FINAL REPORT
Assessment of a Paddock-based Automated Livestock Management System to Compare Differences in Cattle Performance Using Supplementation

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Summary

Automatically drafting cattle in paddock using auto-drafting technology is a relatively new application of automated livestock management systems (ALMS). These systems operate autonomously on-farm, providing a range of benefits such as decreased labour inputs, individual animal monitoring and improved management options. One application is to use ALMS to provide some animals with supplement but not others, however, as the technology is still being developed and refined, an evaluation of the technical challenges is required to ensure the development of a robust protocol. This project refined the methods to evaluate the performance of cattle that were grazing in the same paddock but allocated to separate supplementation treatments. The ALMS automatically drafted cattle to one of two pens containing either supplement and water (treatment) or water only (control). The cattle were successfully trained to use a walk-over-weigh system which included an auto-drafter. The training period used individual animal data collected from electronic tag readers to determine when the cattle accessed the system. Trough water was the primary attractant to encourage animals to cross the walk-over-weighing system and rainfall events, which created surface water, made the training of animals more difficult. Four cattle were removed as they did not consistently use the system to access water. Weekly mean weights of individual animals were derived from the walk-over-weigh data in addition to static weights recorded every 4 weeks at a separate set of yards. Electronic readers mounted at both the treatment and control exits were used to determine the accuracy of the auto-drafter, which recorded a mean weekly mis-draft rate of less than 1%. The walk-over-weigh data was strongly correlated with the static yard weights (R = 0.99), demonstrating that walk-over-weigh systems can provide reliable weekly mean weights. Automated weigh bars under the supplement feeder recorded daily consumption that was aggregated to provide weekly supplement use. Both the static and walk-over-weigh weight data showed a mean positive effect of supplementation on live weight and the static weight data showed a statistically significant difference. The combination of rainfall data, supplement use, visitation to the water compound, and individual growth rates could provide a detailed method for producers to develop customised supplementation strategies. An economic assessment was requested, this was beyond the scope of the project however, the project team used economic data supplied by Wilmar to quantify the economic benefit of strategic supplementation. The return on investment per animal over the trial period was $24.30. It should be noted that the CQUni project team that carried out this research do not have economics expertise and this report provides as much detail as possible on all assumptions used for the economic evalutation.

Project Scope

Aims

The aim of the project was to evaluate the accuracy and efficacy of automated livestock management systems (ALMS), including walk-over-weighing and auto-drafting, to implement individual animal supplementary feeding in extensively grazed beef cattle.

Deliverables

The collaborative agreement identified the following deliverables:

- CQUniversity will compile a Final Report evaluating the accuracy and efficiency of automated livestock management systems (ALMS), including walk-over-weighing and auto-drafting, to implement individual animal supplementary feeding in extensively grazed beef cattle
- CQUniversity will include in the above Final Report an assessment of live weight performance and nutritional profiling performance of cattle with consumption rate of supplement.

Proposed Outcomes

The project aimed to consider the practical and technical application of automated animal monitoring and management. In particular it proposed to determine methods that would enable cattle producers to use research methodologies to assess the specific value of supplementary feeding for their unique cattle production system. In developing the methods, the project aimed to solve a number of industry problems related to managing animal nutrition:

- Develop, refine and test a set of technologies that can be used to increase the level of control over nutrition management to decrease the risk associated with variable feed supply for extensive grazing systems.
- Establish methods that will allow producers to evaluate their feeding options, including optimising their control over cattle access to grazed grass with the flexibility to automatically implement intensive feeding regimes that will meet a set of predefined production outcomes.
- Demonstrate how producers can access detailed daily individual animal based production data and use this information to implement a range of feeding options and strategically deploy nutrients to individual animals.
- Provide training material and contacts to support producers in their ability to confidently implement and manage intensified feeding strategies.

The specific project outcomes highlighted in the proposal document included:

- Field ready hardware and software solutions that can be used by the northern Australian beef industry to strategically intensify their feeding strategies.
- Assess how supplementary feed supplies can be used to deliver strategic intensified feeding options.
- Providing producers with technological methods to strategically and scientifically evaluate the response of their cattle to a range of feeding options, enabling them to make more informed decisions.
- Benchmarking individual animal performance to allow producers to more confidently target production and market goals based on refined monitoring and management technologies.
- New decision support tools that optimise production and profit.

Background

Supplementary feeding in extensive cattle production systems provides an important opportunity to implement strategic nutritional intervention. To effectively manage the use of supplements to meet business and management goals, producers need to evaluate the benefits and costs of providing supplement to stock as well as identifying which animals will gain the greatest benefit from supplementation.

Remote automated paddock-based monitoring and management technologies such as walk-over-weighing (WoW) [1] and auto-drafting [2] are being developed. These technologies provide the opportunity to continuously monitor individual cattle performance and integrate the data with remote management. While there have been a number of studies that have used WoW technology, there are limited reports on auto-drafting technology and its accuracy to record performance and manage individual animals. Introducing remote monitoring and management technologies into a paddock requires knowledge on how animals interact with the system and what training is required to ensure successful outcomes.

This report details the outcomes of using an automatic livestock management system (ALMS) [3], which comprises a WoW unit and an auto-drafting system, to automatically draft heifers designated as treatment into a supplement pen and those designated as control into a pen with no supplement. The aim of the project is to evaluate the accuracy and efficacy of an ALMS to implement individual animal supplementary feeding in an extensive grazing system.

Methods

The trial was conducted at Belmont Research Station, 32km north of Rockhampton, QLD. The weaner heifers were approximately 9 months old at the commencement of the trial and had no experience with an ALMS. The heifers were weighed using stationary weigh scales located within the main cattle handling yards (referred to as a static weight) prior to the start of the trial. On 15th November 2018 the heifers were introduced to the trial paddock (15ha) with ALMS unit located adjacent to the only watering point (Fig. 1). The ALMS unit uses the animal's radio frequency identification (RFID) tag to identify individual animals as they enter the unit. The animal's weight and time of accessing the unit is recorded and the drafting gate is triggered one of two ways depending on pre-determined criteria programmed into the ALMS i.e. if the animal is in the treatment or control group. The ALMS is located at the entrance to a compound containing water, thus animals are required to enter the unit to access water. Initially, there was no fencing surrounding the trough or ALMS unit, and the drafting gate was not operational to allow the heifers to familiarise with the infrastructure. Over 3 weeks additional portable panels were gradually installed to form a compound around the trough and ALMS unit.

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[1] Walk-over-weighing refers to a generic technology that identifies and weighs an animal as it walks over a weigh platform

[2] Auto-drafting refers to a system that automatically drafts an individual animal

[3] An automatic livestock management system is the integration of paddock-based technologies that enable a range of sensors and actuators to remotely and automatically manage individual cattle

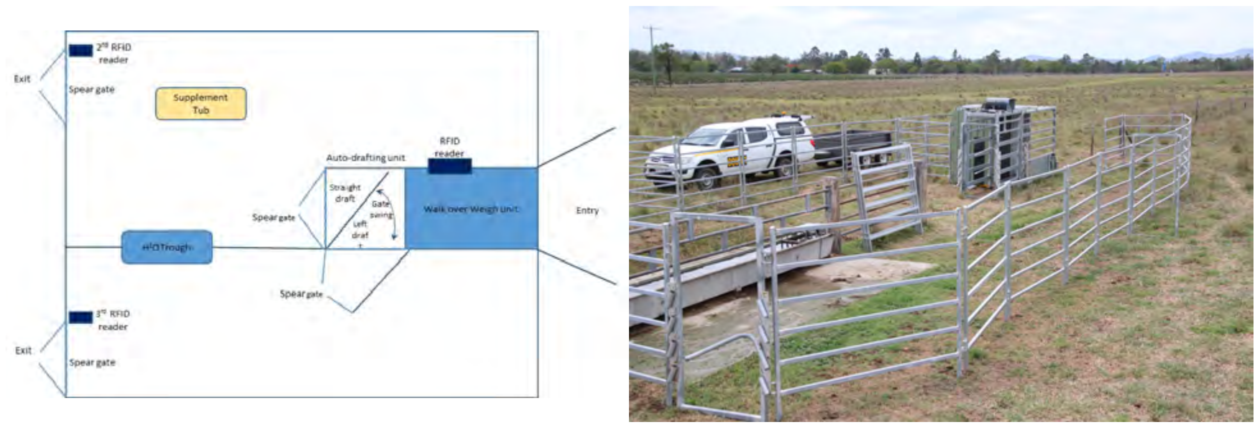


Figure 1: a) Diagrammatic representation of the ALMS unit and compound and b) The ALMS unit and compound during the training period.

The compound was closed off on 10th December 2018, thus the heifers were required to enter the ALMS unit to access water. During the next 2 weeks the heifers were mustered on six occasions and encouraged through the entry using portable panels in a "V" shape. Supplement (OrganicFlo 10NP+Phos, Wilmar Sugar Aust. Ltd, Sarina) was offered inside the compound from the 21st December as an enticement for all animals. All heifers were crossing the ALMS independently by the 24th December 2018.

The auto-drafter was activated on 2nd January 2019. The heifers were mustered through the ALMS on 12 occasions over 4 weeks to familiarise them to the swinging drafting gate and to ensure the ALMS was not restricting access to any individuals (see figure 2). By the 17th January four heifers were consistently avoiding the ALMS; these animals were removed from the group for their own welfare and to also allow the main experiment to commence. On the 17th January 2019 the compound was divided in half and the heifer's allocation of treatment or control was programmed into the ALMS. An RFID reader was installed on the treatment pen exit to determine the accuracy of the drafting gate. Eighty-five percent of the heifers were using the ALMS daily by the 30th January 2019 and 100% by the 15th February 2019. The training period was considered complete on the 3rd February 2019 and the experimental trial commenced, 4 weeks after the drafting gate was initiated.

The individual animal data recorded by the RFID reader on the ALMS unit provided detailed data on the frequency that individual cattle accessed the compound, in addition to their weight. The frequency that cattle accessed the ALMS was statistically compared using a t-test between treatment and control animals during both the training and trial [4] period. The trial period ran for 12 weeks from the beginning of February to the end of April.

Static weights of the heifers were recorded at the main cattle yards every 4 weeks to correlate with the in-paddock weights recorded by the ALMS unit and a Pearson's correlation was used to statistically compare the two. The ALMS weights were averaged on a weekly basis rather than using individual daily weight records as erroneous weights can often be recorded when two animals enter the platform together or walk over too quickly, thus the weights are averaged over a week to ensure erroneous records do not bias the data. The weekly average algorithm sorts through all of the daily data once a week and identifies any outliers based on determining the standard deviation of the data being greater than 25kg. The algorithm iteratively removes those values that are furthest from the mean and then recalculates the weekly average. The algorithm only assigns a weekly average when the standard deviation is less than 25kg and at

[4] Training is the pre-experiment period and trial is the experimental period

least four daily values have been recorded per week. If less than four values are recorded per individual per week the data is considered too unreliable and no weekly average weight is assigned.

Figure 2: Cattle familiarising themselves with the compound, walk-overweighing, autodrafting and supplements during the training period

Results and Discussion

Walk-over-weighing training

After 3 weeks of pre-training the compound was closed so the heifers had to enter the ALMS unit to access water (Day 1 of WoW training, 10th December 2018). The heifers ALMS use was monitored daily using the remote RFID data and they were visually observed regularly to see how readily they used the ALMS of their own free will. After 2 days of enclosing the ALMS compound 73% of heifers were using the ALMS independently each day. The heifers were mustered over the ALMS six times following the compound being enclosed. By Day 14, 100% of the heifers were freely entering and exiting the compound each day. There were a number of rainfall events during the training period Figure 3 These rainfall events decreased the frequency that the heifers accessed the ALMS, as the presence of surface water removed the incentive for the heifers to use the ALMS to access water, thus, training was more difficult during these times.

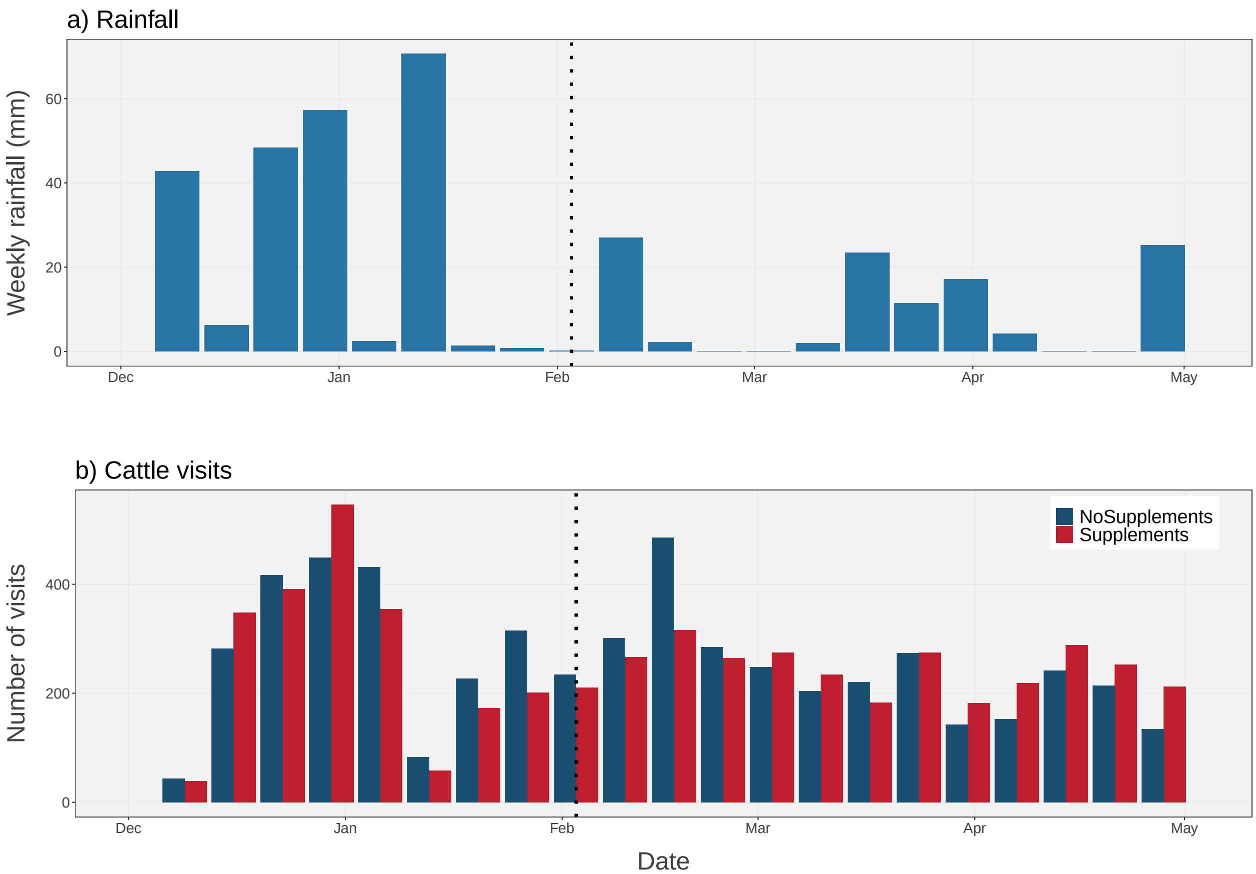


Figure 3: a) Weekly rainfall from the Rockhampton Bureau of Meteorology weather station and b) a comparison between supplemented and non-supplemented cattle visits to the ALMS compound during the training and trial period. The dotted line marks the end of the training and start of the trial periods.

Auto-drafter training

Once all the heifers were consistently using the ALMS independently for a period of 9 days the auto-drafter was connected (Day 24). The autonomously recorded RFID data on the ALMS and the corresponding exit reader showed that all the heifers were accessing the ALMS, but approximately 20% did not move all the way through i.e. they entered the weigh platform close enough to have their ID read, but then reversed off the platform in response to the swinging drafting gate, as evidenced by a lack of corresponding exit readings.

The percentage of heifers using the auto-drafter independently increased to approximately 90% within 5 days of the auto-drafter being connected. However, rainfall on days 30-31 created surface water in the paddock that remained for at least 5 days up until day 34, decreasing the incentive for the heifers to use to the ALMS due to alternative drinking sources and green grass that had a high moisture content. It was a further 2 weeks before the percentage of heifers using the ALMS with the auto-drafter returned to over 80%.

The data showed there were four heifers that consistently refused to use the ALMS, which resulted in 20% non-usage. Visual observations indicated that the moving drafting gate was deterring the heifers using the system. To aid training, all 37 heifers were mustered to the watering point every 2-3 days and encouraged through the auto-drafter 18 times over a 5 week period (spread over Days 25-60). The four heifers not using the ALMS were monitored closely for signs of thirst, water deprivation and ill-health, and while they were noted to be smaller in size compared to the rest of the group, they were all in good health. On Day 60 (36 days after the auto-drafter was initiated) a decision was made to remove these four heifers from the trial. From that time, the percentage of heifers using the WoW and auto-drafter was consistently over 90%, and quite often 100%. The remaining 33 heifers did not require any further encouragement or training.

From day 60 one heifer did not access the ALMS for nearly a week, although she remained in good condition and showed no signs of dehydration. A paddock inspection found a small leak from a water pipe connection and it was suspected that she was drinking from the small puddle. The leak was fenced off and the following day the heifer began using the ALMS again.

Success of the auto-drafter

Initially an exit reader was only fitted to the treatment pen, however, issues with the entry and exit data not aligning, either from a treatment animal being mis-drafted into the control pen or a treatment heifer backing out in response to the drafting gate after being read by the ALMS unit, prompted an exit reader to be fitted to the control pen to provide a complete record of all entry and exit events. Additionally, the configuration of the exit readers resulted in a large read range which required the data to be filtered prior to analysing exit events that occurred between entry events.

Two exit readers were used for the remaining 83 days of the trial (08/02/19 to 02/05/19). During this time 23 mis-drafts were recorded (Table 1 with 16 different heifers being mis-drafted on 17 different days. This number of mis-drafts does not include three occasions when the ALMS stopped and required rebooting, resulting in the drafting gate remaining open until the system was reset at midnight.

Table 1: Summary of weekly visits and number of misdrafts for each week of the trial

Week ending	Total visits	Total mis-drafts	Percentage mis-drafts
10 Feb 2019	568	2	0.35
17 Feb 2019	802	3	0.37
24 Feb 2019	550	4	0.73
03 Mar 2019	523	1	0.19
10 Mar 2019	438	0	0.00
17 Mar 2019	404	1	0.25
24 Mar 2019	549	7	1.28
31 Mar 2019	325	2	0.62
07 Apr 2019	372	0	0.00
14 Apr 2019	531	2	0.38
21 Apr 2019	467	0	0.00
28 Apr 2019	346	1	0.29
05 May 2019	209	0	0.00

Of the total mis-drafts, 17 were from the control group that resulted in them accessing the supplement pen, and six misdrafts were from the treatment group providing access to the control pen. The ALMS entry data shows that the mis-drafting events could have occurred for a number of reasons including:

- heifers had entered the ALMS but waited too long to exit the unit, and then a second animal from a different treatment group entered behind which triggering the drafting gate to a different direction, allowing the first animal access to the wrong treatment pen, or
- two or three animals trying to enter the ALMS at once causing the gate direction to change without allowing the first animal enough time to enter the correct pen.

There was a higher mis-draft rate into the treatment pen, which may have resulted from the timing of the drafting gate closing following an RFID being read. The auto-drafting gate default option is straight ahead into the supplement pen. The gate operates to move or close behind animals drafted into the supplement pen but swings to the right or 'opens up' in front of animals going into the control pen. If a control heifer moved too quickly over the WoW platform, the gate would swing to the right after she has already moved forward off the platform drafting her into the supplement pen. This explanation is largely speculative as there were no corresponding visual observations to confirm this occurrence.

Accuracy of the walk-over-weigh system

The comparison between static and weekly ALMS weights is shown in Figure 4 A Pearson correlation coefficient (R value) of 0.99 indicates a highly positive relationship between the ALMS derived weights and static weights, confirming the accuracy of the in-paddock weighing scales.

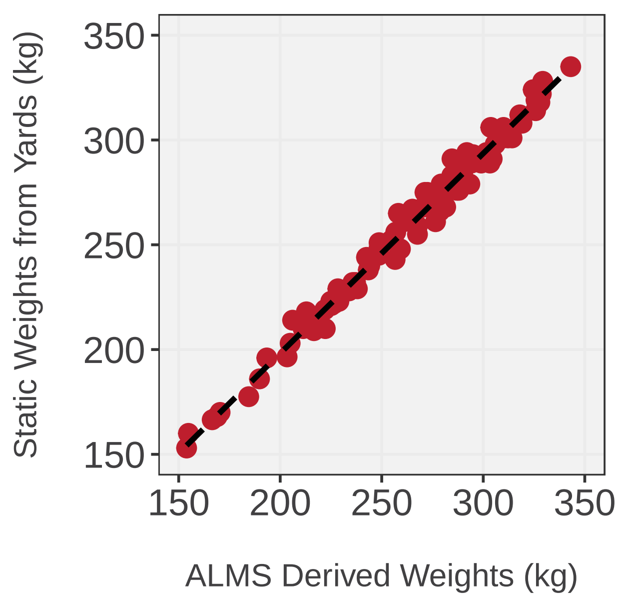


Figure 4: Comparison of static weights recorded in the cattle handling yards with the weekly weights recorded from the in-paddock automatic livestock management system (ALMS) unit

The ALMS unit allows greater recording of an animal's weight compared with traditional weighing. A total of 413 individual weekly weights were recorded throughout the trial period. Two heifers did not record sufficient daily data in the first 2 weeks to calculate a weekly average weight, however, all heifers recorded weekly weights for the rest of the trial.

Comparing visitation numbers between treatment and control groups

The heifers crossed the ALMS over 10,000 times during the training and trial periods. Figure 5 shows the histogram distribution of weekly visits for the treatment and control groups during the training and trial periods. The density plots show that visitation numbers during the training periods were similar between the treatment and control groups compared to the trial period. There were a number of occasions where the cattle rested on the weigh bridge, which resulted in multiple individual RFID records with the same date and time; this duplicated data were removed. A Shapiro-Wilk's test confirmed that the visitation data was not normally distributed and a log transformation was applied prior to using a t-test to compare the treatment and control groups during the training and trial periods.

Table 2 provides the summary data for each group during each period. The mean number of visits per week were not different between the treatment and control groups during training. There were more visits during the training period compared to the trial period and one animal crossing the ALMS unit 120 times during one week. It is not surprising there was no significant difference in the supplement access.

Table 2: Comparison of weekly visits for trial and training periods

	Supplement Group				No Supplement Group				
Period	Mean	Max	Min	SD	Mean	Max	Min	SD	*P-value*
Training	18.2	73	1	15.69	17.76	123	1	15.41	0.82
Trial	14.3	48	2	5.78	13.46	71	1	8.86	0.24

Intake and cattle response to supplements

The supplement tub was placed on automatic load bars to calculate daily consumption on a per group basis, the overall average daily intake was 1.37L/head/day. The daily totals were aggregated on a weekly basis and aligned with the ALMS access data to calculate the supplement use for each visit (see figure 6). The supplement use per visit increased throughout the trial. The mean static weight (± s.d.) of the heifers at the start of the trial was 245kg (± 40.66), with a minimum of 160kg, maximum of 306kg. The ALMS data showed similar values with a mean weight of 254kg (± 40.49) a minimum of 151kg and a maximum of 304kg. The heifers were randomly allocated to treatment and control groups at the start of the ALMS training period, irrespective of weight. As the groups were not balanced for live weight, the average weight of the treatment heifers was greater than the control at the start of the trial period, the average weight of the control group was 240kg and the average weight of the teatment group was 254kg. After 90 days of supplement at the end of the trial the average weight (± s.d.) of the treatment heifers was 298kg (± 41.4kg), with a minimum of 219kg, maximum of 345kg and average daily gain (ADG) of 0.60kg. This compares to the control group's average weight (± s.d.) of 279kg (± 55kg), minimum 172kg, maximum 357kg and average daily gain (ADG) of 0.49kg. The growth rates of the treatment and control groups over the trial period is shown in Figure 7.

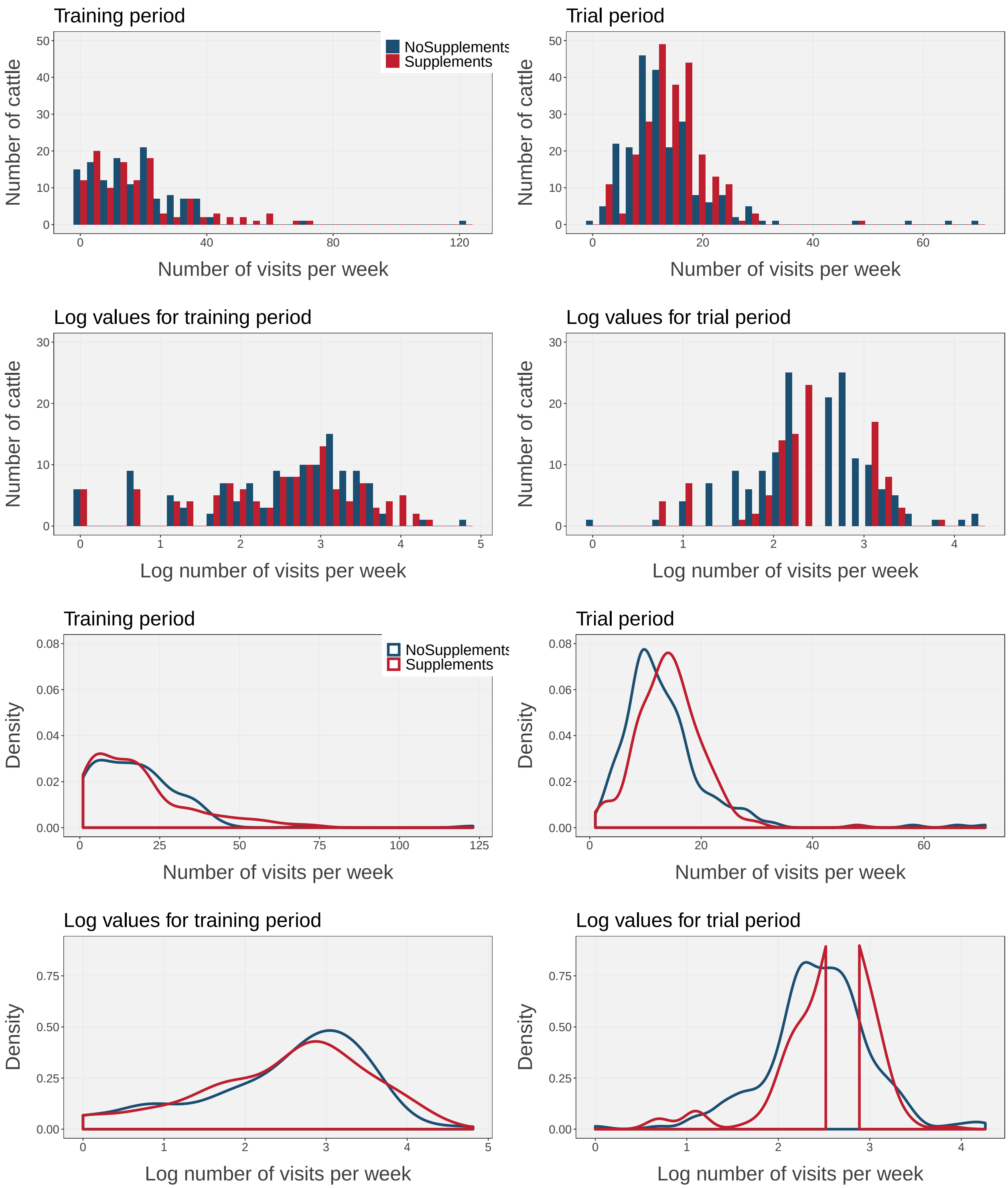
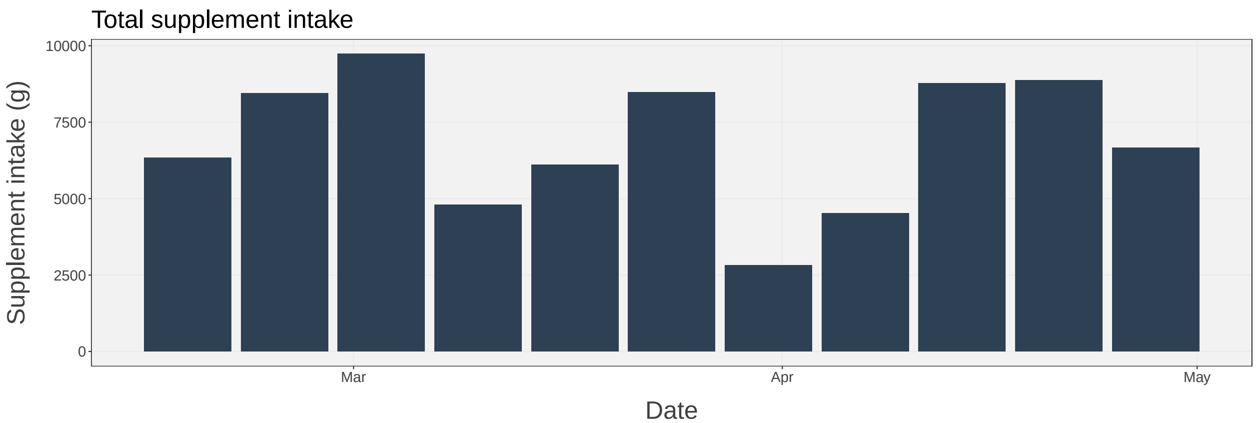


Figure 5: Comparison of cattle access to the ALMS compound during the training and trial period



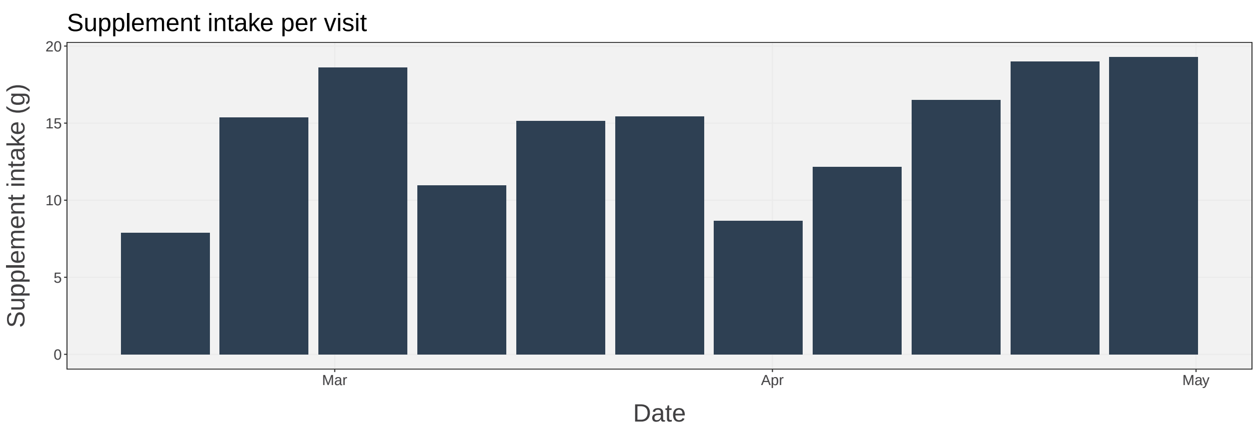


Figure 6: Total supplement intake and intake per visit for each week of the trial

Table 3 shows the comparison of growth over the 90 days between the supplemented and non-supplemented groups using both the WoW data and the static weights. The static weights showed a statistically significant difference ($p<0.05$) between the supplemented and non-supplemented groups with the supplemented group having greater weight gain, this was equivalent to 0.11kg/head/day equivalent to a 22% difference.

Table 3: Comparison of total growth (kg) using ALMS and crushside weight data for supplemented and non supplemented groups during the trial period

	Supplement Group				No Supplement Group				
Weighing system	Mean diff	Max diff	Min diff	SD	Mean diff	Max diff	Min diff	SD	*P-value*
Static weights	49.03	70.0	31.0	10.65	39.47	73.0	14.0	14.98	0.04
ALMS weights	40.06	54.2	30.8	7.43	32.23	63.6	0.4	16.68	0.09

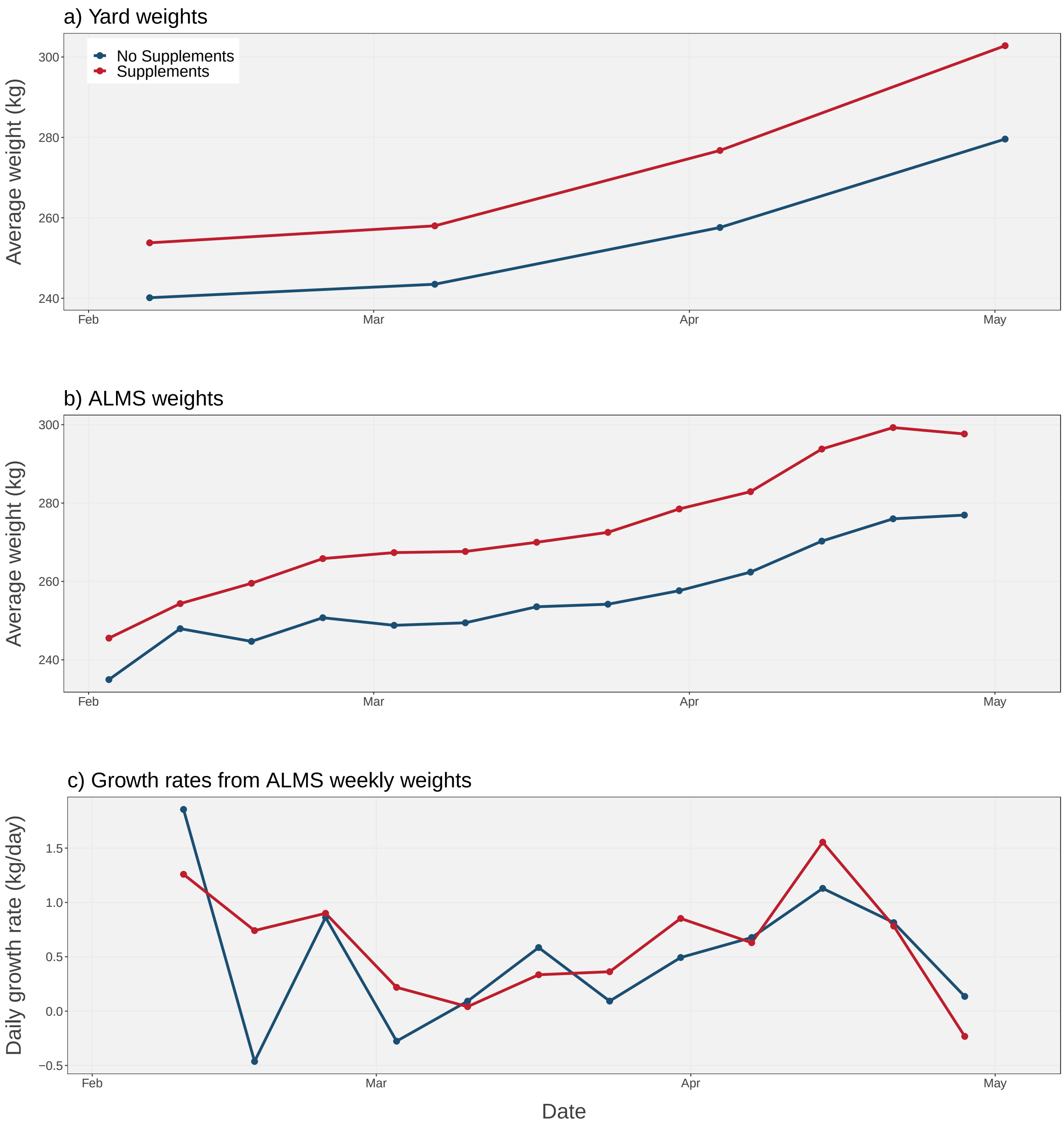


Figure 7: Growth comparisons of the control and supplement treatment groups when (a) weights were recorded using static yard weights, and (b) using in-paddock ALMS weight data. Plot (c) shows the heifer average daily growth rates using the in-paddock ALMS weight data.

The value of supplements

The trial was designed to evaluate how remote automated technologies might be used to monitor and manage cattle access to supplementary feed, however, the experiment also tested the response of growing cattle to Wilmar Organ-icFlo 10NP+Phos supplements. The OrganicFlo supplement is a liquid (approximately 30% dry matter) containing 10%natural protein, calculated on a dry matter basis. The energy rich supplement is a by-product of the bioethanol fermen-tation procees from the Wilmar Bioethanol Distillery at Plane Creek, Sarina. The product has additional phosphorous, which helps address any cattle phosphorous defficiences. These defficiences can be critical in the wet season when it is important to maintain cattle productivity during periods of rapid pasture growth, particularly for breeder cattle in the post-partum period. With intakes of 2 litres per animal per day the Wilmar OrganicFlo 10NP +Phos will provide around 6g of phosphorous per head per day.

Prior to running the trial soil tests were conducted the results showed the phosphorous levels, using the Colwell extrable P test, were 22 mg/kg. This value could be considered low for a high input grass system it should be adequate for more extensive improved pastures. The heifers grazed freely on 15ha of improved grass pasture, predominantly Rhodes grass (*Chloris gayana*) a summer-growing, stoloniferous perennial. Although no pasture samples were taken, visual assessment of the pasture ascertained good ground cover throughout the trial with some 'haying-off' evident towards the end of the trial period. Figure 8 shows that early in the trial the summer rainfall events produced good pasture growth. The added phosphourous in the supplements would address any defficiencies in forage phosphorous.

Figure 8: a) Pasture and cattle on 24th January showing good grass growth after rain event and b) Pasture and cattle on 21st February showing a good body of feed but beginning to dry off

The daily average supplement intake per animal is shown in figure 9. This intake is based on automated daily weights of the supplement feeder to determine how much supplement was consumed. There were a number of days where the automated weight system failed to record a daily weight which resulted in some days with no value. The days where the supplements container was refilled were also removed as the daily intake was based on a zeroed value at midnight and additions to the container could not be accurately estimated. The average intake is expressed as grams per animal per day. The overall average daily intake per animal was 1574g per animal per day with a maximum daily intake of 2629g and a minimum of daily intake 958g per animal per day. Based on the specific gravity of the supplements (1.151kg/m^3) the average daily intake was calculated to be 1.37 litres per animal per day. This provided 5.22g of phosphorous per day which is close to the recommended 6gP/head/day.

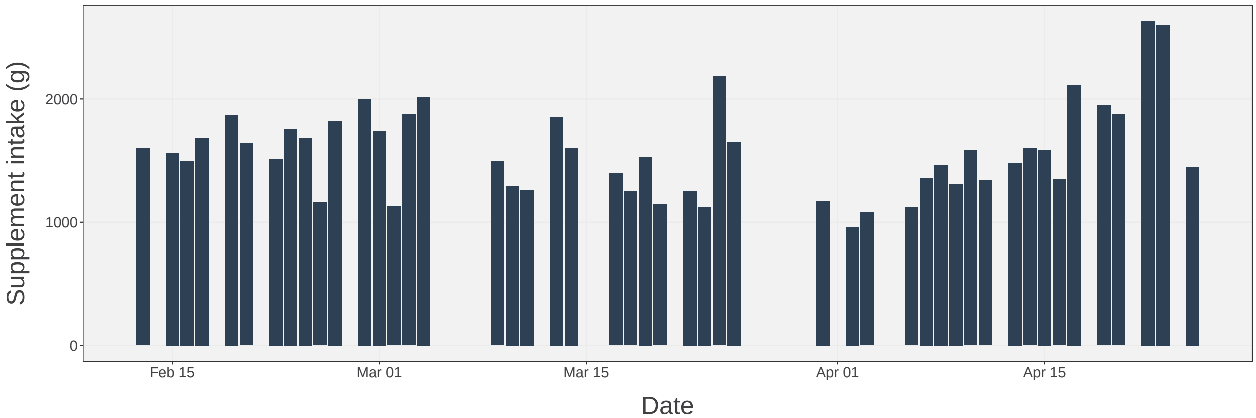


Figure 9: Average daily intake using the weight change of supplement feeder. Zero values are due to missing records due to erroneous automated weight measures or due to the supplements being filled during the day

The overall growth rate, based on the static yard weights, showed a significant difference between the supplemented and non-supplemented groups (see table 3). Using the Wilmar cost benefit analysis tool it was possible to determine the economic benefit of feeding the OrganicFlo 10NP+Phos supplements. Table 3, from earlier in the report, showed the overall average total growth (using static yard weights) was 39kg for the non-supplemented group and 49kg for the supplemented group. This growth occured over 84 days. Using an average daily intake of 1.37 litres per day and a delivered cost of $202.55 per m^3 ($150 for the product and $52.55 for delivery) this provides an average cost, over the 84 days, of $0.28 per head per day. Based on the growth of the cattle and a beef price of $3.20 per kg the non-supplemented group achieved an average revenue gain of $124.80 per head and the supplemented group acheived an average revenue of $156.80 per head. After costs the supplemented group achieved an average of $8.74 increased revenue compared to the non-supplemented group.

The real value of integrating the ALMS system with supplementary feeding is to provide a flexible management tool that can continuously monitor individual performance. The auto-drafter could be used to strategically deliver nutrients to those cattle that are most likely to show a positive economic return. For example the difference between the worst non-supplemented and best supplemented animal showed an increased revenue of $132.00. Equally the difference between the worst performing supplemented animal and the best performing non-supplemented animal after costs was $180.00 with the worst performing individual on supplements making a loss of $157.66. These calcluations assumes an even distribution of intake between all supplemented cattle.

The ALMS system provided weekly growth rate data based on weekly average weights from the ALMS, these were combined with the weekly supplement intake to explore the average weekly cost of supplements. The overall weight gain estimated using the weekly data from the ALMS did not show a significant difference between the supplemented and non-supplemented groups of cattle. However, the weekly data provides an interesting time series and was used to show the weekly return after costs for the supplemented group and a financial comparison of the supplemented group compared to the non-supplemented group for each week (Figure 10). The average increase in value for the supplemented group compared to the control group (return on investment per animal) was $24.30. The ALMS data provided more frequent and detailed information on the cattle response to supplements and the weekly cost benefit assessment demonstrated more variability in the benefits of supplementation compared with the overall data using the static yard weights. This variability in performance might reflect variations in seasonal conditions. Further work monitoring weekly cattle performance under more marginal feed conditions with limited available phosphorous could provide an interesting comparison of the benefits of using OrganicFlo 10NP+Phos.

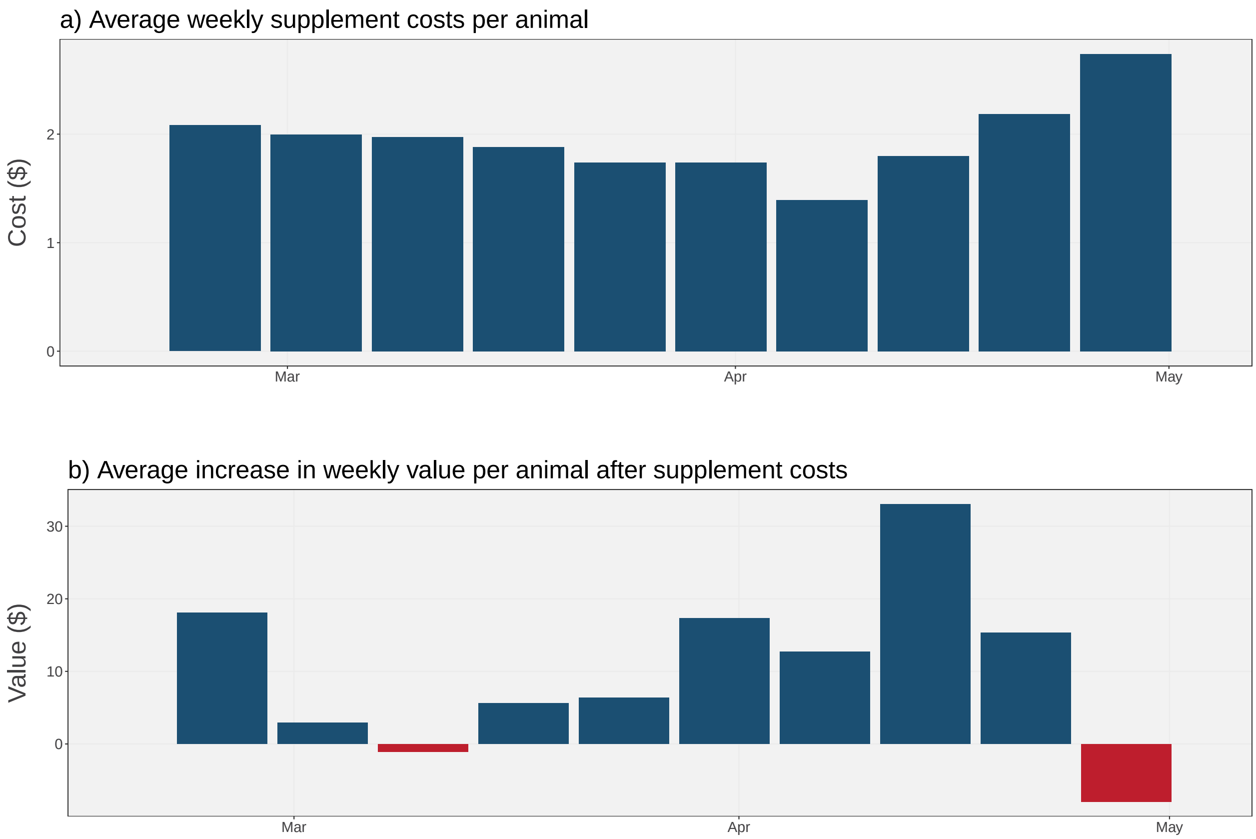


Figure 10: Weekly cost benefits of supplementation (weekly intake is based on average daily intake x 7 days) (a) Weekly costs of supplements based on weekly intakes, and (b) average increase in value of supplemented cattle after costs.

Conclusions

The work conducted in this project demonstrates the opportunities of using an ALMS unit with a combined walk-over-weighing and auto-drafting system to evaluate the effect of supplementation on growing cattle. Training the heifers to use the system presented more challenges than initially planned, which revealed some important considerations for future trials. In particular, the establishment process highlighted the technical challenges that may be encountered when setting up an ALMS, along with potential methods to train cattle to use the system effectively. Some of these challenges included:

- Training the heifers to use the ALMS took longer than anticipated, possibly due to the heifer's age and naivety to yards, portable panels and general handling.
- Surface water in the paddock, including rainfall and leaking pipes, interrupted the heifer's ALMS training.
- Several bars on the exit spear became dislodged, possibly from the heifers attempting to enter the compound via the exit, which allowed the heifers to both enter and exit through the exit. The spear bars were re-inserted and fixed with wire to prevent them coming out again.
- One spear on the ALMS exit was moved so that the entry to the treatment pen was blocked. The spear bar was re-aligned and wired into place to avoid the same issue happening again.

- Consideration needed to be given to the time delay between the RFID tags being read and the auto-drafting gate swinging, the speed at which the gates swung and the pressure on the rams in the gate.
- One heifer lost her NLIS tag towards the end of the trial and ALMS weights were not recorded for her until a replacement tag was given. Note: this heifer was a treatment animal and because the gate defaulted to the treatment pen after 3 minutes of a control animal triggering the gate, she was drafted correctly without an NLIS tag so long as the control animal entered greater than 3 minutes prior.
- Initially the ALMS reader was not relaying data correctly to the CQUniversity server. The problem was rectified following two visits to the paddock to get the system recording and sending data correctly.
- Heifers RFID tags were being read at the exit reader from outside the compound due to the panel holding the reader having a 'parasitic effect', which can occur when the metal bars in contact with the RFID reader extends the read range of the reader to the length of the metal. This issue was solved by re-configuring the portable panel set up so the heifers RFID tags could only be read when directly beside the reader.
- The weigh bars under the supplement tub recorded erroneous data when a connector got wet and a wire became detached. The fittings were dried out and re-attached with re-enforced water proofing.
- There were issues with the modems on the exit readers turning off and needing to be re-booted. Data wasn't lost but the transmission of data files to CQUniversity servers was interrupted.
- Failure of the auto-drafter due to multiple heifers camping on the WoW platform. This resulted in a large volume of weight data being collected, so much so the system shut down. The system re-booted at midnight but until that time the auto-drafting RFID reader wasn't working and the drafting gate did not function so all heifers were drafted into the control pen.
- Exit readers were required on both the control and treatment pens to accurately record all mis-drafts. Initially only one exit reader was fitted, however, it was found that the heifers did not always enter the ALMS completely on numerous occasions so it was difficult to infer if they had been mis-drafted or not entered the compound at all.

Most of the technical and training challenges were quickly and easily overcome. Training the heifers to use the ALMS was made more difficult due to the lack of previous exposure by the cattle to handling facilities and the presence of surface water in the paddock. This time could be reduced with pre-exposure to weigh platforms and auto-drafting gates, possibly during the weaning process. It would also be beneficial to train the cattle through the dry season when the incentive to access supplement and water would be greater.

The design of the compound should consider whether the exit readers can detect the NLIS tags from outside the compound and whether animals can get under exit spears. Future work should ensure the exit readers are located on timber panels to avoid an amplification effect and only cattle leaving the compound can be recorded. Shade over the weigh platform encouraged some animals to lie on the weigh platform, which blocked access for others and also caused problems with data recording. Providing alternate shade close to the compound might alleviate the problem.

The trial demonstrated the capability of an ALMS unit to collect detailed data on supplement use and heifer productivity. It also demonstrated that the auto-drafter accurately separated cattle into two groups. An economic assessment of the costs and benefits of supplementing the cattle highlighted the overall value of supplementing cattle. The comparison of a control group of cattle that had no supplements with the supplemented group, using weekly performance data, provided insight into the ongoing benefits of supplementation. Cattle producers often face the challenge to determine the economic benefits when growing cattle have access to supplements. This trial shows that by utlising a control and treatment group in a herd of cattle these data could be potentially used as proxies to determine when to introduce supplements to the main herd of cattle. Tracking costs and benefits provides valuable insight for in paddock feeding strategies. This project provides a great foundation for further industry work using ALMS to monitor and manage cattle herds with greater efficiency and precision than traditional methods.