final report

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Effect of pen stabilisation on cleanliness of slaughter cattle

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Executive summary

In southern Australia, wet weather during cooler winter months can lead to increased manure depth and cause dags to form on cattle hides. These conditions can significantly influence processing profitability if not managed properly. In particular, under Australian Standards, animal cleanliness is assessed prior to slaughter. This requires animals to be free from mud and dags and abattoirs are often required to wash cattle more intensively during wet and cold conditions.

Pen cleaning is an ongoing requirement of feedlots Australia wide, but depending on local weather conditions and pen foundations, management practices that are used to maintain and clean pen surfaces year-round varies considerably. Winter dominant rainfall combined with soft (clay) pen foundations complicates heavy equipment access to feedlot pens during wet conditions. Depending on the severity of the winter, this may mean conventional equipment such as front-end loaders and bob cats cannot easily access pens for cleaning. Alternatively, when machinery, such as excavators, are brought into muddy pens, the pens are often over excavated, resulting in an increased pen repair cost when dry conditions return.

Enabling better access of pen cleaning equipment during wet winter conditions may:

- Decrease manure depth, dag formation and dag coverage;
- Decrease cattle washing requirements to reduce dags prior to cattle processing;
- Decrease manure depth and manure moisture resulting in decreased odour production;
- Reduce damage to pen foundations from cattle movement and equipment, decreasing seepage of nutrients through the previously impermeable interface layer;
- Decrease manure depth improving cattle performance; and
- Maintain health and safety of feedlot staff (primarily pen riders) as they move through the pens to assess cattle health.

Two major issues are associated with over excavation of the manure layer, both of which incur economic costs to feedlot operators. The first issue is removal of clay and gravel foundation material, which requires additional labour for pen repair before cattle can be reintroduced. The second issue is the introduction of inorganic (clay and gravel) materials into the manure, which depreciates the potential fertilizer or compost value of the manure.

This project evaluated lime and cement stabilisation of newly constructed feedlot pens. The proposed technology has the potential to enable each of the opportunities listed above. Furthermore, as equipment may be able to enter pens in winter, the improved pen cleaning interval will reduce manure thickness on the pen floor, theoretically resulting in a decrease in odour production.

A control and stabilised row of pens were constructed adjacent to each other for the trial. The control row was constructed with clay from the on-site quarry as per the regular feedlot pen construction. Soil testing was undertaken for the site in 2016 and consisted of an assessment of bearing capacity using the California Bearing Ratio (CBR) method, particle size distribution and Atterberg limits. The rates of application for the stabilised row were 2 % v/v for lime and 2% v/v for

cement. Testing of the stabilised surface was not conducted prior to the introduction of cattle to determine the success of stabilisation in situ.

Cattle were introduced to the two adjacent rows in March-April 2018 and data collation was conducted until February 2020, with the following collected for each pen:

- Average dag scores for the lots prior to washing at the plant
- Microbiology sampling from processors
    - E. coli and salmonella (ESAM)
    - Carton meat total viable count (TVC)
    - Shiga toxin-producing E. coli (STEC)
- Cattle productivity, such as offal yield and carcase yield
- Meat quality, including MSA
- Animal welfare
- Pen cleaning information, including timing of all machinery used in the cleaning and volumes of manure
- Ash content in manure

Cleaning of the pens was conducted four times during the trial, with the final cleaning following an extended wet winter. The final milestone was brought forward and survey of pens was conducted earlier than the proposed date due as the lime/cement stabilisation construction had visually deteriorated.

Results of the surveys report that the stabilised row had more pits in the surface than the control row in comparison to the original surface survey. Analysis of the feedlot and processor data indicated that the control row performed better overall than the stabilised row. Many variables may have influenced the results of the trial, with particular focus on the movement of cattle between trial pens and other feedlot pens which were not assessed, and the different time spent in the trial pens by lots.

It is recommended future research be conducted with greater control over the construction of the pens and the operations in the pens (a smaller scale trial may be easier to manage and reduce variability), and a focus on consistency with data collection between the pens.

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1 Background

Stabilising of pen surfaces in feedlots may enable regular pen cleaning during wet winter conditions, in turn minimising the build-up of dags and minimising risks to animal productivity and welfare. Common methods for pen stabilisation include mechanically stabilising through way of blending or screening the existing material, or where this is not feasible, applying chemical stabilisers such as cement, lime, polymers, enzymes, or bituminous materials (Davis & Stafford 2016).

In southern areas of Australia, colder and wet winters lead to difficult pen surfaces which can cause dags on the cows hides, lameness, and difficulty in cleaning the pens with the typical excavator and loader equipment.

There is little information available regarding the use of cement and lime to stabilise feedlot pen surfaces in Australia. Successful stabilisation using cement was conducted for a feed yard in Texas (Parker et al.), however the conditions in Texas are quite different to those in southern areas of Australia, and the soil type utilised was coarser grained. Cement stabilisation occurs in road surfacing and sub-grade construction; however, these surfaces are not commonly exposed to the same concentrated loading and cleaning processes. Recommendations from the Feedlot bedding study (Watts et al.) included the development and demonstration of pen surface stabilisation on a feedlot with clay pen surfaces for beneficial insight for other Australian lot feeders.

A feedlot in Southern Australia proposed a trial of pen stabilisation of two new rows of pens. A chemical stabilisation method was used on one row and the other a control, with the aim to improve the durability of the pen surfaces, reducing dags and allowing for easier winter pen cleaning.

Prior to conducting the project, it was theorised that meat processors in the beef feedlot industry may have the potential to benefit from pen stabilisation practices in the following ways:

- Reducing dag loading and therefore cleaning required prior to processing; and
- Reducing food safety risk experienced through processing of excessively daggy cattle.

Pen stabilisation has the potential to instigate the following improvements for beef feedlots:

- Reducing dag loads on cattle during winter;
- Reducing lameness of cattle during winter;
- Reducing health and safety risks to feedlot staff (primarily pen riders) as they move through the pens to assess cattle health;
- Reducing the delay to clean pens during prolonged wet periods;
- Reduction of manure depth post cleaning which is expected to reduce odour production;
- Reducing damage caused to pen surfaces by the cattle and during wet cleaning and associated costs through time losses and repairs; and
- Reducing pen surface material picked up by the cleaning machinery leading to a greater value fertiliser and the potential for the manure to be used in anaerobic digestion to produce methane.

2 Project objectives

The objective of this project was to determine the impact of feedlot pen surface stabilisation on:

1. Cattle cleanliness (dag load) and washing requirements at slaughter
2. Meat safety (ESAM, Carton meat TVC, STECs)
3. Cattle productivity (carcase weight gains (HSCW) and offal yields)
4. Meat quality outputs (colour, pH decline, dark cutters, marbling, etc)
5. Animal welfare outputs (incidence of lameness based on and retrospective analysis of Emergency Kills and feedlot animal health data)
6. Animal health outputs (post-mortem animal health data, and feedlot animal health data, etc)
7. Feedlot costs as:
    a. Pen cleaning interval and time
    b. Quantity and composition of feedlot manure removed
    c. Cost of pen cleaning and pen surface maintenance

3 Methodology

The proposed experimental design included two treatments: stabilised pen surfaces (9 pens) and standard clay control pen surfaces (10 pens). The 10^{th} control pen was excluded from the trial to allow consistency across the project. Pens in the proposed expansion area of the host feedlot can hold 200 head. Therefore, with the 18 pens in the trial, a maximum of 3,600 head were assessed at any one time.

Nine milestones were proposed across the two years of the trial to enable construction, data collation and results to be reported on. The final milestone was brought forward due to excessive damage to the stabilised pens by the 2020 winter.

Handbooks for use by the feedlot staff were prepared for the project for data collection. These are attached in Appendix B.

3.1 Surveying of pens

Surveys were taken of the two rows of pens, the first prior to the introduction of cattle to the pens in March 2018 and the second in April 2020. These two surveys were compared to determine what had occurred over the life of the project to the two pen surfaces. The differences in height between the two rows pre- and post-cattle use and cleaning may provide guidance as to how well the pens performed, and how successful the pen stabilisation was in preventing the surface from deteriorating.

3.2 Feedlot data

The feedlot staff were requested to collect data from pen cleaning (timing and loading), lot movements into and out of the pens, animal health, animal welfare, dag loading and manure sample composition.

3.2.1 Feedlot livestock

Feedlot livestock data in each of the pens was recorded, including:

- Days in pen for each lot (day in and day out)
- Number of cattle in each lot
- Number of deaths from each lot
- Average weight of the lot when received at the feedlot and when leaving the feedlot
- Total feed in kilograms
- Average lot dag score
- Number of cattle which experienced lameness

3.2.2 Pen cleaning

During cleaning of the two rows of pens, the following was recorded:

- For each machine (truck, loader, excavator) operator each day in the operator logbook:
    - Hours of work in each pen
    - Weather on the day

- Trucks were weighed empty at the beginning of the day and after lunch breaks
- Each truckload from the loader was taken over the weighbridge to record total tonnage from the pens

A prolonged wet winter was experienced at the feedlot in the 2019 autumn/winter which delayed cleaning efforts. The feedlot staff began cleaning the trial pens when the weather allowed and realised that this was further delaying cleaning of the rest of the feedlot due to constant weighing of the trucks and the increased load that was removed from each pen. The methodology was adapted in this instance to prevent further delays or build-up of manure in the rest of the feedlot pens. The trucks were weighed empty at the beginning of each day and weighed only a few of the loads each day. The number of truckloads collected was counted for each pen which could be multiplied by the average load to provide the total tonnage.

Pen cleaning was conducted four times over the time of the trial on each row of the pens in the following periods:

- **Winter 2018**
  - Mounding:
    - Stabilised pens from 26 June to 28 June
    - Control pens from 23 July to 27 July
  - Haul out from 19 September to 26 October
- **Summer 2019**
  - Mounding from 29 January to 30 January
  - Haul out from 29 January to 1 February
- **Autumn 2019**
  - Mounding not conducted
  - Haul out from 16 April to 7 May
- **Spring 2019**
  - Mounding conducted three times during winter – the final being from 8 September to 25 September
  - Haul out from 3 September to 29 October

3.2.3 Manure sampling and composition

Within two days of pen mounding was conducted by the excavator/loader two composite samples from multiple locations in accordance with the Pen Cleaning Handbook was collected. This sample was analysed by ALS Water for total solids, volatile solids and ash/non-volatile solids.

3.3 Processor data

The host feedlot engaged two processor plants in NSW and South Australia, both of which were required to collect the dag loading, meat microbiology, cattle productivity and meat quality for each lot that was processed from the control and stabilised pens. The data is linked to the control and stabilised pens through review of kill date, kill lot and body number.

It was intended to only assess lots which had remained within the pen for greater than 50 days. The feedlot was to provide notice to the plant of the lots requiring assessment from the trial pens prior to receival at the plant.

3.3.1 Cattle cleanliness

Dags were to be taken as an average from the entire lot prior to washing of the animals.

3.3.2 Meat safety

Analysis of ESAM, carton meat TVC and STEC was to be conducted on carcasses from lots that had been on the trial pens for greater than 50 days.

ESAM testing was to be conducted after chilling but prior to boning. Carton meat TVC and STEC was to be carried out as normal on the blended product.

3.3.3 Cattle productivity

Productivity measures including carcase weight gains (HSCW) and offal yields were to be recorded for each animal from the trial pens.

3.3.4 Meat quality

Meat quality indicators such as colour, pH, MSA index, lean meat yield and marble score were to be recorded for each animal from the trial pens.

3.3.5 Animal welfare and animal health

Lameness and other health issues experienced by cattle in the trial pens was assessed by feedlot staff and documented in health records for the pens.

3.4 Data analysis

3.4.1 Loading factor

The loading factor was established to identify any differences between the animal loading on the pen surfaces. Differing loading on the pen surface through cattle hooves may result in uneven stresses across the rows and potentially extra damage to those with higher loading. The loading factor was determined by number of cattle in the pens multiplied by the average weight (average of weight in and out), divided by the area of the pens. The loading factor can also be reported in a common measure of standard cattle units (SCU), based on the average weight of the cattle as a percentage of the standard cattle unit of 600 kg.

3.4.2 Statistical Analysis

3.4.2.1 Box and whisker plots

Box and whisker plots are useful for comparing the variability of a dataset. As there are nine pens for both the stabilised and control rows, and hundreds of cattle moving in and out of each, it is useful to have a visual aid to show the actual data rather than simply averages. Box and whisker plots were produced for many of the variables analysed in the trial, providing a justification for the difference in averages. The mean for each dataset is shown by the cross and the median is shown by the middle line. The box and whisker plots are useful for comparison where the t-test, as described below, is not appropriate.

3.4.2.2 Student T-test

Statistical analysis through two sample t-testing was the most appropriate form for the datasets in this research. T-testing enables the direct comparison of two datasets for the same measurement. T-testing uses the mean, standard deviation, and size of dataset to determine a t value. This t value is compared to a p value which is the confidence interval (commonly 0.05) to determine whether the two datasets are statistically different.

However, the t-test should not be conducted on non-normal datasets or datasets with large outliers.

T-testing was used to compare the performance of the control versus the stabilised pens for the following variables:

- Lean meat yield
- Paid body (HSCW)
- pH
- MSA Index
- Cattle weight in
- Cattle weight out
- Average daily gain
- Deaths
- Hours spent cleaning
- Tonnes collected in cleaning
- Fixed and total solids percent of manure collected

4 Results

4.1 Pen stabilisation

Construction of the subgrade for the pens was undertaken in Spring 2017, with testing done in November. Appendix H contains the results of the testing for both rows conducted by Geotechnical Testing Services. Multiple tests were conducted over two weeks for the pens to establish the pen subgrade to a 98% compaction standard.

The pen stabilisation contract was executed between the host feedlot and a construction contractor in late 2017. Plant was successfully transferred to the site in early December 2017, with stabilisation occurring mid-December.

Originally, lime and cement for the stabilisation were to be blended prior to transport to the feedlot and then applied as a combined mixture in one pass. However, due to unavailability of cement from the original cement provider, the process for stabilisation was split into two components. The first pass involved applying hydrated lime to the pen surface, wetting it, blending to a depth of 200 mm into the pen surface (Fig.) and allowing it to cure for two days. Following this, cement was applied, wetted, and blended into the soil and lime surface to a depth of 200 mm. The correct application rates were confirmed using a plastic sheet (**Error! Reference source not found.**). The rates of application were 2 % v/v for lime and 2% v/v for cement.

Fig. 1 Blending lime into the top 200 mm of the pen surface


Fig. 2 Staff calibrating the application rate

After 3 months of resting the pen surfaces, cattle were introduced to the pens.

Compaction testing of the stabilised or control pen surfaces post-treatment were not conducted prior to introduction of cattle to the pens. Therefore, it is unknown whether the surface was at the required standard as determined through the soil stabilisation testing in the laboratory.

4.2 Surveying of pens

Survey was conducted by the feedlot contractor in March 2018 and a second contractor conducted the final survey in April 2020. The two surveys were analysed using online software with access provided by the second contractor. Comparison between the two datasets indicates:

- Majority of the surface of the control pens was higher than the original survey, suggesting that the manure had been compacted on the surface forming an interface layer.
- More pitting noticeable in the stabilised pens, with almost half as much build-up of an interface layer as the control pens.
- Cut and fill volumes from the original survey to the final survey are as follows, representing the volume required to change the final survey back to the original survey:
    - Control pens:
        - Cut = 3,290 m^3
        - Fill = 68 m^3
    - Stabilised pens:
        - Cut = 1,694 m^3
        - Fill = 368 m^3

Appendix G provides the survey data and report describing the above volumes.

The results indicate that more solids were removed from the surface of the stabilised pens than the control pens during the trial.

Table 1 below provides the outcomes of an analysis of the final survey data along with the tonnes removed from the pens. The surveyed net change is the volume removed from the surface (negative means volume added to the surface) as recorded through comparison of the survey. The solids removed describes the recorded solids removed during all four cleans in each pen. Volume removed describes the converted tonnes to cubic metres, through multiplication of a density of 700 kg/m^3 for manure (Tucker et al, 2015). Volume manure deposited is the volume removed different from the net volume change, as this discounts manure that was left behind as the interface layer and any volume removed from the original pen surface. The volume manure deposited per SCU is the total manure deposited in the pen divided by the number of SCUs in the pen.

Volume removed from the stabilised row was substantially higher than the control, which is consistent with the pitting and lower pen surface observed and surveyed of the stabilised row. The approximate volume of manure removed from the pens measured reasonably consistent between the control and the stabilised.

Table 1 Volumes of solids removed from control and stabilised pens

Pen	**Surveyed net volume change (m^3)**	**Solids removed during cleaning (t)**	**Volume removed during cleaning (m^3)**	**Volume manure deposited (m^3)**	**Volume manure deposited per SCU (m^3)**
Control					
Pen 80	-351	1,881	2,687	3,038	1.2
Pen 81	-370	1,540	2,201	2,571	1.4
Pen 82	-200	2,145	3,064	3,264	1.9
Pen 83	-227	2,038	2,912	3,139	1.7
Pen 84	-335	1,645	2,350	2,685	1.5
Pen 85	-282	2,186	3,122	3,404	1.7
Pen 86	-351	1,594	2,277	2,628	2.1
Pen 87	-354	1,277	1,824	2,178	1.3
Pen 88	-345	2,367	3,382	3,727	2.4
Average	**-313**	**1,853**	**2,647**	**2,959**	**1.7**
Stabilised					
Pen 90	-234	1,968	2,811	3,045	1.8
Pen 91	-14	2,453	3,504	3,518	2.0
Pen 92	-118	2,075	2,965	3,083	1.9
Pen 93	-147	2,232	3,189	3,336	1.8
Pen 94	-116	2,289	3,271	3,387	2.3
Pen 95	-158	1,791	2,558	2,716	1.7
Pen 96	-115	1,828	2,611	2,726	1.8
Pen 97	-210	2,334	3,334	3,544	2.1
Pen 98	-228	2,325	3,322	3,550	2.0
Average	**-149**	**2,144**	**3,063**	**3,212**	**1.9**

4.3 Feedlot data

4.3.1 Site observations

4.3.1.1 Autumn 2019

No site visit was conducted during the Spring/Summer 2018-19 season. However, a number of field observations were made and recorded during communications between Premise and the Feedlot Manager.

- In general, no substantial differences had been observed between the stabilised and control pens;
- The Spring/Summer season was dry aside from one significant rainfall event (112 mm) on the 13th – 14th December and one small follow up event (12.4 mm) on 16th December;
- There had been a bit of dust through the summer, which would have been more severe without the significant December rainfall event;
- Both the pen surfaces have remained in good condition during the first year of the experiment;
- Following pen construction, the top of the stabilised surface was observed to be breaking up. It is assumed that this was due to the timing of construction, which saw the pens completed at the end of summer, with no significant rain to add moisture. After one year of having cattle in the pens and manure being added to the surface, both surfaces were observed to have bedded in well. The pen surface was observed to swell during Autumn/Winter 2018.
- Observations at the end of February 2019 indicated that it had been easier to clean surfaces while leaving the interface layer intact than observations earlier in the experiment.

4.3.1.2 Time & motion studies September 2019

The time and motion studies were carried out on site between the 17th and 20th of September. The process was observed to involve three steps: manure mounding, manure removal and transfer to weigh trucks, and manure weighing.

4.3.1.2.1 Manure mounding

Manure mounding is undertaken by a Komatsu Avance PC200 excavator with a 0.97 m^3 bucket size and a 103 kW engine. Observations of the excavator mounding manure in the control pens indicated that it takes between 5 and 6 hours to sufficiently mound the manure in each pen, prior to the transfer into haul out trucks (Table 2).

Table 2 - Excavator mounding times of control pens

Pen	Date	Start	Break	Finish	Minutes
82	17/09/19	07:00	-	13:00	360
83	18/09/19	07:00	-	12:00	300
84	18/09/19	12:00	-	17.15	315

4.3.1.2.2 Manure removal and transfer to trucks

Mounded manure is picked up by a Komatsu WA300 loader with a 3.6 m^3 bucket size and a 143 kW engine. This is a lengthy process during winter cleans, taking 19 and 25.5 hours for all manure to be removed from the control and stabilised pen respectively (Table 3). The extended hours for cleaning could be attributed to the need to weigh each truck and the accumulated manure over the wet winter period.

Table 3 - Loader manure removal and truck transfer times

Stabilised/Control	Pen	Date	Start	Break	Finish	Minutes
Stabilised	92	12/09/19	*13:15*	-	*17:00*	225
Stabilised	92	13/09/19	***07:00***	***00:45***	***17:00***	555
Stabilised	92	17/09/19	07:30	00:45	16:15	480
Stabilised	92	18/09/19	08:00	00:45	13:20	275
						1,535
Control	81	18/09/19	13:25	-	16:20	115
Control	81	19/09/19	07:30	00:45	16:30	495
Control	81	20/09/19	07:30	*00:45*	*17:00*	525
						1,134

Note: Times italicised are those which were taken from the loader logbook.

4.3.1.2.3 Truck weighing

Only three of the four trucks were operating during the period of the time and motion studies due to unavailability of staff. Teys were optimising the cleaning and weighing process but were constrained by several factors including:

- Incoming and outgoing trucks have priority on the weighbridge;
- The weighbridge is only open between 7:30 am and 4:30 pm;
- Trucks are owned and operated by contractors, which means that any leave taken by one of the contactors reduces efficiency.

4.3.1.2.4 Control pens

The surfaces of the control pens were reasonably smooth, which means that minimal clay is removed during mounding by loader. The duration of cleaning is quite long, with one pen taking just under two working days to conduct haul out and scraping. The excavator mounds manure in the pens within 5-6 hours in the control rows, however, due to sporadic start times/breaks/finish times by the excavator operator, it was difficult to obtain accurate timings of operation during the time and motion studies.

Fig. 3 *Control Pen 81 during clean*

Fig. 4 *Alley of control pens*

4.3.1.2.5 Stabilised pens

In contrast to the smooth surface of the control pens, the stabilised pens have an undulating formation (Fig. 5 and Fig. 6). This seems to result in a greater amount of clay being removed during cleaning compared with control pens. Mounding of the pens took approximately 2 days in the control rows. Unfortunately, observations of clearing of the stabilised pens were not possible because the excavator did not clear any of the stabilised pens during the period of the cleaning. Anecdotally, the stabilised pens were observed to be more compact during the 2019 winter than during the 2018 winter. Fig. 7 shows part of the cracked surface in the alley next to the stabilised pens.

Fig. 5 Stabilised Pen 91 after clean


Fig. 6 Stabilised Pen 91 after clean showing undulating surface


Fig. 7 Cracked surface material in alley outside stabilised Pen 90

4.3.1.2.6 General observations

The following general observations were made during the time and motions studies:

- Feedlot staff identified that pen foundation clays from the on-site quarry are variable and can be poor quality. There appears to be variation in soil types between the two rows, with different colour clay present in each.
- Any follow up time and motion studies should consider commencing after many of the pens have been cleaned. This will allow for increased observations of cleaned surfaces and the excavator and loader drivers should be able to provide a more detailed description of the cleaning process and any observed differences between the two rows.

4.3.2 Feedlot livestock

The trial pens were operated at the feedlot's discretion during the trial. Closed lots are summarised in Table 4 and Table 5 for the control and stabilised rows, respectively. It is noted that the lots for the control pens tended to be changed more frequently, resulting in 19 more lots going through the control than the stabilised. Lots that were in the stabilised pens tended to remain in the pens for a longer amount of time. Fig. 8 and Fig. 9 provide box and whisker plots of the days spent in pen and the percent of time at the feedlot spent in the trial pen for each of the control and stabilised lots.

Table 4 - Livestock closeout data for control pens

General Details			Closed Lots												
Pen Number	Stocking Date	Last Complete Close Out	No. Lots	Pen Days	Avg. Pen Days	Time in Pen (DOF)	Cattle In (hd)	Deaths (hd)	Deaths (%)	Avg. Weight In (kg/hd)	Avg. Weight Out (kg/hd)	Avg. Intake (kg/hd/day)	Average dag score	Incidence of lameness	Lameness (%)
80	20/03/18	20/02/20	12	568	47	47%	2,873	21	0.73	408	629	15.5	1.9	5	0.17
81	5/04/18	18/09/19	12	619	66	54%	2,054	11	0.54	407	633	16.1	2.3	12	0.58
82	20/03/18	15/12/19	9	586	71	51%	1,953	12	0.61	410	661	14.2	1.4	18	0.92
83	5/04/18	03/01/20	11	642	88	71%	2,120	26	1.23	412	651	16.6	2.0	7	0.33
84	29/03/18	07/02/20	10	560	75	60%	2,033	16	0.79	421	660	15.9	2.7	13	0.64
85	5/04/18	13/11/19	13	579	64	50%	2,263	28	1.24	416	648	15.3	1.9	19	0.84
86	29/03/18	17/01/20	9	611	102	71%	1,394	30	2.15	404	681	18.6	2.0	8	0.57
87	5/04/18	16/02/20	12	588	53	63%	1,954	18	0.92	405	649	16.3	2.4	13	0.67
88	30/03/18	15/01/20	12	575	87	65%	1,812	24	1.32	401	638	16.1	2.9	9	0.50
Overall	**n/a**	**n/a**	**100**	**5,373**	**54**		**20,217**	**198**		**3,684**	**5,857**	**145**		**104**	
Average	**n/a**	**n/a**	**11.1**	**597**	**71**	**58%**	**2,246**	**22**	**0.98**	**409.3**	**650.8**	**16.1**	**2.2**	**11.6**	**0.53**

Table 5 Livestock closeout data for stabilised pens

General Details			Closed Lots												
Pen Number	**Stocking Date**	**Last Complete Close Out**	**No. Lots**	**Pen Days**	**Avg. Pen Days**	**Time in Pen (DOF)**	**Cattle In (hd)**	**Deaths (hd)**	**Deaths (%)**	**Avg. Weight In (kg/hd)**	**Avg. Weight Out (kg/hd)**	**Avg. Intake (kg/hd/day)**	**Average dag score**	**Incidence of lameness**	**Lameness (%)**
90	11/04/18	09/12/19	8	653	96	71%	1,890	25	1.32	418	644	15.0	3.0	9	0.48
91	11/04/18	22/09/19	8	486	82	60%	1,975	30	1.52	432	635	16.9	2.6	9	0.46
92	12/04/18	06/02/20	9	563	93	76%	1,968	18	0.91	395	619	15.8	2.0	10	0.51
93	12/04/18	20/02/20	8	515	64	55%	2,149	26	1.21	423	616	14.5	3.0	2	0.09
94	18/04/18	17/01/20	7	528	75	58%	1,768	12	0.68	392	623	16.4	2.0	26	1.47
95	10/04/18	21/02/20	10	618	97	76%	1,785	6	0.34	414	633	15.9	2.2	16	0.90
96	18/04/18	29/12/19	11	564	66	48%	1,653	14	0.85	419	668	16.9	2.8	14	0.85
97	10/04/18	16/02/20	10	583	78	59%	1,941	20	1.03	401	636	15.4	2.4	12	0.72
98	12/04/18	06/02/20	10	532	67	58%	2,024	28	1.38	403	644	14.7	2.8	13	0.61
Overall			**81**	**5,042**	**64**		**17,153**	**179**		**3,698**	**5,718**	**143.3**		**111**	
Average			**8.8**	**560**	**80**	**62%**	**1,906**	**20**	**1.03**	**410.9**	**635.3**	**15.9**	**2.6**	**12.3**	**0.65**

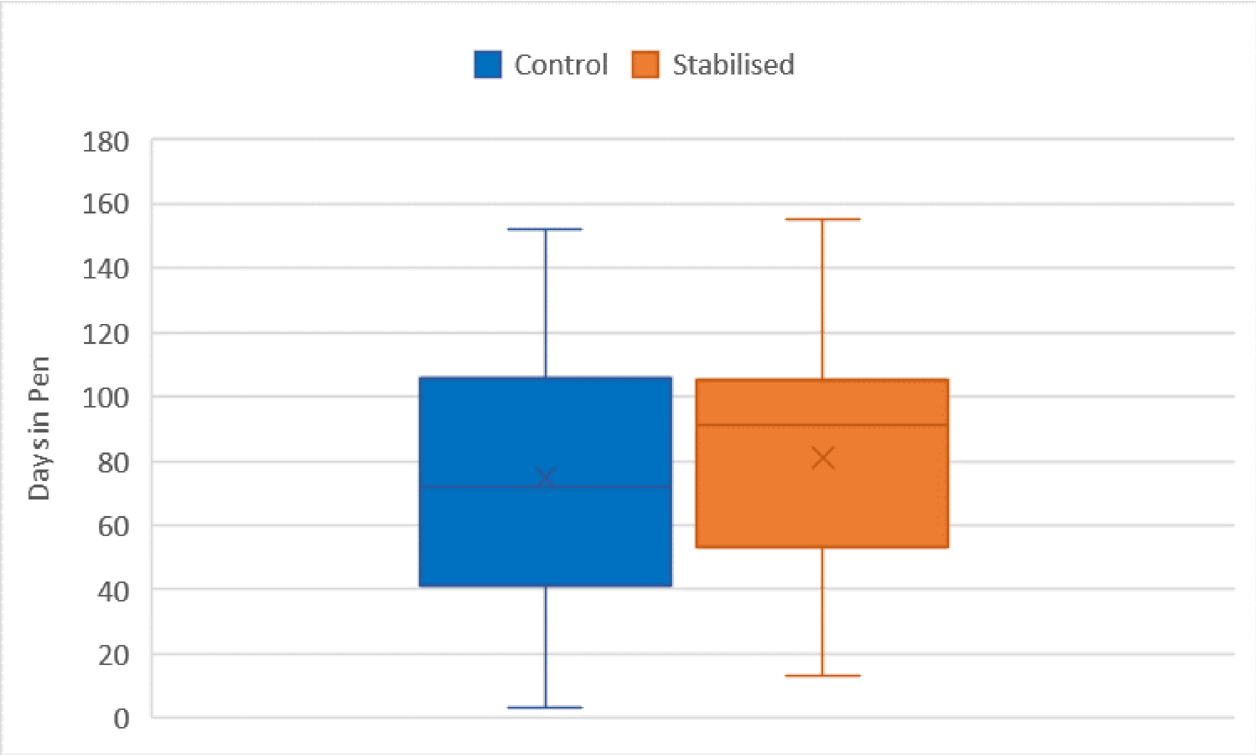

Fig. 8 Control and stabilised days spent in trial pen

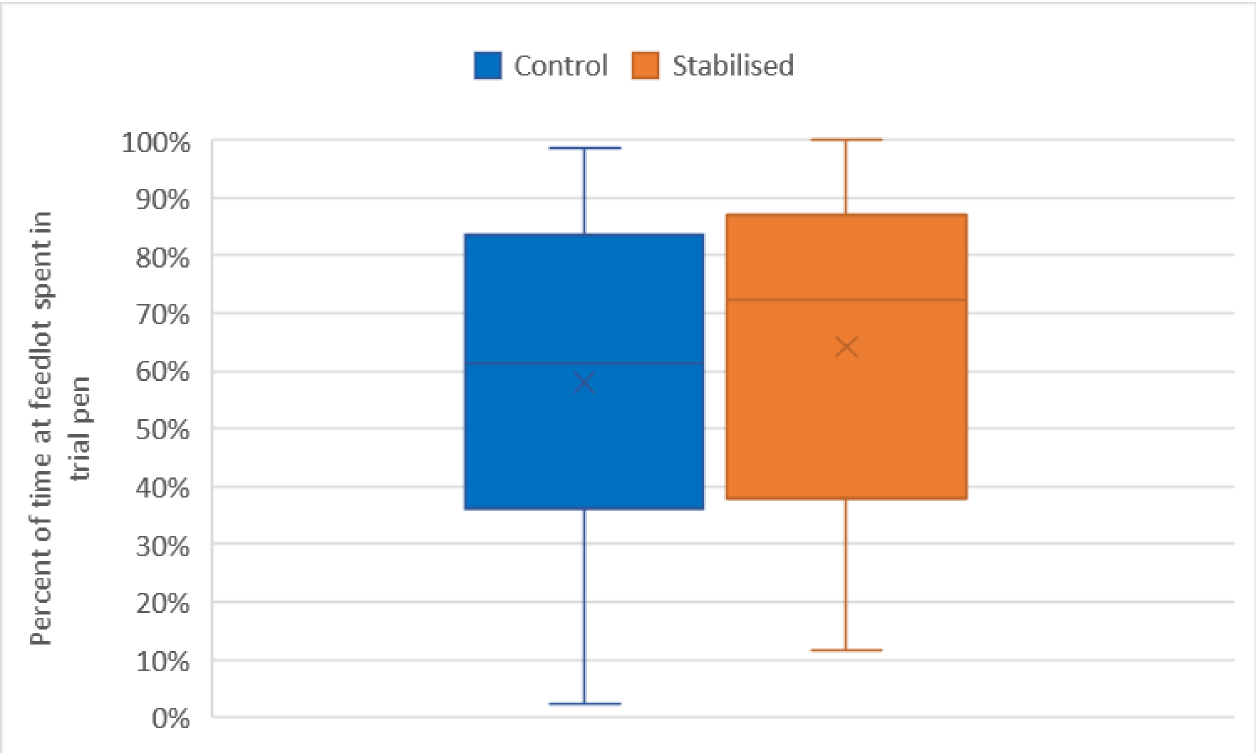

Fig. 9 Control and stabilised time spent in trial pen as percentage of time spent at feedlot

4.3.3 Pen cleaning

Table 6 describes the average amount of manure harvested from each of the control and stabilised pens. The Winter 2018 and 2019 cleans vary greatly in the number of tonnes collected and therefore the daily harvested manure and solids. This may be influenced by the increased moisture in the manure and/or the methods for calculating total tonnage done in the Winter 2019 clean. More manure was harvested from the stabilised pen in all cleans except the Autumn 2019. Fig. 10 and Fig. 11 show the variation of the Winter 2018 clean in terms of hours spent cleaning and tonnes collected.

Table 6 Average manure harvesting results

Row	Manure accumulation (days/pen)	Manure harvested (tonnes/pen)[1]	Head days (days/pen)[1]	Harvested manure/head day (kg/head/day/pen)	Harvested solids/head day (kg/head/day/pen)
Winter Clean 2018					
Control	202	546.9	49,656	11.0	3.4
Stabilised	167	546.1	39,557	13.6	4.5
Summer 2019					
Control	104	43.7	27,145	1.6	0.3
Stabilised	124	73.9	31,579	2.34	0.4
Autumn 2019					
Control	91	100.8	16,771	6.0	0.8
Stabilised	80	84.0	20,196	4.2	0.7
Winter 2019					
Control	161	1,161	43,269	26.8	4.56
Stabilised	162	1,440	44,095	32.7	6.54

Table 7 compares the control and stabilised row cleaning in terms of tonnes collected and hours taken by all plant combined. The results of the Winter 2018 clean are shown as this period represents the critical period, and due to inconsistencies in the Winter 2019 data collection across the pens (refer Section 3.2.2).

Table 7 Summary table of raw manure, total and fixed solids collected (total and machine hour basis) – (Winter 2018)

Average	Control	Stabilised
Hours[1]	37.6	33.1
Raw tonnage collected	546.9	546.1
Tonnes/hr (raw manure)[1]	14.6	16.5
Total solids (t)	261.9	258.5
Total solids/hr[1]	7.0	7.0
Fixed Solids (t)	166.2	181.5
Fixed Solids/hr[1]	4.4	4.4
Fixed Solids % of total	30%	33%

[1.] Hours presented are based on total machine hours and therefore, if a loader and truck both work the same 5 hours, this equates to 10 machine hours.

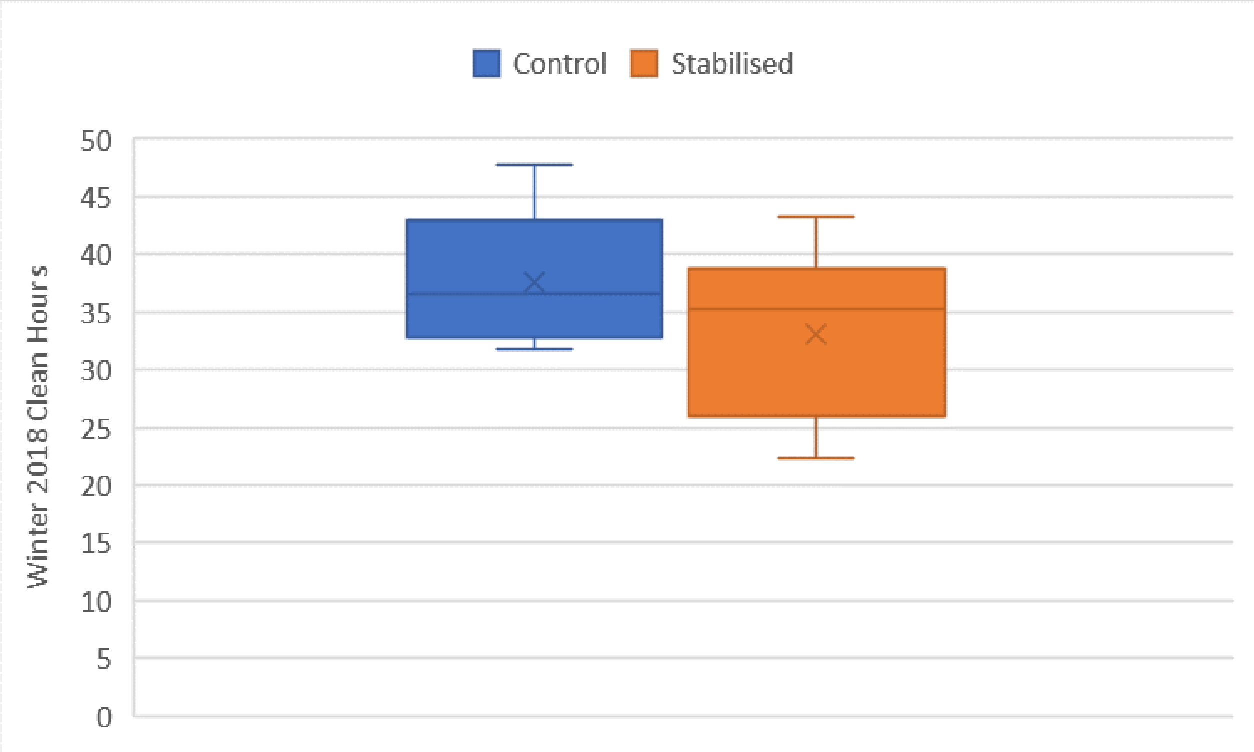

Fig. 10 Control and stabilised hours spent on pen cleaning – winter 2018

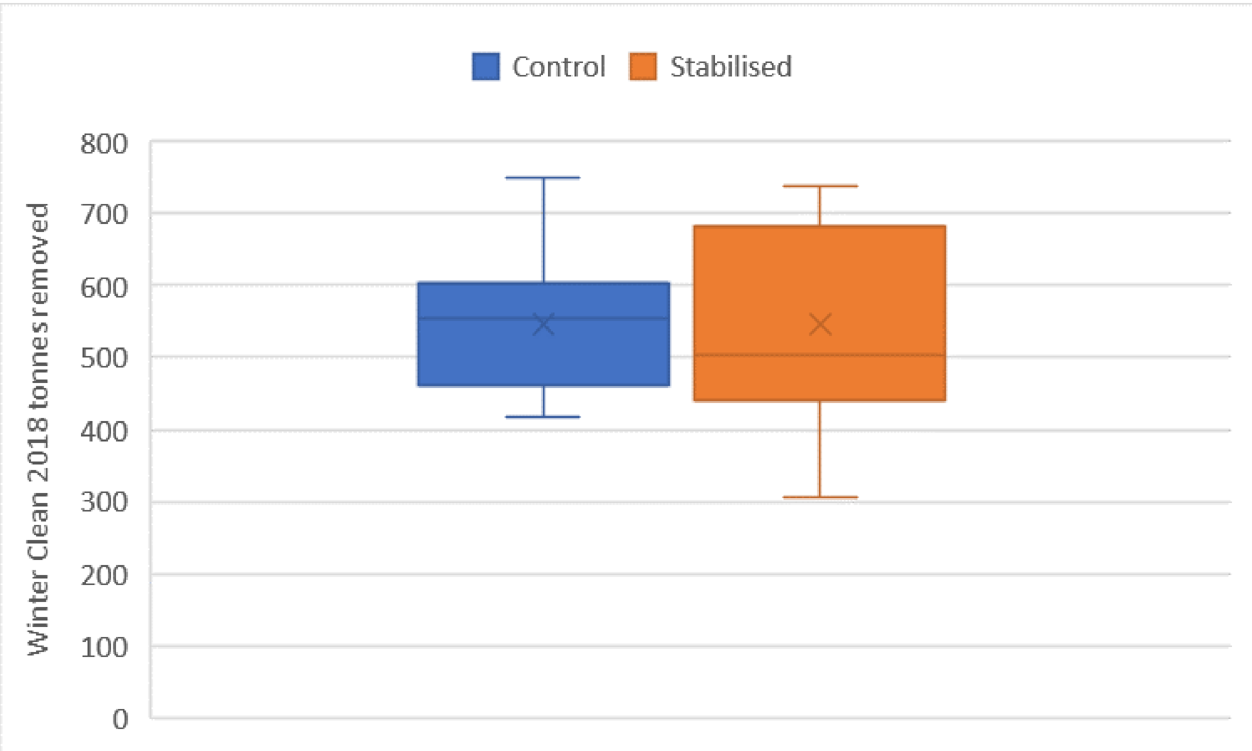

Fig. 11 Control and stabilised tonnes removed in pen cleaning – winter 2018

4.3.4 Manure sampling and composition

Sampling of manure from the pens following scraping was conducted for each clean, providing a total of four samples for moisture content, total solids, volatile solids and fixed solids. From the results shown in Table 8, the average fixed solids content as a percentage of the total harvested manure from the pens is approximately 21% and 23% for the control and stabilised rows, respectively. The variation of these is shown visually in Fig. 12.

Table 8 Average TS/VS results from harvested manure within the trial pens

Control Pens					Stabilised Pens				
Pen No.	Moisture Content	Total Solids (% w/wet w)	Volatile Solids	Fixed Solids	Pen No.	Moisture Content	Total Solids (% w/wet w)	Volatile Solids	Fixed Solids
80	52%	48%	60%	41%	90	53%	47%	52%	49%
81	52%	48%	63%	37%	91	51%	49%	52%	48%
82	53%	47%	51%	49%	92	52%	48%	60%	40%
83	54%	47%	58%	42%	93	49%	52%	54%	46%
84	49%	52%	59%	42%	94	51%	49%	49%	51%
85	51%	49%	54%	46%	95	56%	44%	53%	48%
86	53%	47%	57%	43%	96	48%	52%	48%	52%
87	50%	50%	55%	45%	97	52%	48%	48%	52%
88	50%	50%	54%	46%	98	54%	46%	53%	47%
Avg.	**51%**	**49%**	**57%**	**43%**	**Avg.**	**52%**	**48%**	**52%**	**48%**

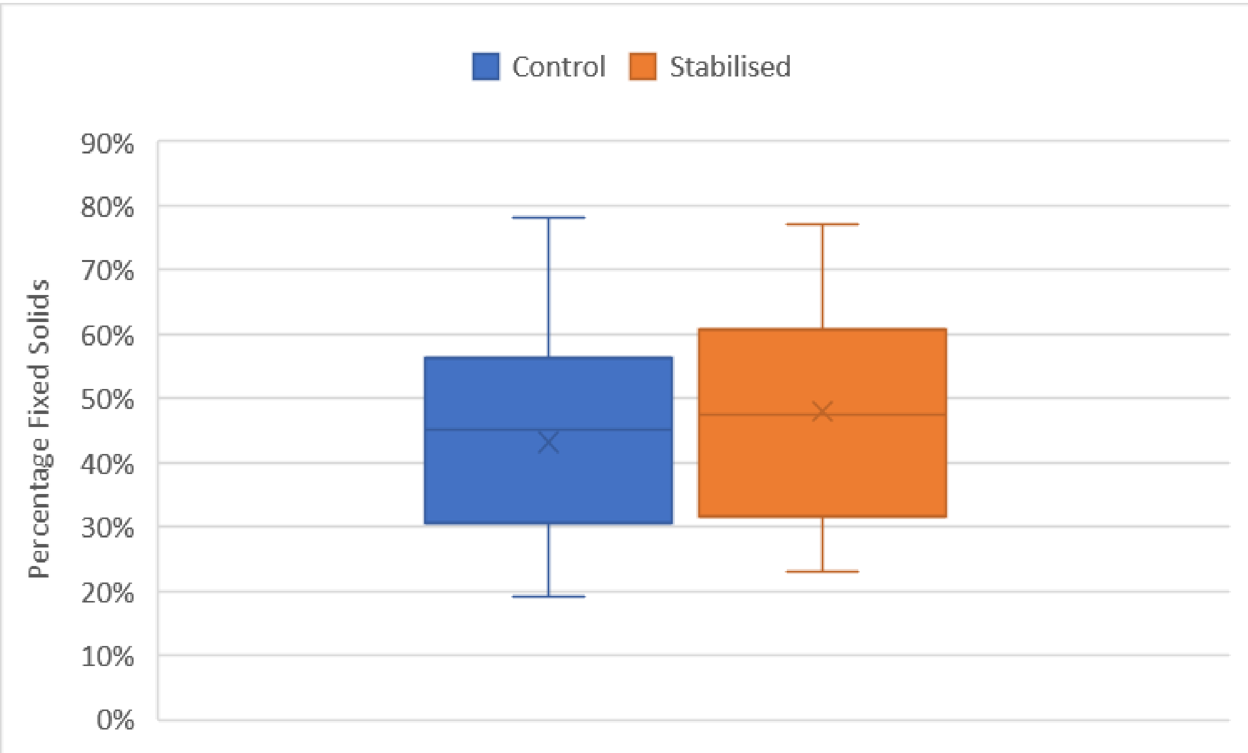

Fig. 12 Control and stabilised fixed solids percentage variation

4.3.5 Loading factor

A loading factor was established for each pen based on number of cattle, average weight of cattle and the pen surface areas (3000m^2). Standard cattle units (SCU) are a common reference point for MLA, measuring the equivalent of a 600kg cow. Loading factors based on the SCU were also established. Table 9 and Fig. 13 provide comparisons of the control and stabilised pens loading factors.

Table 9 Loading factors of control and stabilised pens

Control Pen	Loading Factor kg/m²	SCU/m²	Stabilised Pen	Loading Factor kg/m²	SCU/m²
80	497	0.83	90	334	0.56
81	356	0.59	91	351	0.59
82	349	0.58	92	333	0.55
83	376	0.63	93	372	0.62
84	366	0.61	94	299	0.50
85	404	0.67	95	312	0.52
86	252	0.42	96	300	0.50
87	343	0.57	97	335	0.56
88	314	0.52	98	353	0.59
Average	**362**	**0.60**	**Average**	**332**	**0.55**

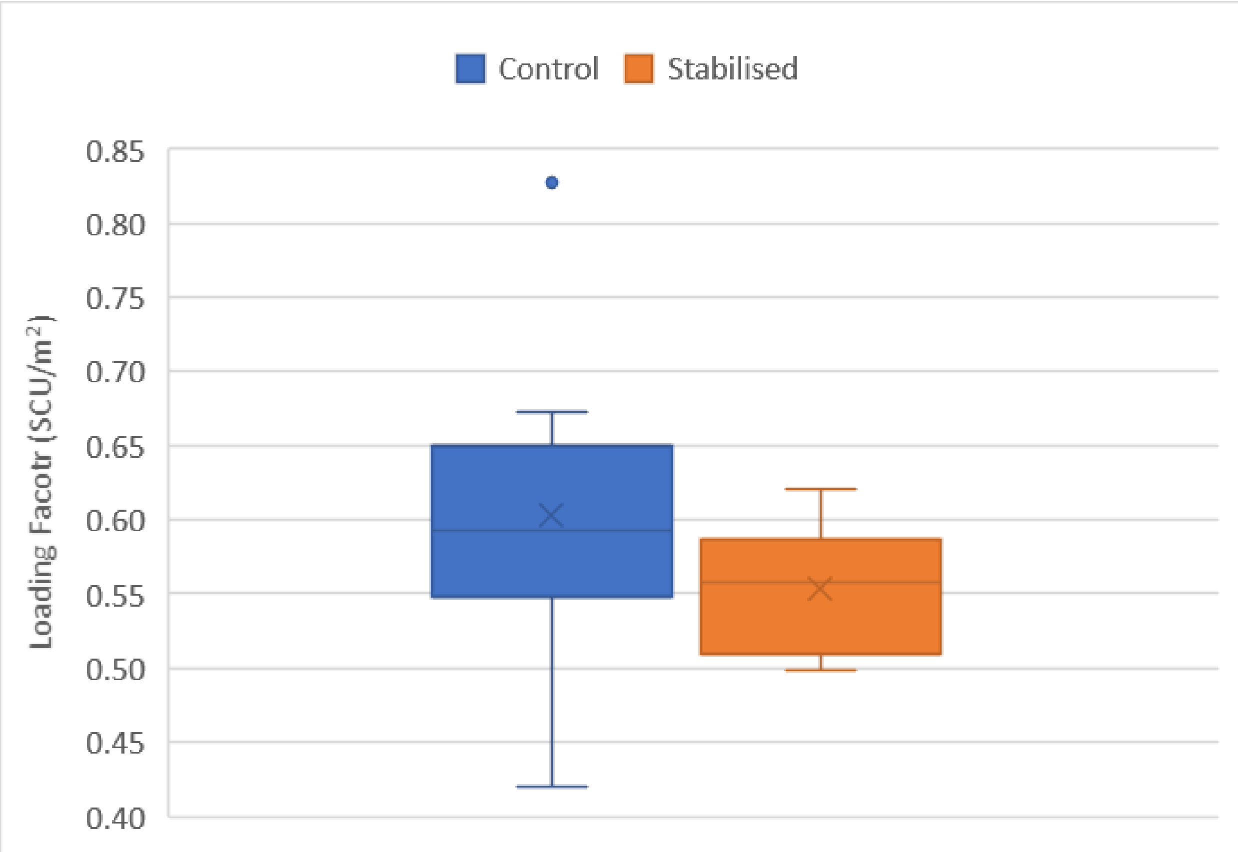

Fig. 13 Control and stabilised loading factors in SCU

As seen above, the loading factor for the control pens has a greater range and on average is higher than for the stabilised pens, although much more variability. This suggests that most of the control pens would potentially be more prone to wear from cattle over the two-year period.

Based on the comparison of the final survey to the original, this does not seem to be the case. More pitting occurred on the surface of the stabilised pens than the control (refer Appendix G).

4.4 Processor data

4.4.1 Cattle cleanliness

Dag scoring was conducted on lots in the pens during the winter months. Average dag loading scores for each pen are shown in Table 10, with the stabilised row showing a slightly higher average. This is also illustrated in Fig. 14.

Table 10 Dag scoring – March 2018 – February 2020

Control Pens			Stabilised Pens		
Pen No.	Processed Cattle	Average Dag Load[1]	Pen No.	Processed Cattle	Average Dag Load[1]
80	2,873	1.9	90	1,890	3.4
81	2,054	2.3	91	1,975	2.6
82	1,953	1.4	92	1,968	2.0
83	2,120	2.0	93	2,149	3.0
84	2,033	2.7	94	1,768	2.0
85	2,263	1.9	95	1,785	2.2
86	1,394	2.0	96	1,653	2.8
87	1,954	2.4	97	1,941	2.4
88	1,812	2.9	98	2,024	2.8
Total	**20,217**	**2.2**	**Total**	**17,153**	**2.6**

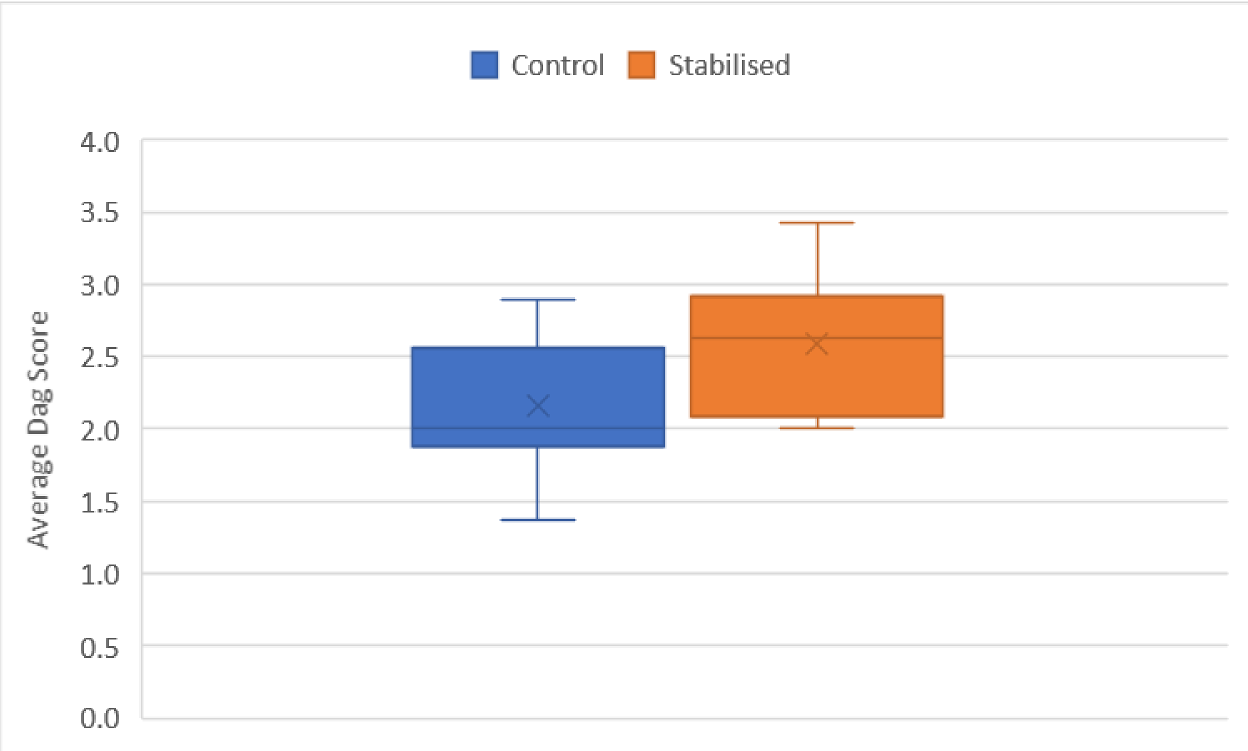

Fig. 14 *Control and stabilised dag scoring variation*

4.4.2 Meat safety

Safety testing was conducted on cattle from lots which spent greater than 50 days in the trial pens. Table 11 and Table 12 describe the results of meat safety testing from the control and stabilised pens.

Table 11 ESAM testing results – Control Pens – March 2018 – February 2020

Control Pens									
Kill Date	Processor	Pen Number	Lot Number	Days in Pen	Body	Certificate	Standard Plate Count CFU/cm^2	Coliform Sponge CFM/cm^2	Escherichia coli Sponge CFM/cm^2
31/07/2018	A	87	1810B1/C1	112	284	W696009	4.2	<0.083	<0.083
28/08/2018	B	85	1821E1	91	404	M705017-A	1.7	<0.083	<0.083
21/09/2018	A	80	1822C1	109	86	W712829	7.5	<0.083	<0.083
09/10/2018	A	83	1823C1/C2	106	485	W717537	7.5	<0.083	<0.083
11/10/2018	A	84	1825F2	39	399	W718500	1,100	<0.083	<0.083
18/10/2018	A	82	1826E2	106	686	W720699	13	<0.083	<0.083
05/02/2019	B	87	1845C1	71	302	M753252	2.5	<0.083	<0.083
26/02/2019	A	87	1833C1	87	525	W753800	17	<0.083	<0.083
					651		66	<0.083	<0.083
					164		35	<0.083	<0.083
27/02/2019	B	89	1843F1	71	213	M761107	<0.83	<0.083	<0.083
13/03/2019	A	83	1846C1/B1	117	509	W764170	9.2	<0.083	<0.083
					22		2,100	<0.083	<0.083
					988		25	<0.083	<0.083
					1024		NA	NA	NA
21/06/2019	B	85	1815D1	68	379	M798232	92	<0.083	<0.083
22/06/2019					409		1,500	<0.083	<0.083
11/07/2019	B	82	1907E1	141	570	M805671	1,800	<0.083	<0.083
26/08/2019	B	86	1909L1	128	288	M820311	5	<0.083	<0.083
21/10/2019	B	80	1921L1	71	208	M838656	~2.5	<0.083	<0.083
23/10/2019	A	85	1925E1	148	192	W839166/2	~1.7	<0.083	<0.083
09/12/2019	A	82	1927L1	152	190	W855767/4	~21	1.8	<0.083
15/01/2020	A	88	1936F1	87	450	W866087/1	~24	~0.17	<0.083
28/01/2020	A	87	1941F2	80	289	W870189/1	~13	<0.083	<0.083
					408	W870189/4	~18	<0.083	<0.083
22/02/2020	A	89	1937C2/1937B2	160	337	W879417/4	~14	<0.083	<0.083

Table 12 ESAM testing results – Stabilised Pens – March 2018 – February 2019

Stabilised Pens									
Kill Date	Processor	Pen Number	Lot Number	Days in Pen	Body	Certificate	Standard Plate Count CFU/cm²	Coliform Sponge CFM/cm²	Escherichia coli Sponge CFM/cm²
26/07/2018	A	91	1814E1/F1	53	2	W694771	2.5	<0.083	<0.083
14/09/2018	A	94	1822F1	111	62	W710596	28	<0.083	<0.083
20/09/2018	A	96	1837C2/B2	119	320	W712529	2.5	<0.083	<0.083
03/10/2018	A	92	1823B1	92	91	W715653	30	<0.083	<0.083
14/02/2019	A	95	1843F2	48	143	W756684	37	<0.083	<0.083
					190		62	<0.083	<0.083
					574		72	<0.083	<0.083
22/03/2019	A	93	1847F2	116	536	W768472	2.5	<0.083	<0.083
					819		220	<0.083	<0.083
					1087		43	<0.083	<0.083
					292		18	<0.083	<0.083
25/03/2019	A	95	1850E1	98	201	W768938	14		
					497		120		
					847		3.3		
					969		44		
24/06/2019	B	98	1905E1	124	550	M798617	1.7	<0.083	<0.083
15/07/2019	B	90	1911F2	97	215	M806041	3.3	<0.083	<0.083
					619		21	<0.083	<0.083
16/07/2019	B	96	1906L1/L2	59	448	M806589	58	<0.083	<0.083
					484		19	<0.083	<0.083
					451		62	<0.083	<0.083
					733		39	0.17	<0.083
22/07/2019	B	94	1912E1	80	547	M808560	42	<0.083	<0.083
23/09/2019	B	97	1917L1	101	313	M829698	~4.2	<0.083	<0.083
02/12/2019	A	92	1929E2	131	228	W853055/3	~11	~0.083	<0.083
	A	92	1929E2	131	292	W853055/5	50	~0.083	<0.083
03/12/2019	A	92	1929E2	131	120	W853523/1	~19	<0.083	<0.083
09/12/2019	B	93	1935E1	104	575	M855999	<0.83	<0.083	<0.083
10/12/2019	A	90	1930E2	132	170	W856271/3	~1.7	~0.083	<0.083
23/12/2019	A	96	1929L1	115	180	W860894/3	92	<0.083	<0.083
30/12/2019	A	96	1929L1	121	450	W861562/5	~0.83	<0.083	<0.083
06/01/2020	A	93	1930L1	96	400	W862670/1	~1.7	<0.083	<0.083
06/01/2020	B	97	1938E1	79	191	M862892	26	<0.083	<0.083

4.4.3 Cattle productivity

Productivity in terms of hot standard carcase weight was recorded by the processors for each cow that spent time in the trial pens. Table 13 and Table 14 describe the paid body and weight gain results for all cattle processed prior to end of February 2020. Fig. 15 and Fig. 16 show box and whisker plots for the weight in and out and paid body for control and stabilised pens.

Table 13 Cattle paid body (HSCW) for Trial Pens - March 2018 – February 2020

Control Pen	Cattle Processed	Paid Body (HSCW) (kg)	**Stabilised Pen**	Cattle Processed	Paid Body (HSCW) (kg)
80	1,737	347	**90**	1,890	367
81	1,248	348	**91**	1,214	364
82	1,117	413	**92**	1,968	356
83	1,547	377	**93**	1,346	340
84	1,603	370	**94**	1,269	357
85	1,587	358	**95**	1,241	357
86	1,847	386	**96**	1,098	360
87	1,766	355	**97**	1,413	364
88	1,482	353	**98**	1,535	352
Total	**13,934**	**3,307**	**Total**	**12,974**	**3,218**
Avg. Pen	**1,548**	**367**	**Avg. Pen**	**1,442**	**358**

Table 14 Cattle productivity for Trial Pens - March 2018 – February 2020

Control Pen	Average weight at entry (kg)	Average weight at exit (kg)	Average weight difference (kg)	**Stabilised Pen**	Average weight at entry (kg)	Average weight at exit (kg)	Average weight difference (kg)
80	408	629	221	**90**	418	644	226
81	407	633	227	**91**	432	635	202
82	410	661	251	**92**	395	619	224
83	412	651	239	**93**	423	616	193
84	421	660	240	**94**	392	623	231
85	416	655	239	**95**	414	633	219
86	404	681	276	**96**	419	668	248
87	405	649	244	**97**	401	636	235
88	401	638	237	**98**	403	644	241
Total	**3,684**	**5,857**	**2,173**	**Total**	**3,698**	**5,718**	**2,020**
Avg. Pen	**409.3**	**650.8**	**241.5**	**Avg. Pen**	**410.9**	**635.3**	**224.4**

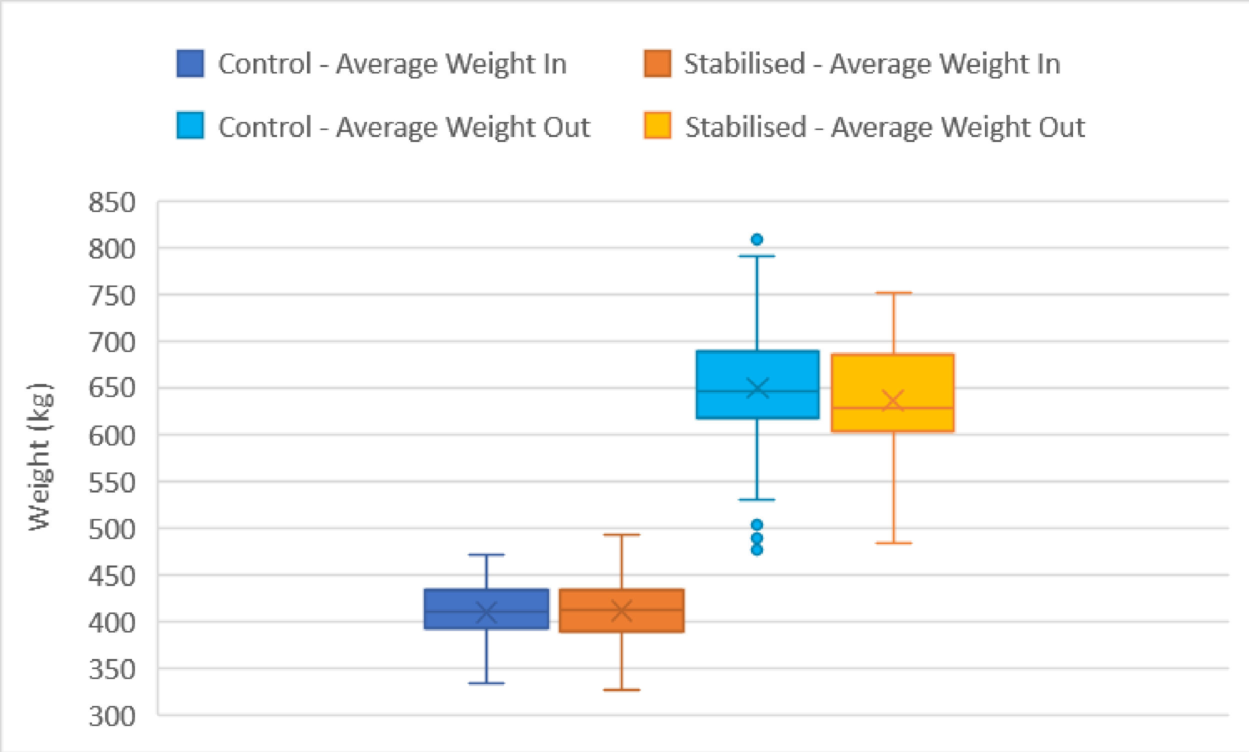

Fig. 15 Control and stabilised average cattle weight variation

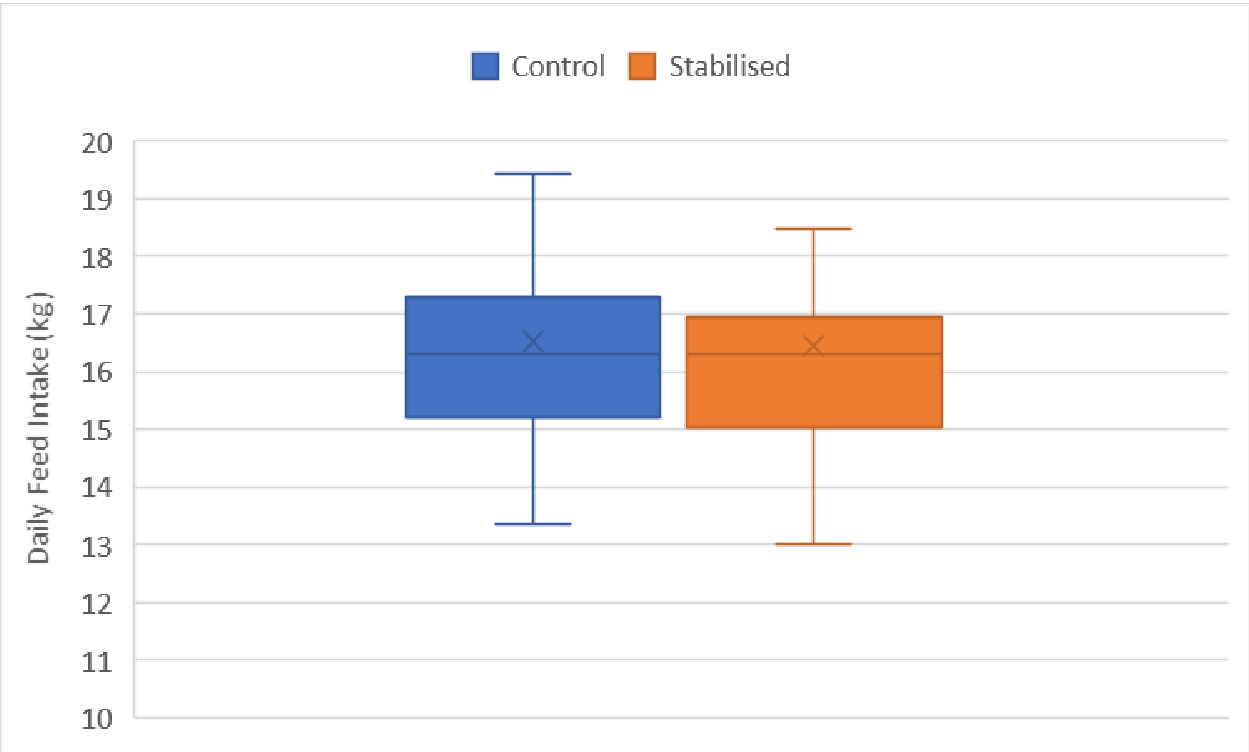

Fig. 16 Control and stabilised daily feed intake variation

4.4.4 Meat quality

Meat quality outputs including colour, MSA index, lean meat yield, marble score and pH were recorded by the processor for all cattle which spent time in the trial pens. Table 15 and Table 16, as well as Fig. 17 through Fig. 20, show the average outputs and range of these results for each of the control and stabilised pens.

Table 15 Cumulative Meat Quality Outputs for Control Pens - March 2018-February 2020

Pen No.	Colour	MSA Index	Lean Meat Yield (%)	Marble Score (MSA)	pH
80	2.33	55.5	0.55	403.8	5.52
81	2.32	57.5	0.56	424.5	5.55
82	2.34	57.4	0.51	489.0	5.52
83	2.34	53.7	0.54	390.0	5.55
84	2.30	54.9	0.54	415.2	5.53
85	2.34	60.8	0.54	430.8	5.51
86	2.23	55.7	0.52	416.7	5.52
87	2.39	55.7	0.54	388.0	5.54
88	2.47	56.7	0.55	394.8	5.55
Avg. Pen	**2.34**	**56.4**	**0.54**	**417.0**	**5.53**

Table 16 Cumulative Meat Quality Outputs for Stabilised Pens - March 2018 – February 2020

Pen No.	Colour	MSA Index	Lean Meat Yield (%)	Marble Score (MSA)	pH
90	2.30	57.6	0.55	414.9	5.55
91	2.35	57.6	0.55	401.2	5.52
92	2.29	61.0	0.55	402.5	5.53
93	2.39	56.7	0.54	395.6	5.53
94	2.19	60.6	0.53	420.0	5.51
95	2.35	58.0	0.55	420.7	5.51
96	2.31	57.5	0.54	433.8	5.54
97	2.28	56.9	0.54	402.8	5.54
98	2.21	56.1	0.55	421.5	5.51
Avg. Pen	**2.30**	**58.0**	**0.54**	**412.5**	**5.52**

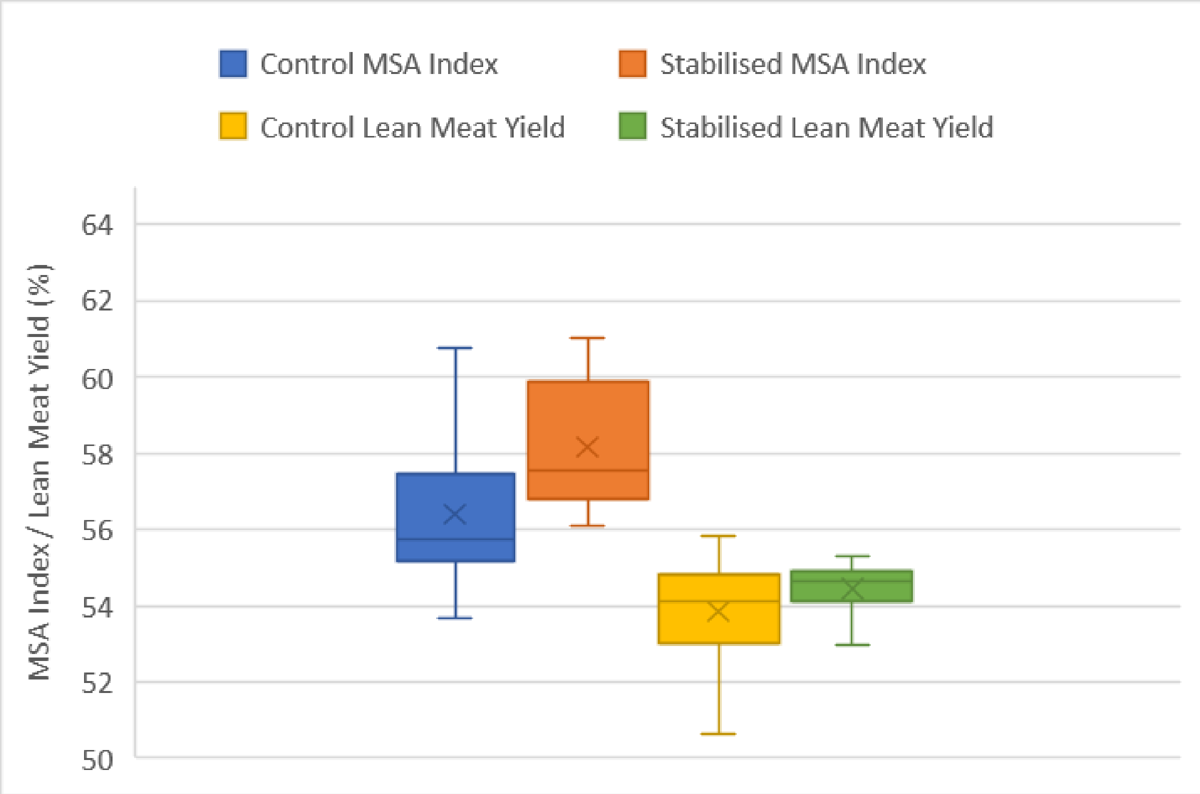

Fig. 17 Control and stabilised MSA index and lean meat yield variation

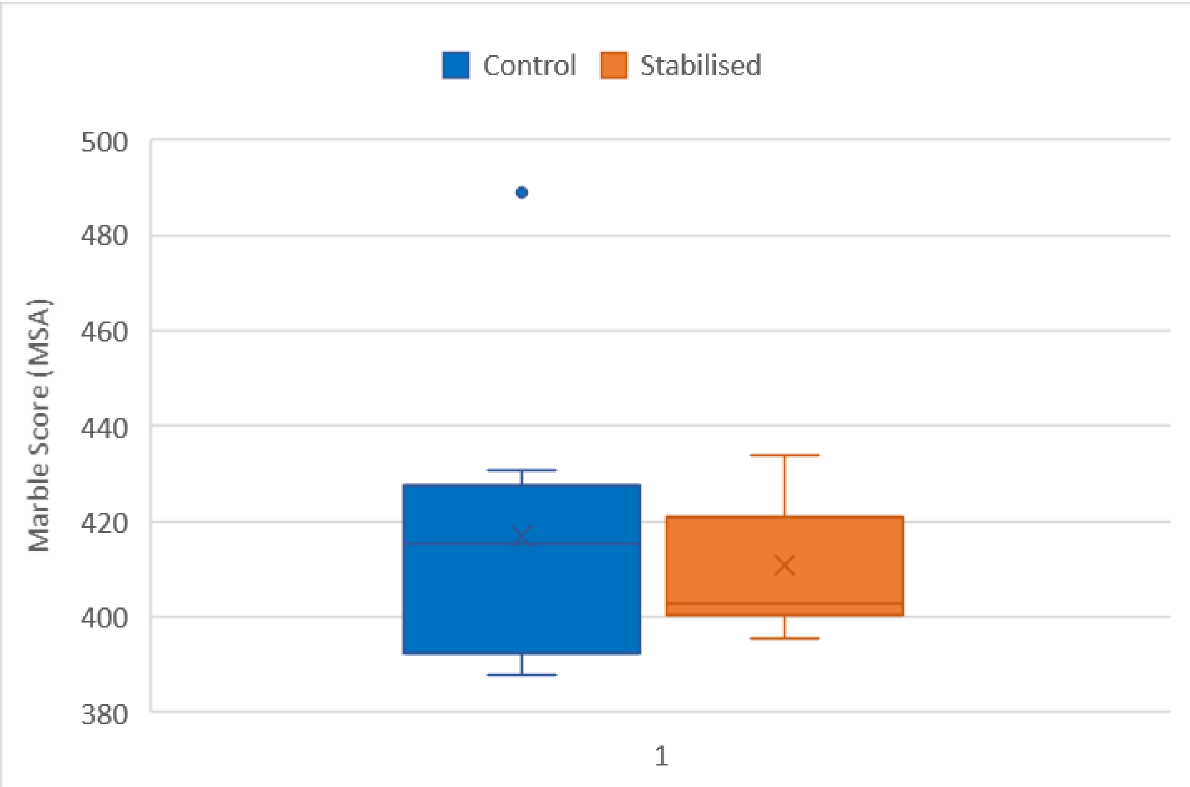

Fig. 18 Control and stabilised marble score variation

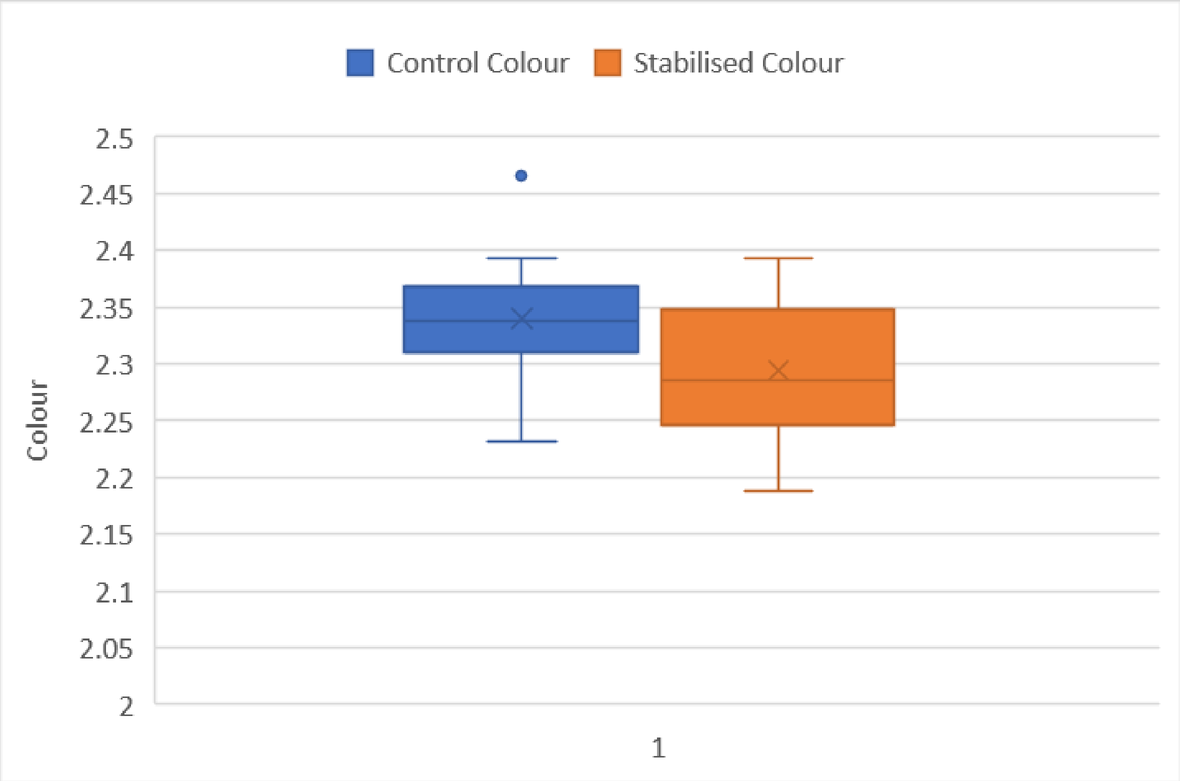

Fig. 19 Control and stabilised colour variation

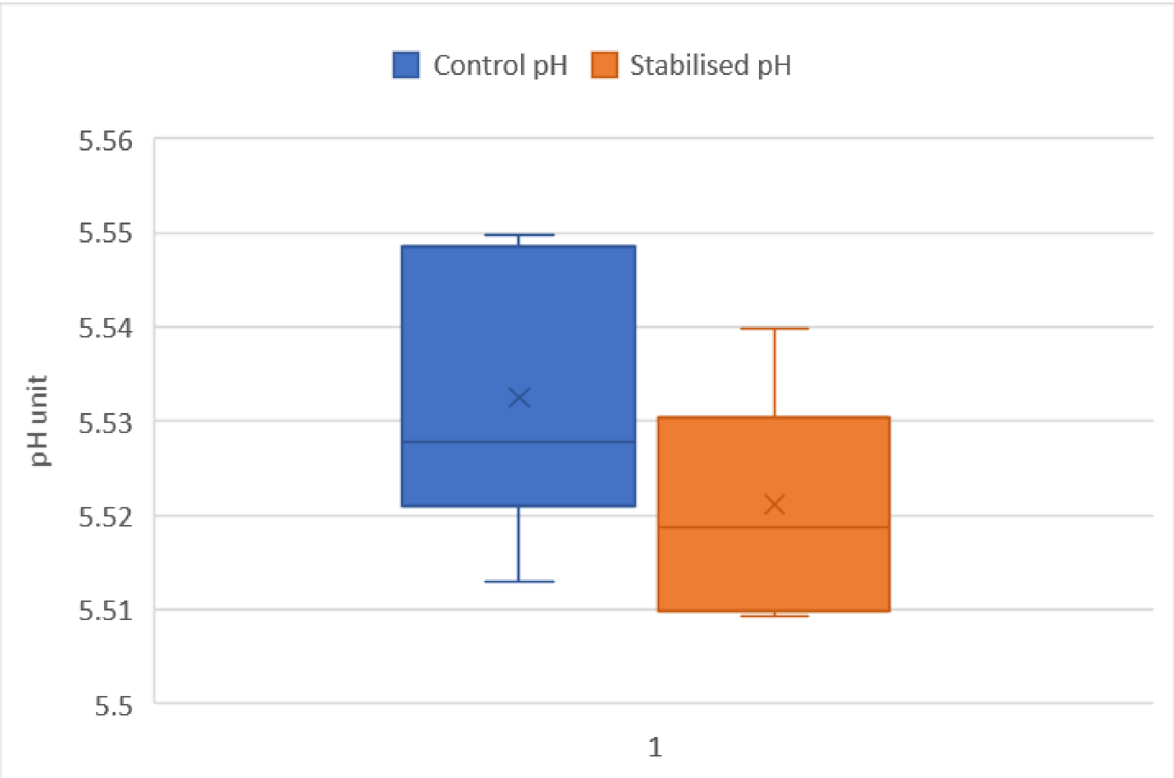

Fig. 20 Control and stabilised pH variation

4.4.5 Animal welfare and animal health

Incidents of lameness were recorded in hospital records from the feedlot. Treatment records have identified that 0.53% (104) of animals were pulled for lameness in the control pens and 0.65% (111)

of animals were treated for lameness in the stabilised pens. Table 17 and Fig. 21 describe the percentage of cattle that experienced lameness whilst in each of the pens. Appendix D contains the health records for each pen.

Table 17 Cattle lameness in control pens – March 2018 –February 2020

Pen No.	Cattle in Pens	Lameness Pulls	Lameness Pull (%)	Pen No.	Cattle in Pens	Lameness Pulls	Lameness Pull (%)
80	2,873	5	0.17%	90	1,890	9	0.48%
81	2,054	12	0.58%	91	1,975	9	0.46%
82	1,953	18	0.92%	92	1,968	10	0.51%
83	2,120	7	0.33%	93	2,149	2	0.09%
84	2,033	13	0.64%	94	1,768	26	1.47%
85	2,760	19	0.69%	95	1,785	16	0.90%
86	1,847	8	0.43%	96	1,653	14	0.85%
87	2,224	13	0.58%	97	1,941	12	0.62%
88	2,353	9	0.38%	98	2,024	13	0.64%
Total	**20,217**	**104**		**Total**	**17,153**	**111**	
Avg. Pen	**2,246**	**11.6**	**0.53%**	**Avg. Pen**	**1,906**	**12.3**	**0.65%**

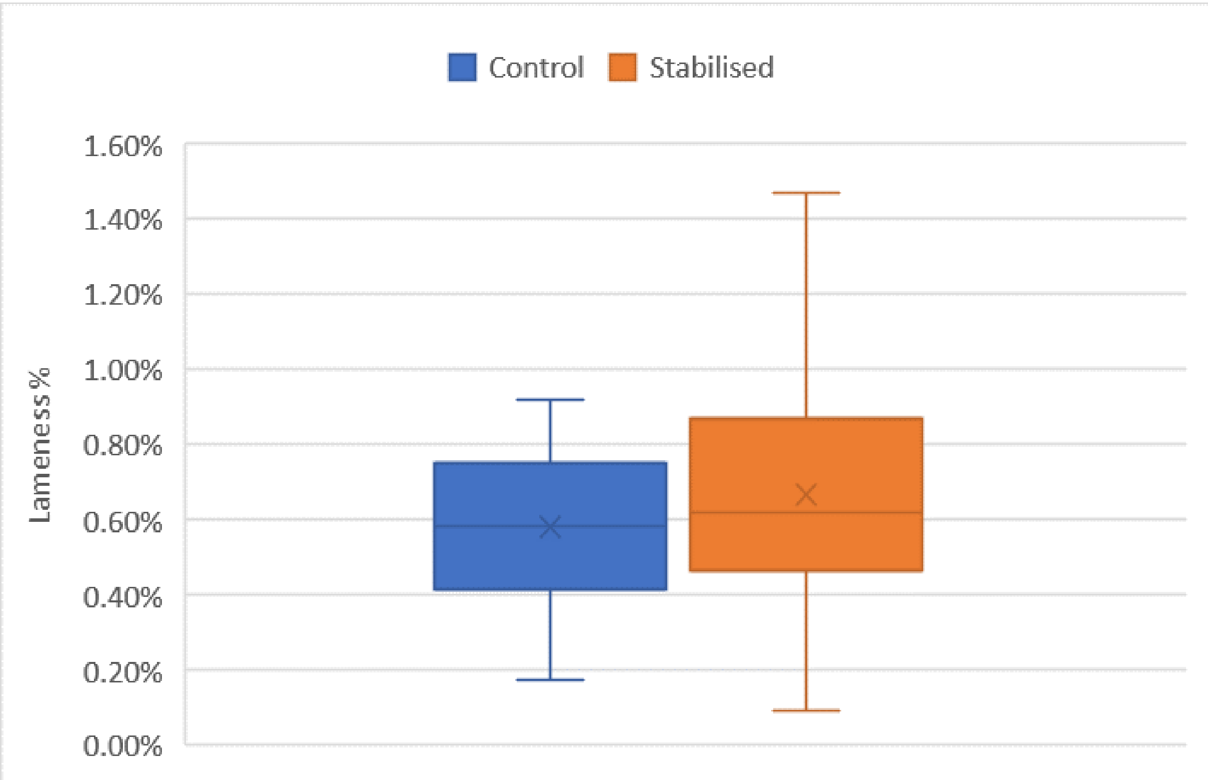

Fig. 21 Control and stabilised lameness variation

4.5 T-testing

As described in Section 3.4.2.2, t-testing is a suitable form of statistical analysis for the datasets produced through this trial. T-testing at the 5% significance level indicated that majority of the datasets listed were in fact not statistically different. The few exceptions to this included:

- Lean meat yield - indicated sufficient evidence to support the claim that the stabilised treatment resulted in an increase in lean meat yield as compared to control pens. The mean variable for stabilised pens was 55% (control mean was 54%) with standard deviation of 0.035 (control standard deviation was 0.039).
- Paid body (HSCW) - indicated sufficient evidence to support the claim that the stabilised treatment resulted in a decrease in paid body as compared to control pens. The mean variable for stabilised pens was 354kg (control mean was 365kg) with standard deviation of 52 (control standard deviation was 48).
- MSA index - indicated sufficient evidence to support the claim that the stabilised treatment resulted in an increase in MSA index as compared to control pens. The mean variable for stabilised pens was 58.6 (control mean was 57.4) with standard deviation of 3.6 (control standard deviation was 3.2).
- pH level - indicated sufficient evidence to support the claim that the stabilised treatment resulted in a decrease in pH as compared to control pens. The mean variable for stabilised pens was 5.52 (control lean meat yield was 5.54) with standard deviation of 0.087 (control standard deviation was 0.093).
- Average daily gain - indicated sufficient evidence to support the claim that the stabilised treatment resulted in a decrease in average daily gain as compared to control pens. The mean variable for stabilised pens was 1.75 (control mean was 1.82) with standard deviation of 0.44 (control standard deviation was also 0.44).

5 Discussion

5.1 Project objective outcomes

The objective of this project was to determine the impact of feedlot pen surface stabilisation on:

1. Cattle cleanliness (dag load) and washing requirements at slaughter
2. Meat safety (ESAM, Carton meat TVC, STECs)
3. Cattle productivity (carcase weight gains (HSCW) and offal yields)
4. Meat quality outputs (colour, pH decline, dark cutters, marbling, etc)
5. Animal welfare outputs (incidence of lameness based on and retrospective analysis of Emergency Kills and feedlot animal health data)
6. Animal health outputs (post-mortem animal health data, and feedlot animal health data, etc)
7. Feedlot costs as:
    a. Pen cleaning interval and time
    b. Quantity and composition of feedlot manure removed
    c. Cost of pen cleaning and pen surface maintenance

The outcomes of these objectives as described in Section 4 are summarised below:

- Cattle cleanliness was not observed to have improved due to the stabilised pen surface, with a slightly higher average dag loading recorded for cattle from the stabilised pens.
- Meat safety was reasonably consistent across cattle from both the control and stabilised pen surfaces.
- Cattle productivity and meat quality (lean meat yield) was shown to be higher for the control pens than the stabilised, even whilst the daily feed intake remained reasonably similar, indicating the cattle performed better in the control pens. Other meat quality outputs such as colour, remained similar between the control and stabilised pens.
- The average daily feed intake per head and average weight in was determined to be similar in both rows based on information provided from the feedlot. As well as this, the amount of time spent in the pen in terms of days and percentage of time spent on the feedlot were not statistically different between the two rows. This suggests results were not skewed due to feedlot operations in the pens.
- Incidence of lameness (number of cases and percentage of all cattle) was higher in the stabilised pens than the control pens.
- Pen cleaning lengths showed varied results, with the stabilised row having a shorter average pen cleaning time in the Winter 2018 and Autumn 2019 cleans, and a longer average pen cleaning time in Summer 2019. Due to the variability of methodology in the Winter 2019 clean it is difficult to compare the cleaning time of the two rows.
- The volume removed from the pen in terms of manure and solids indicated manure volumes were relatively similar for the control and stabilised rows, however the solids removed were more significant for the stabilised. This is supported by the pitting observed on the pens and the higher total solids percentages recorded.

- Repair of the pen surfaces was observed to be similar for both the control and stabilised row and was estimated to cost around $8,008 per pen. No cost benefits could be observed for the repair of stabilised pens.

The results of the trial presented in Section 4 suggest that the control pens performed to a higher standard in terms of project objectives than the stabilised pens.

5.2 Physical pen surface outcomes

The control pens in the trial were prepared and constructed in the same way that the existing feedlot pens have been previously to assess the stabilisation process compared to pen surfaces currently used. It was noted by staff at the feedlot that the control pens experienced greater damage than the pens in the rest of the feedlot during the trial. This suggests that the clay pens in the rest of the feedlot performed to a higher standard than the control pens used in the trial.

The top of the stabilised pen surfaces was observed to be breaking up in the early stages of the project. It is assumed that this was due to the timing of construction, which saw the pens completed at the end of summer, with no significant rain to add moisture. After one year of having cattle in the pens and manure being added to the surface, both surfaces were observed to have bedded in well. Austroads (2019) states that in cementitious-bound pavements experiencing cracking due to shrinkage, "*if the cracks are not sealed, then moisture may enter the pavement, which may lead to pumping of fines from erosion and rapid deterioration of the pavement under the action of traffic*". The dry start to the trial pen surfaces may have influenced their performance throughout the trial.

5.3 Reliability of data

This trial highlighted that there are many variables that need to be closely controlled to improve the reliability of the data and resulting outcomes. These include but are not limited to the following:

- It is difficult to state whether the treatment performed the same in-situ as it did in laboratory conditions due to:
  - Inability to test the CBR in-situ
  - Potential for variations in soil from site
  - Combination of lime and cement with the soil on separate occasions instead of the proposed combination at once
- Many of the lots spent time in other pens on the feedlot which may have impacted cattle specific variables such as meat quality, health, and cleanliness.
- The amount of time lots spent in the control or stabilised pens varied between less than ten days up to around 150 days.
- Potential for unintentional variations in works by the excavator and/or loader between the two rows in terms of scraping surface material.
- Records for cleaning of the pens was not always comprehensive and recorded by all machinery operators for each day.

5.4 Ex-post benefit cost analysis

The Ex-ante benefit cost analysis (BCA) indicated the stabilised pens would have a net benefit of $9,772.70 per year of operation for feedlot operators and meat processors (refer Appendix I) based on improvements to hot carcase weight, washing costs, time spent on cleaning the pens and repair works. These improvements were not observed in the trial.

The repair of the pens was reasonably similar in terms of cost of labour, at approximately $8,008 per pen. A summary of the ex-post BCA is also attached in Appendix I.

6 Conclusions & recommendations

6.1 Conclusion

The stabilisation of pen surfaces has the potential to influence feedlot management and the quality of cattle health, meat and improve the working of meat processors in parts of Australia that are influenced by winter dominant rainfall. A two-year trial of nine control pens and nine stabilised pens was conducted to compare the influence of the pen surface on animal health and wellbeing and therefore meat quality, cleanliness of cattle prior to processing and the ease of cleaning during wet winters.

This project has not demonstrated the potential for the stabilisation process to improve the cleanliness of cattle, the workability of the feedlot during winter or specifically to the animal health or meat quality.

It is unknown the exact cause of the lack of success due to the absence of information surrounding the performance of the stabilisation process within the soil. The dry conditions experienced during and following the construction of the pen surfaces may have influenced the performance of the subgrade, in turn undermining the stabilised surface on top. When comparing the performance of the control pens to the rest of the pens in the feedlot with surfaces of the same materials, the control pens experienced much more wear over the two-year trial. This may suggest factors around construction of the trial pens had an important influence of the overall outcomes of both rows. Operational factors such as varying cattle weight at introduction and feed intake in the trial pens have been ruled out as potential influencers to the cattle performance outcomes.

6.2 Recommendations for further study

The following key points are recommended to potentially improve the reliability of outcomes for future stabilised pen surface research:

- Conduct trials at a smaller scale, with more control over the construction of the pens and on cattle movements in and out of the pens. This includes the time spent in each of the pens be consistent, as well as time spent elsewhere on the feedlot.
- A comprehensive design and testing plan be composed to ensure satisfactory performance of the stabilisation prior to introduction of cattle, including methods to reduce cracking in the pen surface due to shrinkage in the curing period.
- If possible, have a single person/team for the life of the trial whose main role at the site is working on the project, which would include:
    - Inspections of the pens and cattle
    - Optimisation of cattle movements for the purposes of the project
    - Ensuring data is recorded by relevant parties, collecting, and collating this data
    - Observation/instruction of cleaning processes

7 Key messages

The stabilisation of the feedlot pens using lime and cement did not work as designed, which may be due to insufficient controls in place during pen construction and/or curing. The hypothesised benefits of the stabilised pens for processors and feedlots were not realised through this trial.

Further research and investigation are required, with a focus on construction and quality control, to determine the optimal construction of stabilised pen surfaces for feedlots in southern Australia.

8 Bibliography

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