvested (t)	198	84	237	Calculated
Reduction in dry matter from stockpiling	35%	35%	35%	Tucker et al. (2015)
Moisture in stockpiled product (%)	27%	27%	27%	From B.FLT.5018
Total stockpiled product produced (t)	176.14	75.08	211.04	Calculated
Woodchip cost ($/t)	$80.00	N/A	$80.00	Section 3.14
Labour - bedding application / removal ($/hr)	$30.00	$30.00	$30.00	Section 3.14
Wet machinery hire ($/hr)	$120.00	$120.00	$120.00	Section 3.14
Stockpiling processing costs ($/t input)	$3.76	$3.76	$3.76	From B.FLT.5018
Cost of feed	$362.45	$362.45	$362.45	Market pricing of ration in Table 1
Cost of water ($/kL)	$0.10	$0.10	$0.10	From B.FLT.5018
Vet treatment ($/head)	$50.00	$50.00	$50.00	Estimate
Mortality disposal cost ($/head)	$30.00	$30.00	$30.00	Estimate
Stockpiled manure sales ($/t)	$12.71	$12.71	$12.71	From B.FLT.5018
Carcase value (c/kg HSCW)	750.00	750.00	750.00	Market average
Shed cost - capital ($)	N/A	$2,862,550.00	$2,862,550.00	Section 3.14
Shed maintenance costs (annual, % of CAPEX)	N/A	0-2%	0-2%	Year 1-5: 0%. Years 6-15: 1%, Years 16-25: 2%

To facilitate comparison between the various treatments, the additional costs and benefits for the SHED-NO BED and SHED-BED treatments were determined from the total values reported. Here, the OUT-BED treatment was used as the base scenario, i.e., the additional benefits and costs for the SHED-NO BED and SHED-BED treatments represent the difference between each and the OUT-BED treatment. The purpose of this analysis was to determine whether the benefits associated with partial covered housing were sufficient to offset the costs (relative to the control), and to indicate which of the two treatments (SHED-NO BED and SHED-BED) would likely result in higher returns.

The project life was assumed to be 25 years for each treatment. A discount rate of 4% was used to determine the present value of costs and benefits associated with each treatment, with all costs reported in 2024 Australian dollars. Payback period was calculated by dividing the initial investment (shed) by the average annual marginal cash flow (relative to the OUT-BED treatment).

Sensitivity analysis was also conducted for different carcase weight values. The core analysis assumed a value of 750c/kg HSCW (denoted as AVE), with values of 600c/kg HSCW (denoted as MIN) and 900c/kg HSCW (denoted as MAX) also assessed.

4. Results

Angus steers weighing 748.1 kg that previously completed 180 days in the feedlot were randomised to three treatment groups (Table 4). For the trial period which lasted 110.6 days on feed, the steers consumed 10.8 kg dry matter intake and gained 0.99 kg per day to exit the feedlot at 857.4 kg. The steers dressed at 56.68% to produce carcasses that weighed 486.0 kg with MSA marbling scores of 594.6 and 9.1 mm of rib fat. These cattle were large, high quality Angus cattle that produced carcasses with above industry average meat quality. Descriptive statistics of study steers are included in Table 4.

Animal performance characteristics are included in Table 5 for each of the three treatments. The steers were similar in entry weight at the commencement of the trial and all three treatments were processed at equivalent days on feed. Treatment had a significant impact on feed intake with SHED-BED consuming 11.08 kg dry matter intake, SHED-NOBED consuming 10.83 kg dry matter intake and OUT-BED consuming 10.63 kg dry matter intake. The effect of treatment on feed intake was not consistent across seasons as there was a treatment by season interaction which is detailed in Figure 14. The effect of treatment also significantly impacted average daily gain and exit weight with SHED-BED having higher average daily gain and exit weights with a significant interaction of treatment and season which is described in Figures 15 and 16. Hot carcase weight was 6.3 kg higher for SHED-BED as compared to OUT-BED. Hot carcase weight was 4.2 kg higher for SHED-BED as compared to SHED-NOBED.

Time from feedlot exit to processing was equivalent across treatments. All cattle were removed from feed at the time of feedlot exit and pen exit order, shipping order, and processing order were allocated and equivalent across treatments to ensure these variables did not have an effect on the results. Cattle exited the feedlot the day prior to processing and spent 24 hours off feed prior to processing. The time from stun to grade was greater than 12 hours. Washing protocols were administered according the abattoir standard operating procedures.

The effect of treatment and season on animal health metrics including morbidity, mortality, and removals is shown in Table 6. SHED-NOBED had higher morbidity, particularly musculoskeletal morbidity, and higher removals, particularly musculoskeletal removals. Cattle with bedding had higher exit rates.

Cattle dag scores and mud and bedding depth are detailed in Table 7. Pens with bedding produced more manure and bedding that was removed from the pen. Cattle in SHED-NOBED had higher dag scores at day 50 than cattle with bedding, however, this different did not persist to day 100.

Pen floor contents were evaluated for a large number of variables (Table 8). Pen contents from pens with bedding had higher carbon:nitrogen, total carbon, and moisture content.

Cattle housed outdoors drank 5 litres more water than cattle under covered housing (Table 9). Approximately 11.8 ML of rainwater would be expected to be harvested off the roof surface according to the long term average rainfall of Rangers Valley, Glen Innes, per annum.

Temperature and humidity data are displayed in Table 10. Although temperatures were very similar between outdoor and covered housing, the humidity was higher under the sheds.

Pictures of cattle at day 0, 50, and 100 for cattle in each treatment group are included as Figures 2-13. Temperature data is included in Figures 17-20.

Table 4. Descriptive statistics of pens of study steers (n=24 pens, n=5178 steers)

Variable	Mean	Stdev	Minimum	Maximum
Trial Entry Weight, kg	748.1	12.2	724.0	772.3
Trial days on feed	110.6	1.5	108.3	112.9
Feed intake, As-Fed, kg	14.8	0.5	14.0	16.4
Feed intake, DM, kg	10.8	0.4	10.2	12.0
Average daily gain, kg/hd	0.99	0.11	0.72	1.19
Cattle weight at feedlot exit per hd, kg/hd	857.4	14.6	828.2	888.8
Hot carcase weight, kg	486.0	11.1	468.4	512.3
Dressing percent, %	56.68	0.88	55.56	58.32
Dentition at processing	2.4	0.3	2.1	3.0
Ossification	149.2	4.8	142.9	159.3
AusMeat meat colour‡	2.0	0.1	1.8	2.2
MSA marbling	594.6	18.1	568.0	623.8
Ausmeat marbling	3.5	0.2	3.2	3.8
Eye muscle area, cm^2	89.3	2.0	84.6	94.1
Rib Fat	9.1	1.7	7.0	13.8
P8 Fat	25.0	1.2	22.9	27.7
Fat colour	0.5	0.5	0.0	1.4
Ultimate pH	5.48	0.09	5.23	5.55
MSA Index	65.66	0.54	64.69	66.44

‡Meat colour was scored as 1A=1.00, 1B=1.33, 1C=1.67, 2=2.00, 3=3.00, 4=4.00, 5=5.00, 6=6.00.

Table 5. Effect of partial covered housing and bedding on carcase characteristics (n=24 pens, n=5053 steers)

	Treatment				*P-value*		
Variable	OUT-BED	SHED-NOBED	SHED-BED	SE	Treatment	Season	Treatment*Season
Individuals, n	1694	1660	1699				
Trial Entry Weight, kg	747.2	749.8	747.5	4.820	0.29	0.79	0.79
Trial days on feed	110.6	110.6	110.6	0.34	0.34	<0.01	0.64
Feed intake, As-Fed, kg	14.53[a]	14.80[b]	15.15[c]	0.140	<0.01	0.13	<0.01
Feed intake, DM, kg	10.63[a]	10.83[b]	11.08[c]	0.103	<0.01	0.13	<0.01
Average daily gain, kg/hd	0.97[a]	0.94[a]	1.06[b]	0.032	<0.01	0.61	0.02
Cattle weight at feedlot exit per hd, kg/hd	853.8[a]	853.5[a]	864.9[b]	5.165	0.01	0.87	<0.05
Gain:Feed, DM	0.091[ab]	0.087[b]	0.096[a]	0.002	<0.01	0.19	0.08
Hot carcase weight, kg	483.2[a]	485.3[a]	489.5[b]	3.026	0.02	0.03	0.06
Dressing percent, %	56.60	56.85	56.60	0.126	0.22	<0.01	0.28
Dentition at processing	2.4	2.4	2.4	0.063	0.43	<0.01	0.68
Ossification	149.1	149.3	149.2	1.357	0.94	0.03	<0.01
AusMeat meat colour‡	2.08[ac]	2.01[b]	2.04[bc]	0.018	0.03	0.02	0.37
MSA marbling	595.8	592.9	595.0	3.710	0.80	<0.01	0.27
AusMeat marbling	3.5	3.4	3.5	0.040	0.43	<0.01	0.49
Eye muscle area, cm^2	89.4	89.0	89.6	0.720	0.73	0.18	0.79
Rib Fat, mm	9.4	8.7	9.3	0.471	0.17	0.02	0.20
P8 Fat, mm	24.7	24.9	25.3	0.403	0.30	0.17	0.41
Fat colour	0.5	0.6	0.6	0.067	0.14	<0.01	0.38
Chiller assessment pH	5.48	5.47	5.49	0.028	0.62	0.11	0.53
MSA Index	65.67	65.60	65.72	0.071	0.15	<0.01	0.66

‡Meat colour was scored as 1A=1.00, 1B=1.33, 1C=1.67, 2=2.00, 3=3.00, 4=4.00, 5=5.00, 6=6.00.

[abc] denote differences (p<0.05) in treatments.

Table 6. Effect of partial covered housing and bedding on morbidity and mortality (n=24 pens, n=5178 steers)

	Treatment			*P-value*		
Variable	OUT-BED	SHED-NOBED	SHED-BED	Treatment	Season	Treatment*Season
Individuals, n	1724	1725	1729			
Morbidity						
Total first pull, n (%)	39 (2.26)[a]	70 (4.06)[b]	42 (2.43)[a]	0.01	0.19	0.07
Digestive	15 (0.87)	18 (1.04)	17 (0.99)	0.72	0.67	0.14
Musculoskeletal	19 (1.10)[a]	44 (2.55)[b]	21 (1.22)[a]	0.01	0.42	0.31
Respiratory	3 (0.17)	4 (0.23)	2 (0.12)	0.73	0.98	1.00
Other	2 (0.12)	4 (0.23)	2 (0.12)	0.77	0.64	0.78
Mortality, n (%)	11 (0.64)	20 (1.16)	8 (0.46)	0.07	0.19	0.61
Digestive	2 (0.12)	7 (0.41)	4(0.23)	0.96	0.98	0.49
Musculoskeletal	6 (0.35)	11 (0.64)	4 (0.23)	0.51	0.98	0.51
Respiratory	0 (0.00)	1 (0.06)	0 (0.00)	1.00	0.99	1.00
Other	3 (0.17)	1 (0.06)	0 (0.00)	1.00	0.99	1.00
Removed, n (%)	19 (1.10)[a]	45 (2.61)[b]	22 (1.28)[a]	0.01	0.06	0.37
Digestive	1 (0.06)	4 (0.23)	7 (0.41)	0.96	0.98	0.49
Musculoskeletal	14 (0.81)[a]	33 (1.91)[b]	12 (0.69)[a]	0.02	0.03	0.93
Respiratory	2 (0.12)	4 (0.23)	2 (0.12)	0.73	0.98	1.00
Other	2 (0.12)	4 (0.23)	1(0.06)	0.84	0.98	0.84
Exits, n (%)	1694 (98.26)[a]	1660 (96.23)[b]	1699 (98.26)[a]	<0.01	0.36	0.30

Table 7. Effect of partial covered housing and bedding on cattle cleanliness and pen depth (n=24 pens, n=5053 steers)

	Treatment				*P-value*		
Variable	OUT-BED	SHED-NOBED	SHED-BED	SE	Treatment	Season	Treatment*Season
Woodchip into pen, tonne	155.58	n/a	154.69	2.063	0.70	0.95	0.87
Manure out pen, tonne	291.64[a]	113.94[b]	335.19[a]	21.001	<0.01	0.51	0.67
Dag score, d0	1.93	2.02	1.93	0.115	0.17	<0.01	0.12
Dag score, d50	1.58[a]	2.50[b]	1.37[a]	0.096	<0.01	<0.01	<0.01
Dag score, exit	1.82	1.94	1.47	0.192	0.22	0.17	0.37
Subjective bedding depth, d0	1.20[a]	1.00[b]	1.19[a]	0.076	0.04	0.05	0.04
Subjective bedding depth, d50	1.69	1.69	1.67	0.131	0.93	0.16	0.25
Subjective bedding depth, d100	1.64	1.42	1.53	0.215	0.42	0.46	0.20
Objective bedding depth, d0	14.35[a]	0.00[b]	13.57[a]	0.300	<0.01	<0.01	0.05
Objective bedding depth, d50	12.71[a]	2.74[b]	12.93[a]	0.278	<0.01	0.04	0.60
Objective bedding depth, d100	13.55	3.97	13.46	0.676	<0.01	0.21	0.19

[abc] denote differences (p<0.05) in treatments.

Table 8. Effect of partial covered housing and bedding on pen floor material (n=24 pens)

	Treatment				*P-value*		
Variable	OUT-BED	SHED-NOBED	SHED-BED	SE	Treatment	Season	Treatment*Season
Moisture Content, %	47.43[a]	35.13[b]	41.42[ab]	3.167	<0.01	0.52	0.45
pH	7.56	7.51	7.58	0.034	0.16	0.22	0.10
Electrical Conductivity (dS/m)	6.70[a]	11.78[c]	8.20[b]	0.442	<0.01	0.83	0.28
Total Carbon, %	40.51[a]	31.73[b]	41.06[a]	1.394	<0.01	0.11	0.39
Total Nitrogen, %	1.67[a]	2.34[b]	1.78[a]	0.099	<0.01	0.19	0.92
Carbon:Nitrogen	25.24[a]	13.78[b]	23.73[a]	0.872	<0.01	0.13	0.66
Estimated Organic Matter, % OM	68.86[a]	53.94[b]	69.80[a]	2.369	<0.01	0.11	0.39
Total Calcium, %	1.39[a]	2.58[b]	1.54[a]	0.085	<0.01	0.70	0.97
Total Magnesium, %	0.38[a]	0.70[b]	0.43[a]	0.017	<0.01	0.14	0.91
Total Potassium, %	1.05[a]	1.82[c]	1.26[b]	0.048	<0.01	0.06	0.19
Total Sodium, %	0.28[a]	0.48[c]	0.33[b]	0.012	<0.01	0.05	0.45
Total Sulphur, %	0.29[a]	0.50[b]	0.33[a]	0.015	<0.01	0.24	0.91
Total Phosphorus, %	0.49[a]	0.93[b]	0.57[a]	0.037	<0.01	0.56	0.91
Total Zinc, mg/kg	144.58[a]	265.00[b]	159.53[a]	7.306	<0.01	0.56	0.99
Total Manganese, mg/kg	125.98[a]	240.84[b]	143.53[a]	9.264	<0.01	0.12	0.13
Total Iron, mg/kg	1915.33[a]	3805.52[b]	1847.82[a]	371.090	<0.01	0.47	0.61
TotaL Copper, mg/kg	31.33[a]	55.06[b]	33.90[a]	1.558	<0.01	0.53	0.80
Total Boron, mg/kg	5.14[a]	8.82[b]	6.20[a]	0.751	<0.01	<0.01	0.60
Total Silicon, mg/kg	1710.72[a]	1305.32[b]	1757.47[a]	198.270	<0.01	0.38	0.37
Total Aluminium, mg/kg	1073.51[a]	1924.88[b]	1096.55[a]	173.800	<0.01	0.42	0.22
Total Molybdenum, mg/kg	0.23[a]	1.74[c]	0.64[b]	0.168	<0.01	0.98	0.66
Total Cobalt, mg/kg	2.37[a]	4.45[b]	2.54[a]	0.144	<0.01	0.08	0.29
Total Selenium, mg/kg	0.34[a]	0.80[b]	0.30[a]	0.235	0.01	0.61	0.41
Nitrogen:Sulphur	5.78[a]	4.66[b]	5.42[a]	0.275	0.02	0.63	0.91
Nitrogen:Phosphorus	3.44[a]	2.52[b]	3.19[a]	0.181	<0.01	0.69	0.91
Nitrogen:Potassium	1.59[a]	1.29[b]	1.42[ab]	0.091	0.02	0.90	0.46

[abc] denote differences (p<0.05) in treatments.

Table 9. Average water intake per individual for cattle housed outdoors or under partial covered housing

	Water intake per individual per day, litres
Conventional Outdoor	41.88
Covered Housing	36.69

Table 10. Monthly average temperature and humidity for outdoor versus covered housing

	Temperature, Celsius		Humidity, %	
	Outdoor	Covered	Outdoor	Covered
May-23	8.13	8.94	63.32	70.44
Jun-23	8.03	8.30	67.64	72.14
Jul-23	8.49	8.47	66.65	71.65
Aug-23	10.62	10.63	60.44	66.59
Sep-23	13.44	13.25	60.84	61.85
Oct-23	17.65	17.70	53.03	53.08
Nov-23	19.03	19.03	65.61	67.01
Dec-23	22.31	22.20	61.79	64.15
Jan-24	22.59	22.31	68.63	75.55
Feb-24	22.32	21.91	68.52	76.23
Mar-24	19.80	19.80	76.38	77.74

Figure 2. Images of pen floors at day zero for replicate two on May 18, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 3. Images of pen floors at day zero for replicate six on Nov 3, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 4. Images of pen floors at day fifty for replicate two on July 7, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 5. Images of pen floors at day fifty for replicate six on December 21, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 6. Images of pen floors at day 100 for replicate one on August 19, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 7. Images of pen floors at day 100 for replicate two on September 2, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 8. Images of pen floors at day 100 for replicate three on September 16, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 9. Images of pen floors at day 100 for replicate four on October 1, 2023 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 10. Images of pen floors at day 100 for replicate five on February 4, 2024 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 11. Images of pen floors at day 100 for replicate six on February 18, 2024 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 12. Images of pen floors at day 100 for replicate seven on March 3, 2024 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 13. Images of pen floors at day 100 for replicate eight on March 18, 2024 including shed with bedding, shed without bedding, and outdoors with bedding

Figure 14. The effects of season and treatment on dry matter feed intake of long-fed Angus cattle

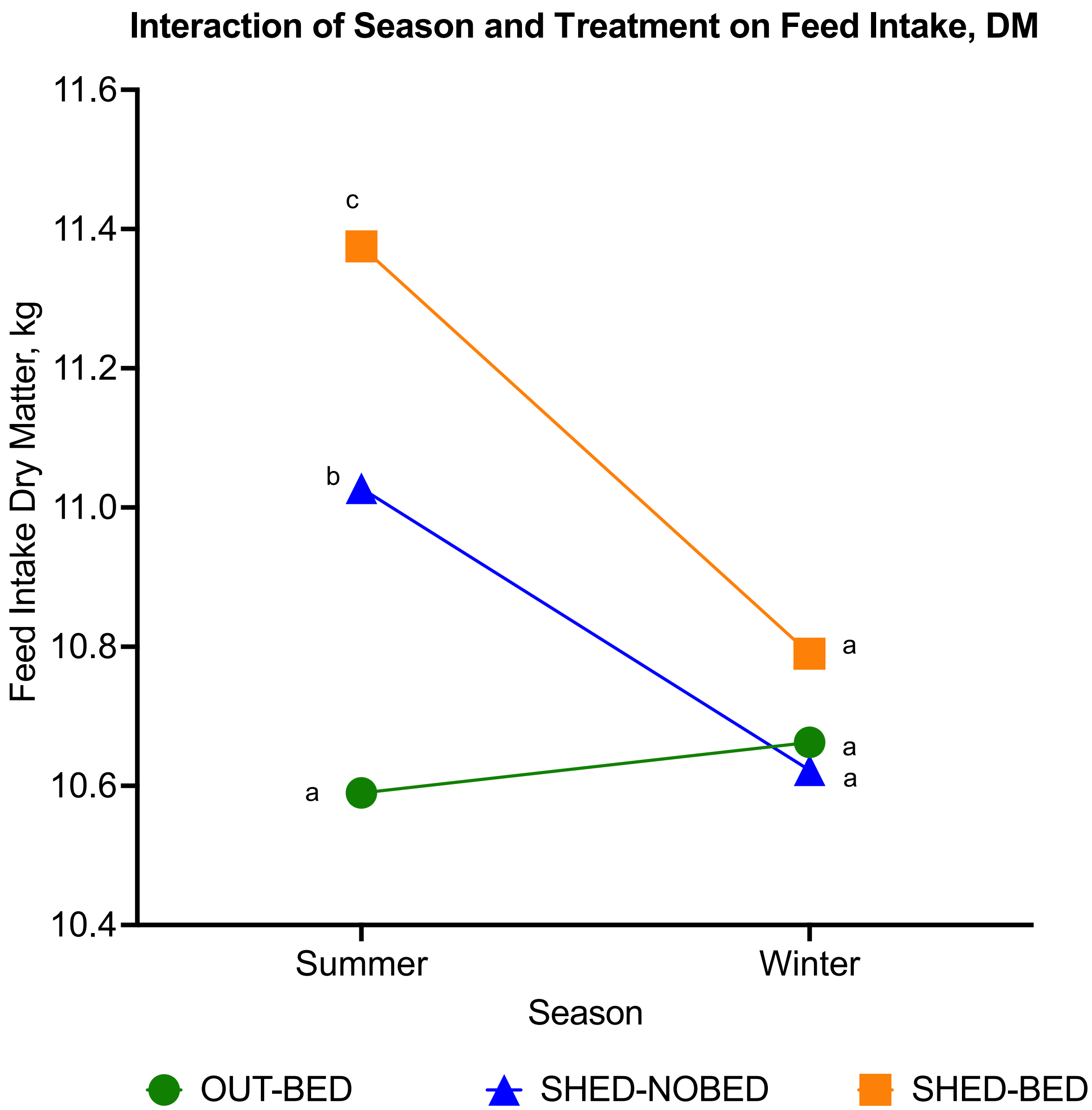


Figure 14. The effects of season and treatment on dry matter feed intake of long-fed Angus cattle

Figure 15. The effects of season and treatment on average daily gain of long-fed Angus cattle

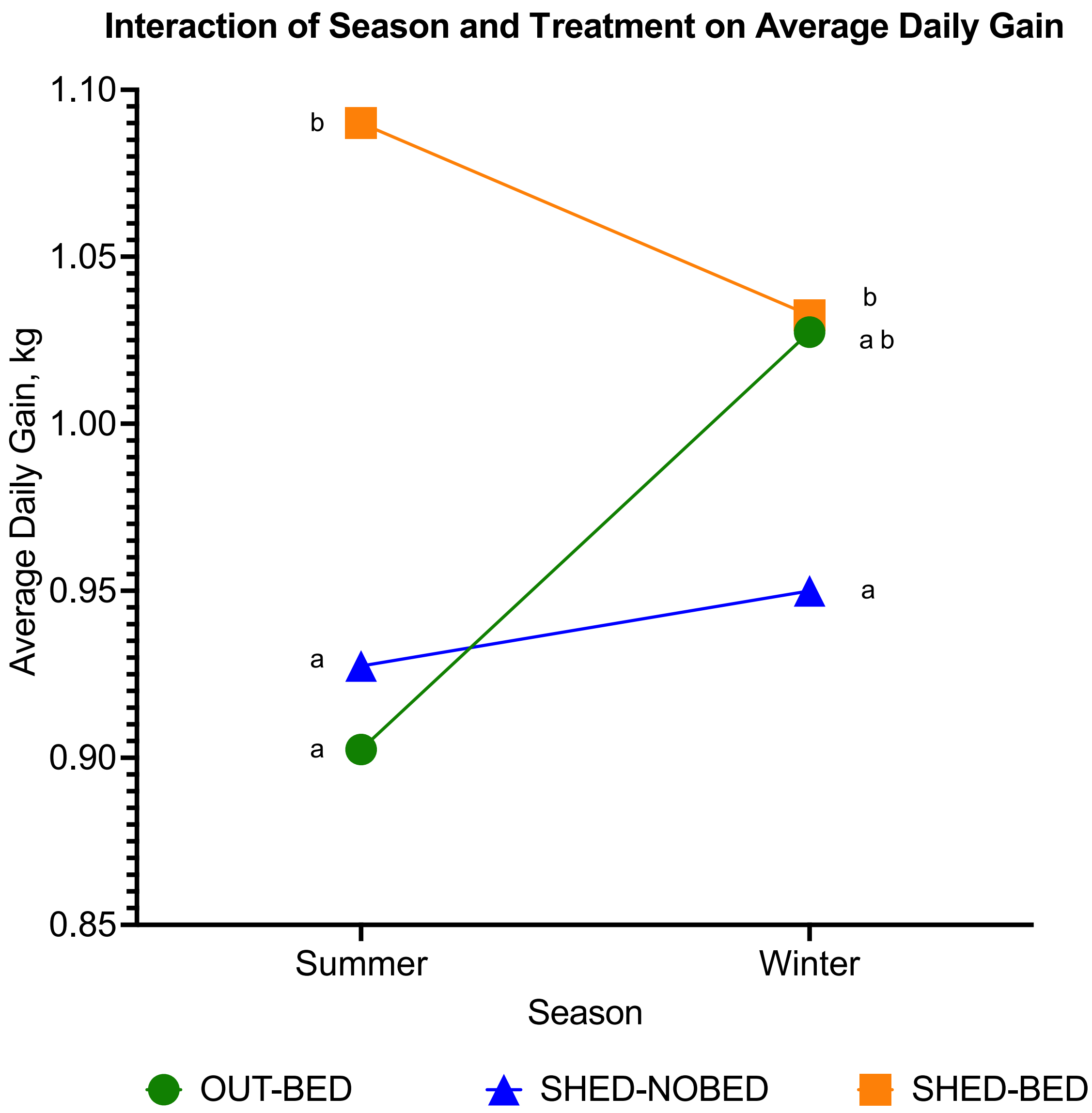


Figure 16. The effects of season and treatment on exit weight of long-fed Angus cattle

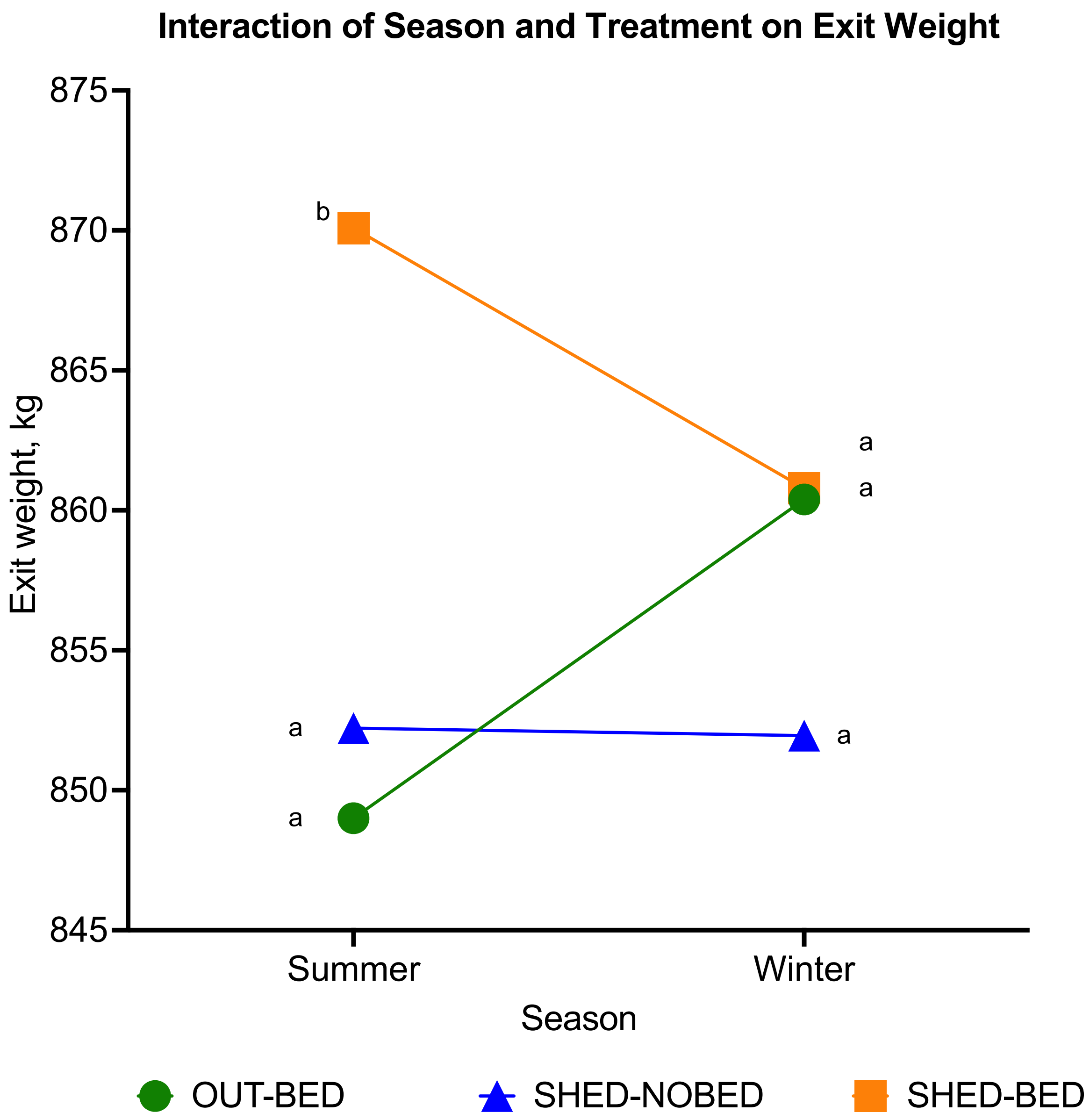


Figure 17. Minimum temperature in winter for conventional outdoor pens versus partial covered housing pens

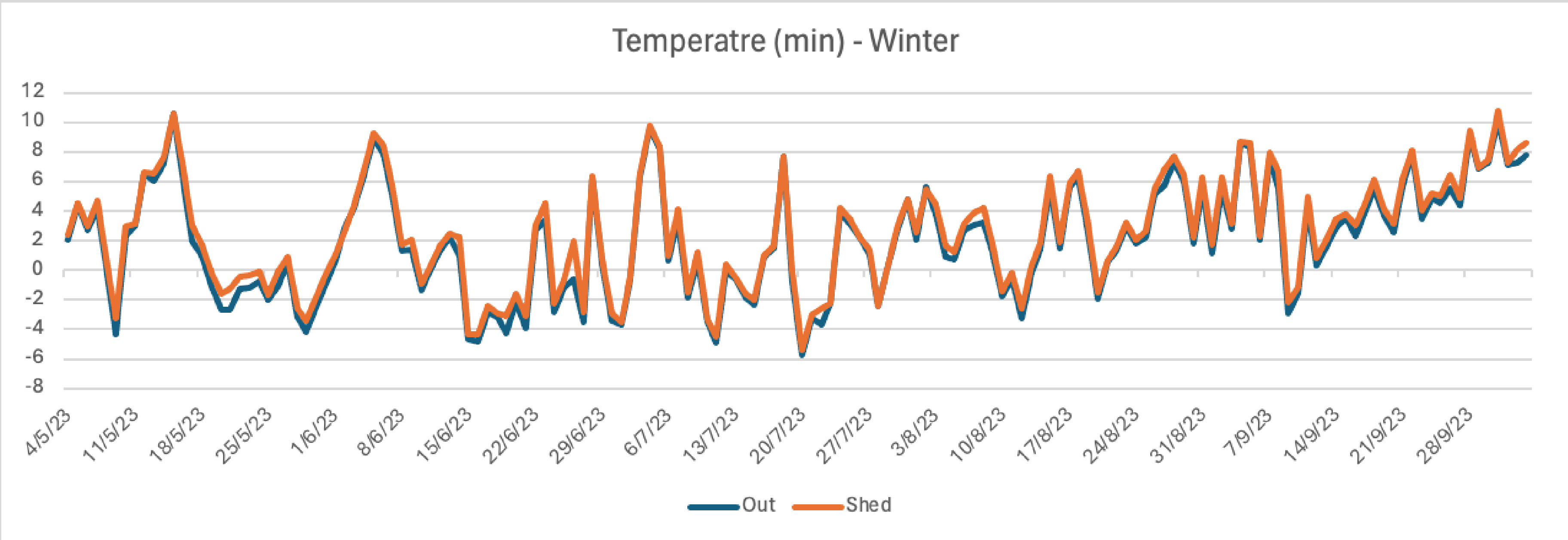


Figure 18. Maximum temperature in winter for conventional outdoor pens versus partial covered housing pens

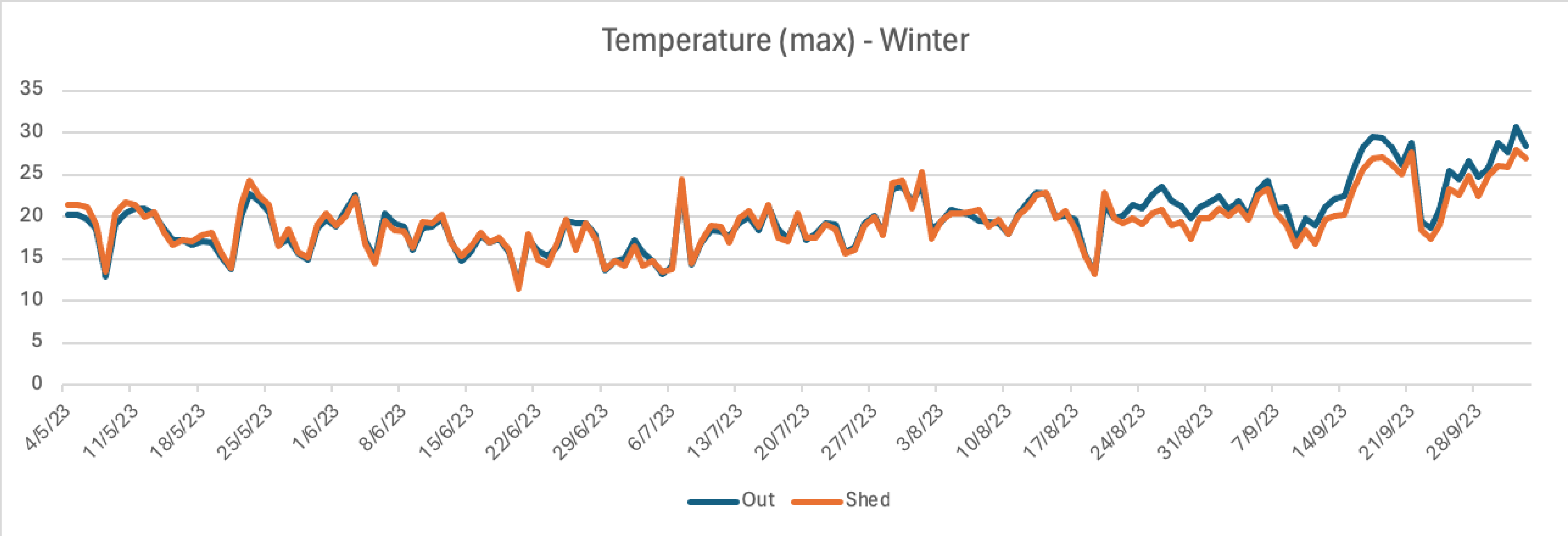


Figure 19. Minimum temperature in summer for conventional outdoor pens versus partial covered housing pens

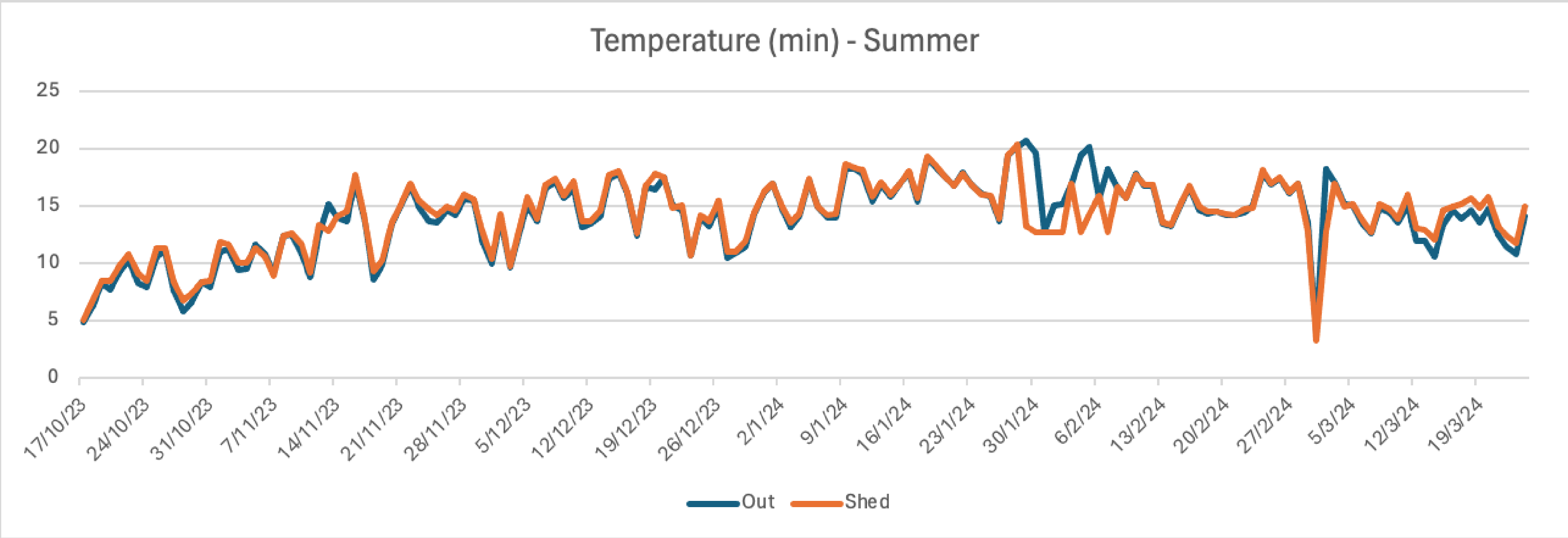
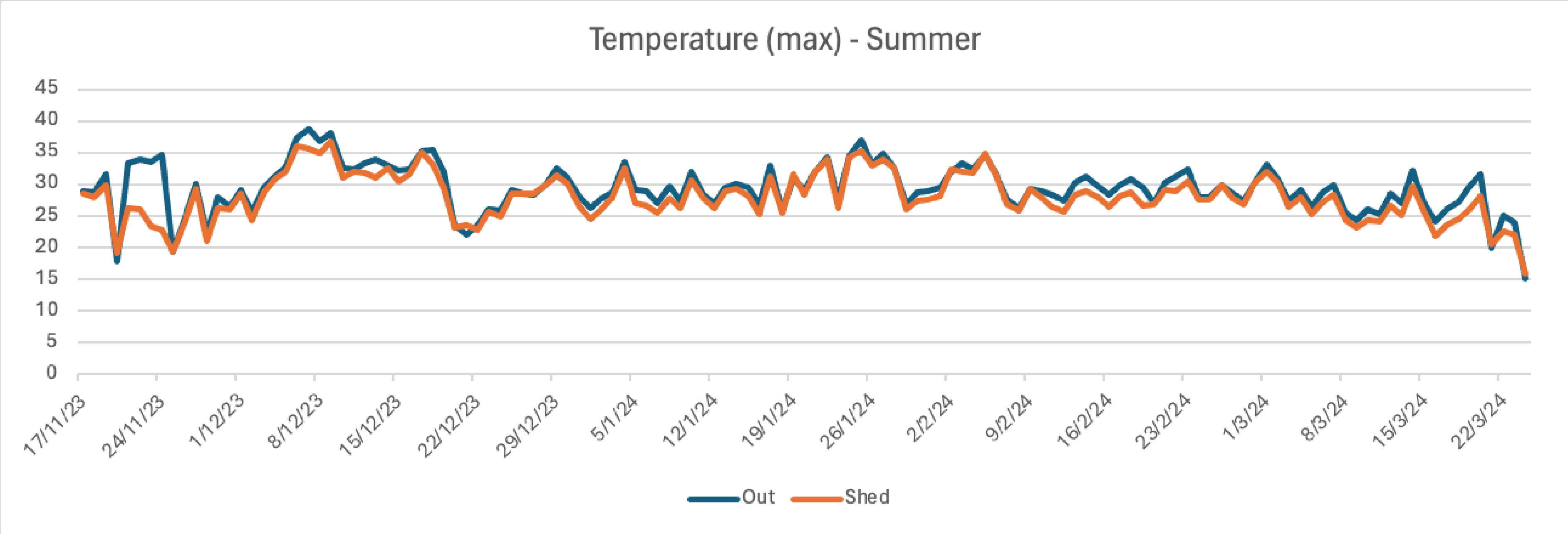


Figure 20. Maximum temperature in summer for conventional outdoor pens versus partial covered housing



For the ex-ante cost benefit analysis, total costs and benefits over the life of each treatment are reported in **Error! Reference source not found.**. Total costs were relatively similar across the OUT-BED and SHED-NO BED treatments driven by lower operating costs (absence of bedding, and reduced labour and machinery hours) but higher capital costs (shed). Higher total costs in the SHED-BED treatment were attributable to capital costs and operating costs associated with bedding application and removal. Total benefits were driven by total output, with the treatment with the highest liveweight gain (SHED-BED) returning the largest benefit and the lowest performing treatment (SHED-NO BED) returning the lowest total benefits.

Table 11. Total costs and benefits over the life of the three treatments

Treatment	Total costs ($ Present Value, PV)	Total benefits ($ Present Value, PV)
OUT-BED	$55,061,282	$317,426,605
SHED-NO BED	$55,003,928	$311,892,273
SHED-BED	$60,621,804	$322,736,239

To compare between the treatments, the additional benefits and costs associated with the SHED-NO BED and SHED-BED treatments were determined, and are reported in **Error! Reference source not found.** for a range of carcase weight values.

Table 12. Total additional costs and benefits, Net Present Values, Internal Rates of Return, and payback period for the three treatments under different HSCW sales values

Treatment	Total costs ($ PV)	Total benefits ($ PV)	Net Present Value, NPV ($)	Internal Rate of Return, IRR (%)	Payback period (years)
OUT-BED (MIN)	$0	$0	N/A	N/A	N/A
SHED-NO BED (MIN)	$7,938,476	$3,516,099	-$4,422,377	N/A*	N/A*
SHED-BED (MIN)	$5,584,754	$4,319,273	-$1,265,481	-0.9%	28
OUT-BED (AVE)	$0	$0	N/A	N/A	N/A
SHED-NO BED (AVE)	$8,939,388	$3,516,099	-$5,423,289	N/A*	N/A*
SHED-BED (AVE)	$5,584,754	$5,333,866	-$250,888	3.1%	17
OUT-BED (MAX)	$0	$0	N/A	N/A	N/A
SHED-NO BED (MAX)	$9,940,301	$3,516,099	-$6,424,202	N/A*	N/A*
SHED-BED (MAX)	$5,584,754	$6,348,458	$763,705	6.4%	12

**Treatment did not return a positive cashflow at any point, hence IRR and payback period could not be determined.*

The results indicated that partial covered housing (SHED-NO BED and SHED-BED) would not be a profitable alternative to the control scenario (OUT-BED) where the MIN carcase weight value was achieved (500c/kg HSCW). The AVE carcase weight value (750c/kg HSCW) also yielded negative NPVs for both the SHED-NO BED and SHED-BED treatments relative to the control. The SHED-BED scenario, however, did yield a positive cashflow resulting in an IRR of 3.1% and a payback period of 17 years, well within the assumed 25-year life of the shed. In practice, the shed could operate for in excess of 30 years meaning that, with a longer project life, the NPV of the investment may turn positive. Where the MAX carcase weight value (900c/kg HSCW) could be achieved, the SHED-BED treatment returned a positive NPV and IRR, suggesting that it would be a profitable investment, and have a payback period of 12 years. Due to the SHED-NO BED treatment resulting in poorer animal performance and finishing weights than the control (OUT-BED), the higher the carcase weight value (foregone income), the poorer the investment appeared.

5. Discussion

The welfare of feedlot cattle is dependent on nutritional provisions, environmental conditions, health status, and social interactions which all contribute to the overall mental state of feedlot cattle (Mellor et al., 2020; Sundman et al., 2024). The Australian feedlot industry is highly committed to animal welfare with an emphasis on environmental conditions which optimise the wellbeing of cattle. Specifically, the Australian Lot Feeders' Association determined that cattle in Australian feedlots should have access to shade by 2026 (ALFA, 2020). Shade-seeking is a strong natural behaviour in cattle and there are several research studies that demonstrated that shade alleviates heat load in feedlot cattle and improves growth and welfare (Gaughan et al., 2008; Grandin, 2016; Edwards-Callaway et al., 2021). Access to shade allows cattle to self regulate their temperature, greatly reducing the risk of heat stress.

The location of a feedlot greatly influences the environmental conditions that cattle experience including rainfall, humidity, temperature, windspeed, and solar radiation. There are numerous forms of shade used in feedlot environments including shade cloth, metal slats, sheds, and variations in designs of covered housing structures. The environmental conditions associated with a location may determine which type of shade or shelter structure has the greatest opportunity for benefit. For example, in a winter high rainfall environment there are benefits of sheds or covered housing to maintain drier pen surfaces. In drier conditions, shade cloth may be suitable as the pens will more naturally dry out with sunlight and solar radiation.

Partial shelter is a option for existing feedlots looking to retrofit a system to existing pens. This is because stocking density and therefore bunk space allocation and pen infrastructure can remain unchanged. This is contrast to fully covered systems which typically require different pen layout to achieve desired stocking density and bunk space allocation.

The present study was completed in the Northern Tablelands of New South Wales, a cool temperate highlands region. Climatic conditions across the Northern Tablelands include relatively high rainfall with average annual rainfall ranging from 750 to 1250 mm, marked summer incidence of rainfall, a 200-day frost interval (April - October) and intensely cold winter conditions. Despite summer-rainfall dominance, the region receives a significant rainfall that does not dry out readily and replenishes soil moistures which can contribute to very wet feedlot pen conditions in some winters. Monthly winter rainfall in the region averages 55 mm per month. Hence, the covered housing form of shade may provide protection from the winter rainfall and provide benefits by keeping the pen floor dry. Thus, the present study was conducted to assess the effect of partial covered housing.

While there are environmental benefits to covered housing, there are also welfare benefits to partial covered housing that have also been shown to result in increased animal performance and health. A meta-analysis by Rust et al. 2024 found that providing animals with opportunity for concurrent choice options may improve behavioural and physiological welfare. In an Australian context, Lees et al. 2022, demonstrated improved productivity parameters and animal welfare indicators of cattle provided with partial covered housing in trials undertaken over two distinct seasons at a research feedlot. During the summer trial, partial cover increased carcase adjusted Average Daily Gain by 100 g/hd/d, feed efficiency by 4 %) and hot standard carcase weight by 7 kg (Lees et al 2022). During very hot conditions (heat load index ≥ 86), cattle under partial shelter and shade cloth treatments had lower mean panting scores when compared to unshaded cattle highlighting improved animal comfort. During the winter arm of the study partial shelter significantly improved carcase adjusted ADG by 100 g/hd/d, feed efficiency by 5.3%; and tended to improve HSCW by 5 kg (Lees et al 2022). In addition, adrenal gland weight was used as an objective measure of chronic stress and it was shown to be greater in unshaded pens, indicating a potential positive welfare outcome by the provision of partial cover in the pen (Lees et at 2022).

The results of the present study identified that cattle under partial covered housing with bedding had increased dry matter intake, average daily gain, and exit weight. These cattle likely spent more time consuming feed as they were more comfortable and also were more efficient as they did not expend as much energy panting or thermoregulating. Brown-Brandl et al. (2013) found that cattle with shade had lowered cattle respiration rates and body temperature. Cattle with partial covered housing and no bedding had higher feed intake than outdoor cattle with bedding, they were similar to the outdoor cattle with bedding in gain as they were less efficient, likely expelling energy on methods of thermoregulation and hence less energy into gain. Cattle under the shed with no bedding were the least efficient. We believe his is because these cattle were likely standing more often than cattle on bedding and hence spent lest time resting in a comfortable manner and more time moving trying to become more comfortable. The unbedded pen surfaces were firm and hence likely less comfortable than the bedded surfaces. While behavioural data was not available in the present study, standing and lying times or accelerometer data would provide interesting insights in regards to animal behaviour and utilization of energy resources.

While cattle under partial covered housing with bedding had increased feed intake, average daily gain, exit weight, and Gain:Feed, the effect of treatment was not consistent across season. The research showed a significant response in summer, even in a mild, wet summer. The authors hypothesise that future research over different years may show even more significant effects, particularly in a wet winter.

Cattle under partial covered housing with bedding had increased hot carcase weight (6.3 kg advantage) demonstrating that bedding and covered housing provide a positive combination for environmental conditions that support animal growth and performance. These results are consistent with the increased finishing and carcass weights of 8.9 kg and 5.8 kg, respectively reported by Edwards-Callaway et al. (2021).

While there was a difference in dag scores at day 50 with cattle with partial covered housing and no bedding showing higher dag scores in pens, the difference dissipated by day 100 which is likely associated with shedding of the coat prior to feedlot exit.

The most significant economic impact in the present study was associated with the effect on morbidity and removals. Specifically, cattle under partial covered housing with no bedding had increased musculoskeletal morbidity. Musculoskeletal removals were doubled in cattle without bedding as compared to cattle with bedding. These results clearly demonstrate that bedding is beneficial to musculoskeletal health in long-fed cattle. Cattle with bedding had 2% higher exit rates compared to cattle without bedding, providing strong data to support the economic investment and return of providing bedding to long-fed Angus cattle.

There are also environmental benefits of covered housing, particularly in regards to water intake. Cattle under covered housing drank 5.2 litres less than outdoor cattle, per day. There was also the additional benefit of water capture from the roof structure, that could be diverted to cattle drinking water. According to regional average annual rainfall this could be around 11.8 ML per annum.

The economic analysis completed here is subject to a several uncertainties. First, shed maintenance costs were estimates only and could be substantially higher in certain circumstances (e.g., if shed is damaged by machinery, or if the shed is located in an environment where steel infrastructure is prone to corrosion). Second, the analysis assumed that there was no benefit to (reduction in) pad maintenance costs as a result of the partial coverage of the pens. Although the shed would protect some of the pen from rainfall, there was no reduction in stocking density between the control (OUT-BED) and shed treatments (SHED-NO BED and SHED-BED) meaning there would be minimal to no benefit in terms of reduced maintenance and repair to the pad (Pers. Comms., Eugene McGahan). Third, coverage or partial coverage of the bunk by the shed may result in a slight reduction in feed wastage. In this analysis, we assumed that this benefit was tacitly captured (included) in the reported feed consumption data (Table 4) and no further benefit was quantified. Finally, whilst the core experimental design compares three different treatment options for one feedlot, the control treatment (OUT-BED) is not necessarily representative of the rest of industry and hence a high degree of caution should be applied if attempting to draw generalised insights from this analysis and other feedlots with different cost of production.

What can be concluded is that, where partial covered housing generates a performance improvement relative to current operations, the financial benefit will be greatest in the highest value production systems (e.g., Wagyu). For a given feedlot, if higher performance can be achieved under partial covered housing (relative to an outdoor pen with or without bedding), it is likely there would still be a financial benefit from the investment, however, whether a return could be achieved would need to be evaluated on a case-by-case basis given the sensitivity to performance and selling prices or cattle feeding programs.

6. Conclusions

- Cattle under partial covered housing with bedding had increased feed intake (0.45 kg DM/hd/d), average daily gain (0.09 kg/d), and exit weight (11.1 kg).
- Cattle under partial covered housing with bedding had increased hot carcase weight (6.3 kg HSCW).
- Bedding has a significantly positive impact on musculoskeletal health in long-fed Angus cattle, reducing morbidity and cull rates.
- Pen contents removed from pens with bedding had increased carbon:nitrogen ratio, total carbon, and moisture content.
- Partial covered housing and bedding were clearly evaluated as potential interventions to improve animal performance and welfare. These results demonstrate cattle have increased feed intake, average daily gain, and hot carcase weight under partial covered housing and bedded conditions.
- For a given feedlot, if higher performance can be achieved under partial covered housing (relative to an outdoor pen with or without bedding), it is likely there would still be a financial benefit from the investment, however, whether a return could be achieved would need to be evaluated on a case-by-case basis given the sensitivity to performance and selling prices or cattle feeding programs.

7. Future research and recommendations

Future research should continue to evaluate the effects of the same parameters over sequential year-round conditions as annual weather conditions including rainfall and temperature are variable and hence have a significant impact on the effects of partial covered housing and bedding. Other future research may provide more insights regarding why the cattle under the shed with bedding are more efficient by providing accelerometer or behavioural data.

8. References

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