ERA Project Final Report

Project Title:

Deploying an advanced analytics platform to quantify livestock greenhouse gas (GHG) emissions and monitor reduction strategies at individual and whole operation scale.

Project ID: B140004
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Project Location: Calgary, Alberta
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Company Changes: After starting the project, GrowSafe Systems Ltd. merged with a bovine IVF company called Vytelle IVF. Following the merge, both companies are now known as Vytelle and the GrowSafe technology has been rebranded under the Vytelle SENSE solution. The original GrowSafe technology has been rebranded to the following:

- GrowSafe Feed Intake = Feed Intake Nodes
- GrowSafe Beef = In-Pen Weighing Positions

Vytelle

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Part A: Data Repository

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List of Symbols and Abbreviations

ADG – average daily gain

BW – body weight

CH_4 – methane

CO_{2e} – carbon dioxide equivalent

DAQ – data acquisition

DDMI – daily dry matter intake

DMI – dry matter intake

DOF – days on feed

EE – effective energy

EPDs – expected progeny differences

F:G – feed to gain ratio

GHG – greenhouse gas

LGS – Livestock Genetic Services

MW – mid-weight

N_2O – nitrous oxide

RFI – residual feed intake

RFID – radio frequency identification

Executive Summary

The purpose of this project was to deploy an advanced analytics platform to quantify livestock greenhouse gas (GHG) emissions and monitor reduction strategies on individual animal and whole operation scales. The project was broken down into two components, Part A) the Data Repository and Part B) the Feedlot Demonstration. The data repository overview involved development of a robust database that would allow for calculation of induvial animal efficiencies and emissions. Throughout the project, historical data were curated and standardized, while new tools were developed to offer standardized evaluations of feed efficiency across the beef industry worldwide. Tens of thousands of phenotypic feed efficiency records, along with hundreds of thousands of pedigree records, were utilized to develop standardized expected progeny differences (EPDs) for feed efficiency for global use in the beef cattle industry. The EPDs were used as breeding values by commercial customers to enhance the efficiency, and sustainability of their herds, and to reduce the greenhouse gas (GHG) emissions. The commercially available Beef Genetics Program gives customers the ability to benchmark the efficiency of their cattle to the rest of the world, and it gives them the tools to enhance the sustainability of their herds. Part B, the Feedlot Demonstration component of this project, was used to determine the ability to reduce GHG emissions through continuous weight monitoring of feedlot cattle for identification of poor performing animals and identification of cattle that are ready for harvest. Vytelle's In-Pen Weighing Positions, used to continuously capture individual animal weights, were installed at two feedlot sites in south-central Alberta. Each feedlot site monitored steers and heifers over three different feedlot cycles from 2016 through 2020. Throughout the feedlot period, cattle were monitored for changes in performance, growth rate and body weight using the In-Pen Weighing Positions. The continuous monitoring allowed for identification of poor performing animals, and identification of cattle that had reached market finish weight. It also allowed for estimation of dry matter intake (DMI) and GHG emissions in the feedlot. It was hypothesized that reducing the days on feed in the feedlot, by identifying market readiness of cattle, would have the biggest impact on feedlot GHG emissions. But, days on feed did not have as big of an impact on GHG emissions as animal performance. Although total animal emissions were dependent on the number of days on feed, animal performance had a greater impact on emissions per unit of beef produced. Emissions captured based on beef produced was found to be more meaningful than total emissions, as the former accounted for whether emissions were produced by animals that were gaining, or not gaining at all. The In-Pen Weighing Positions are commercially available for feedlots as part of the Beef Marketing Program. The program allows for monitoring of high and low performing animals and to adjust management practices so that performance of most animals can be increased to ensure a reduction in GHG emissions. Future studies should combine the findings from Part A and Part B of this project to understand how selection for feed efficiency in the breeding herd can enhance the sustainability, performance, and management of cattle in the feedlot. Part A and Part B of this project were run independently of one another, by combining the efforts of the two project phases, GHG emissions can likely be reduced even further. Ultimately, the greatest improvement in efficiency, and reduction in GHG emissions, will come through a combination of making breeding selection decisions and utilizing the Vytelle SENSE system to monitor and manage the performance of animals.

Part A: Data Repository

Data Repository Overview

This phase involved development of a data repository which allowed for individual animal efficiencies and emissions to be calculated, while taking into consideration specific breeding and animal management decisions. This data repository currently consists of about 81,360 animals measured for efficiency phenotypes, as well as 262,948 animals, from 25 different breeds, with documented genetic relationships to the project. This data repository allowed livestock efficiency to be evaluated with a quantified accuracy on an individual animal basis, allowing specific animal breeding decisions to be assessed for reductions in GHG emissions.

Deviations from Original Work Plan

Data collection from customers was ongoing beyond the scope of the project, much more data was added to the repository than initially expected. Because of this, the genetic evaluations became much more complex. Fewer Canadian customers were recruited for the project than expected, therefore data was added from American customers. Over time, data from Canadian customers was added to the repository, as it was available. In late December 2017, a protocol was filed allowing for Alberta-based customers selecting for feed efficiency to file their carbon offsets for credits, based on the *Quantification Protocol for Selection for Low Residual Feed Intake in Beef Cattle*. The opportunity to file carbon offset credits provided producers with additional incentives to test their cattle for feed efficiency.

Data Repository Final Evaluation

Introduction

Residual feed intake (RFI) is the difference between an animal's measured feed intake and its expected feed intake for maintenance and growth. Cattle with low RFI are efficient, they consume less feed than expected, while cattle with high RFI are inefficient, they consume more feed than expected. Residual feed intake is a moderately heritable trait (Archer et al. 1998; Arthur et al. 2001; Schenkel et al. 2004), which means that it can be used in genetic selection decisions to produce progeny that consume less feed. Selection for low RFI (efficient) cattle will not impact growth, carcass merit, fertility, or lifetime productivity, because it is independent of these traits (Basarab et al. 2003; Crews 2005). Research has indicated that breeding cattle for RFI using estimated progeny differences (EPDs) offers a definite mechanism to reduce enteric methane (CH_4) emissions without compromising animal productivity. In 2000, Vytelle developed feed intake measurement technology (formerly known as GrowSafe Feed Intake Nodes) for beef cattle research. Until 2005, system data was provided in a raw data format for research applications. In 2005, commercial test stations began using the system to calculate RFI values. As RFI is a relative parameter based on the contemporary group of animals, 50% of each group tested are efficient and 50% are inefficient. Though a promising tool to reduce feed costs, manure, and CH_4, there was no method to evaluate animals for genetic merit outside of the contemporary groups they were tested in. The real commercial and applicable value would come from the ability to benchmark and develop EPDs on a large multi-breed scale.

Curating Historical Data

Curating historical RFI data was the first task completed in this project. North American test stations' customers were contacted, and several meetings were held with Canadian breed association representatives and Alberta government researchers to provide data. Contractual approval was obtained from existing global Vytelle customers who were willing to provide RFI data. Vytelle's American customers were the first to commit, and data aggregation from these sites began in January 2015. Historical RFI data was provided in spreadsheet format as originally calculated and published by the researchers employed by the test station; all the data was compiled into one database. During the initial analysis it was found that RFI had not been calculated using the same method by all researchers. Correlations within and between tests were poor which led the research team to conclude that going back to core data would be the only way to avoid poor research outcomes.

Collecting original core data files was a much more difficult task than curating the processed outcomes. In some instances, travel to the test station was required to recover data from computers and archives. Data acquisition hardware, software and file formats differed over the approximately 15 years that data was collected. Vytelle developed software to convert all historically collected data to one updated file format. At most test sites, electronic identification (Vytelle ID), breed registration (pedigree ID), and herd information (visual and Ranch ID) were contained in different spreadsheets, databases, and manual records. Where possible, Vytelle developed retrieval tools to automate the process, but a great deal of customer and project technician manual effort was made to bring this data together. Three generation pedigree information on animals was acquired and compiled using developed tools and methods. Data collected was tested internally for validity, and where necessary, checked against multiple sources (such as breed association databases) to verify its accuracy.

Vytelle developed a server based analytic toolset that could process core data into standardized RFI values. Calculate RFI software, developed by Vytelle, established the appropriate test inclusion criteria which was followed to determine the RFI, average daily gains (ADGs) and dry matter intakes (DMIs) for each animal within a contemporary group. This tool was modified several times for usability in terms of including and excluding animals based upon predefined criteria. This sophisticated audit and statistical process tool used multiple regression techniques and algorithms to analyze animal feed intake and weight data. The tool ensured that all RFI analyses were standardized and calculated in the same way, regardless of test site or location. Standardized data collection and calculation procedures were established and used to assemble all data. Performance data included multiple data points for each animal, including the following:

- RFID number, breed association registry number, and any other unique identifiers
- Sex, breed, herd, and origin of individual animals tested
- Animal birth date, test start and end dates
- Geographical test location, pen(s) used, and descriptions of contemporary groups
- Dry matter content of the ration(s) fed during the trial
- RFI test results for both individual animals and the entire contemporary group
- Individual feed intakes converted to a dry matter basis – DMIs
- Multiple weights taken throughout the trial, regressed to determine mid-weight (MW) and ADG

over the course of the trial

- Vytelle SENSE system performance and operating information, allowing for days where equipment or operator malfunction compromised data collection to be excluded from the trial.

Previously developed software tools were used to add phenotype, environmental, diet and pedigree data to a multiple-breed database that grew to over 259,000 animals. Each animal in the database had EPDs calculated for three traits relevant to efficiency and GHG emissions: RFI, ADG and DMI. The data repository model was unique in the following ways:

- **Multiple-breed inclusion:** the data repository produced within this project contained animals from 36 separate associations and produced EPD values and accuracies that allowed for comparison among the different breeds. In contrast, animal breed associations produce EPD values which are specific to, and only inclusive of, the types of animals that the associations represent. At the start of the project, animals were from 20 different associations.
- **Consistent phenotype collection:** All animals in the data repository had their phenotypic RFI, ADG and DMI calculated using a consistent set of software tools using raw data produced by the gold standard Feed Intake Nodes, ensuring that the data driving EPD production is of the highest quality. The data repository was modified to allow for inclusion of In-Pen Weighing Position weights.
- **Clarity of output:** A major issue found within breed association databases was a requirement to maintain consistency of index values. The implication of this is that published parameters on individual animals may be adjusted to keep animal rankings consistent, rather than providing the best presentation of animal efficiencies. The project data repository allowed rank changes to occur as new data was input while keeping output values consistent and directly usable for GHG reduction strategies.
- **Input flexibility:** the EPD framework developed allowed parameter addition to occur within the EPD database. The parameters included were diet-based parameters for efficiency tests where energy content or specific feed ingredients were available.
- **Database benchmarking:** the EPD database contained percentile rankings for RFI, ADG and DMI EPDs to show where animals rank amongst one another in the extensive database.

Inclusion of Diet Data

Nutritional information was collected where possible. Due to the variety of labs and processes used to determine the contents of feed, a significant amount of professional discretion was required to analyze the data. Dr. Monty Kerley of the University of Missouri evaluated the datasheets and defined protocols and energetic efficiency equations to handle variants of nutritional data. Two main datasheet varieties were typically collected. The first, more common type, provided an energy-based assessment on the feed provided. This allowed for an effective energy (EE) parameter to be calculated for all animals on a specific feed ration. A ratio was then calculated between the EE consumed and EE theoretically required by the animal, which allowed a secondary measure of metabolic efficiency to be calculated. The second type of diet data available was a full ingredient list. This had been found to be far less common than the energy-based assessments, and as such was not directly applicable for genetic analyses. Dr. Monty Kerley was able to use the more detailed data to assess amino acid flows in individual efficiency tests, to determine whether diet rebalancing would be able to reduce DMI, and subsequently, GHG emissions in individuals. Effective energy and/or amino acid flows were not included in standardized RFI calculations because the in-depth nutritional data required was not provided by most test locations, especially as test locations were established in developing and remote areas around the world. The dietary equations may be implemented in future standardized RFI methodologies when detailed ration data can readily, and consistently, be collected from all sites.

Inclusion of In-Pen Weighing Position Data – Days on Feed Analysis

A critical parameter to measuring RFI accurately is the duration of the test used to measure the phenotypes, specifically ADG. Accurate phenotype detection is critical for enabling accuracy of RFI EPDs and subsequent calculation of GHG emission reductions. A retrospective analysis on duration was conducted in collaboration with Dr. Monty Kerley and Dr. Robert Sainz. The analysis was submitted for publication in the Journal of Animal Science. The results of this analysis indicate that RFI may be measured in a reduced timeframe if In-Pen Weighing Positions are used in place of chute weighing. The suggested measurement timeframe using In-Pen Weighing Position weights is 49 days as opposed to 70 days using chute weights, with equivalent RFI accuracy. All Vytelle RFI testing protocols have been updated to recognize the use of In-Pen Weighing Positions to collect accurate phenotypes. Reducing the test timeframe by three weeks will drastically increase the number of animals that phenotypes can be collected on, it also reduces the timeframe required to identify efficient cattle, that produce fewer GHG emissions. The reports and publications prepared regarding this are described in the *Reports and Publications* section.

Genetic Evaluations and Development of a Pedigree Database

A large cross breed animal pedigree database was built and continues to grow. Nearly 700 individual RFI trials have been evaluated and submitted into the database, with nearly 60,000 individual animals tested. The total number of supporting animals in the pedigree database used to determine EPDs reached nearly 260,000. The genetic evaluations in the EPD database depend on performance data and the validity and accuracy of evaluations depend on the pedigree records in the pedigree database. To collect, organize and store the extensive pedigree information required for genetic evaluations, several custom software programs were developed. The four main programs used in combination to process and compile data into the repository are described below:

- **Calculate RFI:** This routine collects and analyzes standardized RFI data.
- **Interpret Generations:** shown in Figure 1. The interpret generations software takes multiple generation data from standardized client or breed association spreadsheets and converts it to a flattened, organized single generation pedigree for storage in the database. This program also prevents erroneous values from being saved to the database.

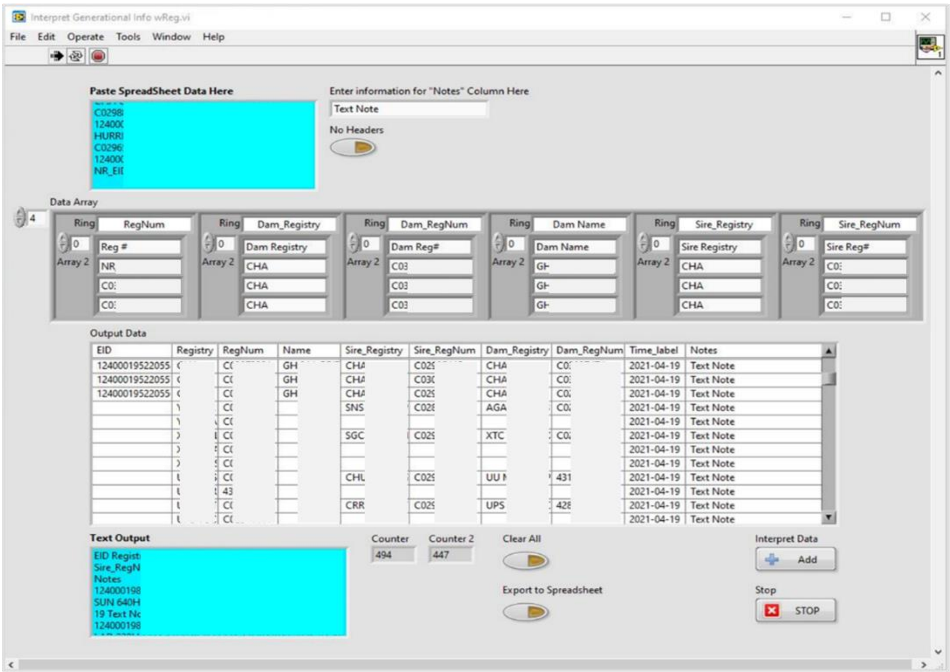


Figure 1. Interpret generations program used for sorting pedigree data. The names and registration numbers of the animals have been hidden for privacy purposes.

- **Parse Spreadsheet Data:** shown in Figure 2. The parsing program searches the pedigree database for conflicts to avoid contaminating the database prior to import.

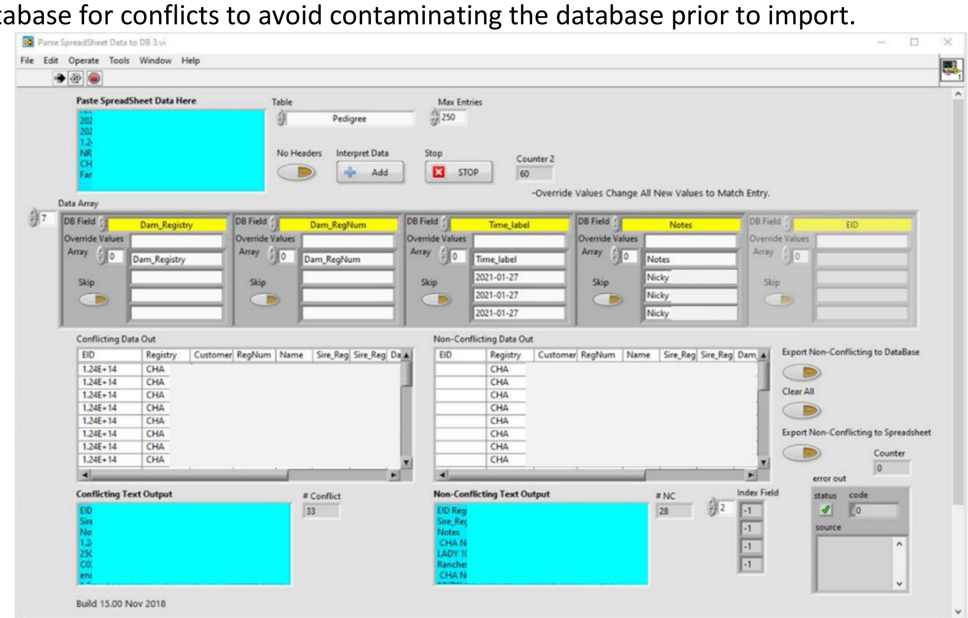


Figure 2. Parse spreadsheet program for adding non-conflicting pedigree data to the database. The names and registration numbers of the animals have been hidden for privacy purposes.

- **Export Ped from DB wReg:** shown in Figure 3. The data export program was produced to extract information from the database for external analysis and calculation of EPDs.

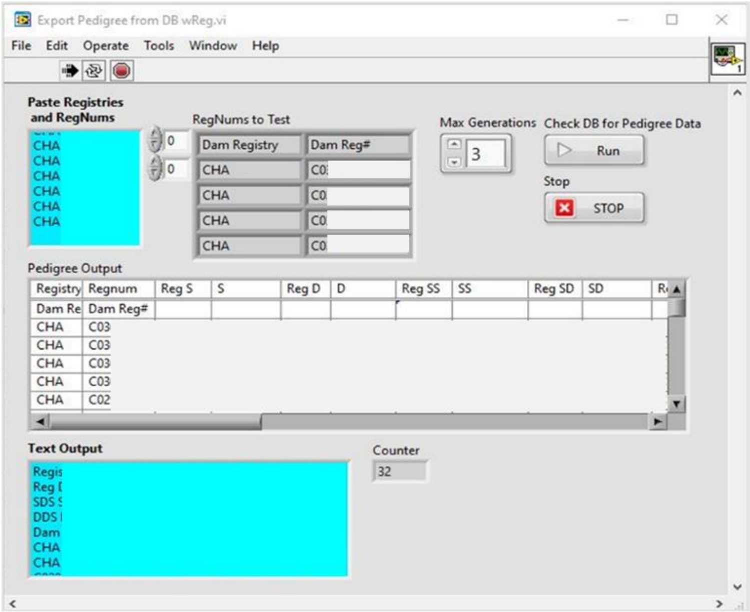


Figure 3. Export pedigree from DB wReg program used to extract pedigree data from the database. The names and registration numbers of the animals have been hidden for privacy purposes.

A collaboration with Livestock Genetic Services (LGS) allowed for calculations of EPDs, EPD accuracies and percentile rankings for RFI, ADG and DMI for all animals in the pedigree database. This included the development of advanced software to perform in-depth statistical analyses. The software can determine genetic merit of animals in a quantifiably accurate way. Unlike traditional EPD calculations provided by breed associations, the genetic evaluation provided for Vytelle allows animals with a mixed lineage to be compared to one another.

Initial EPD models were validated using Vytelle data that was acquired from clients with information partially blinded and placed into two different data sets. This allowed for the EPDs to be processed in parallel and then compared after the fact. As a result, a correlation of approximately 91% was found between RFI EPDs calculated during the two runs, the results are shown in Figure 4. The correlation between the two runs likely resulted from the data standardization procedures and the robustness of the data models that were built.

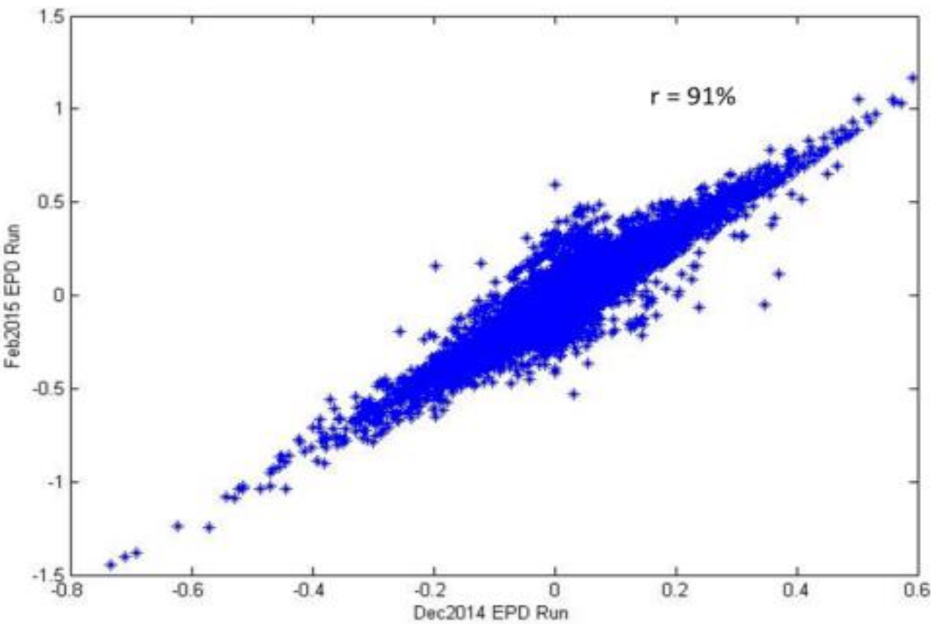
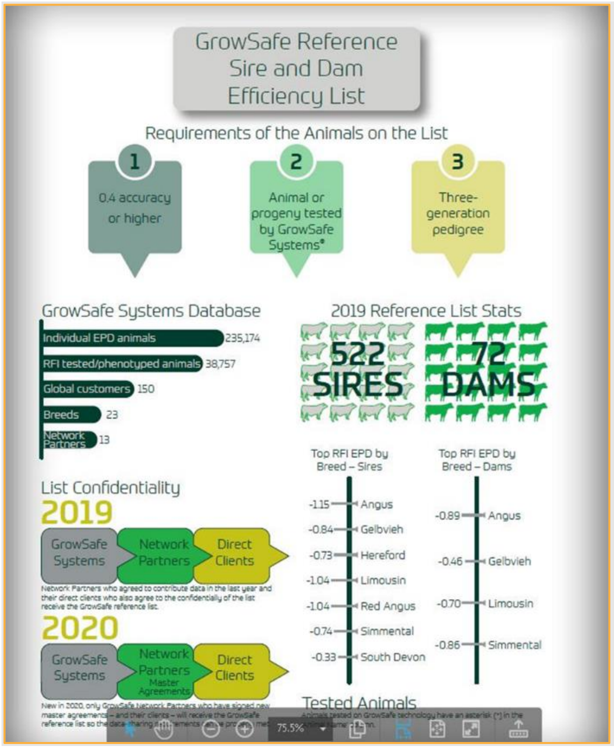
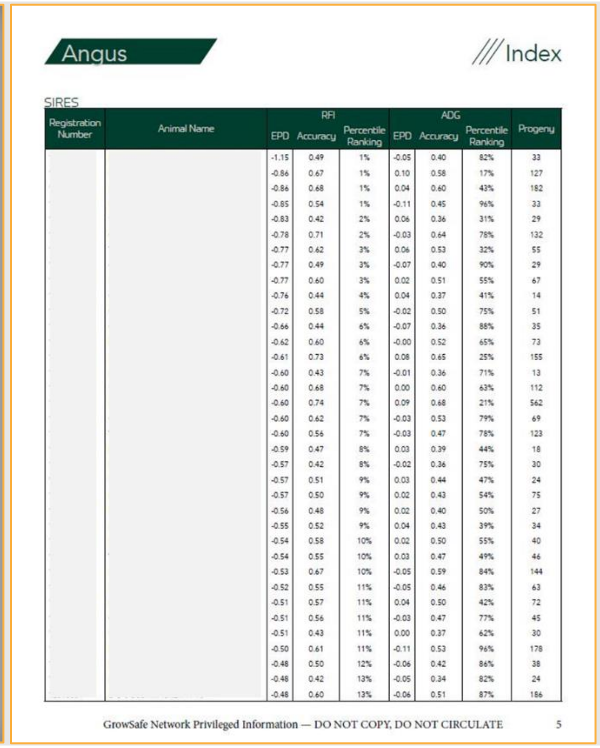


Figure 4. Correlation of EPDs from separate genetic evaluations, during initial EPD model development.

Run Ranking

A complete sire and dam summary EPD ranking list, based on RFI EPD rankings of high accuracy (accuracy ≥ 0.40) sires and dams was produced. The reference sire and dam summaries were produced to provide Vytelle Network customers with insight into the most and least efficient high accuracy dams and sires in the data repository. Providing customers with this data allows them to benchmark and seek out efficient, proven, genetics to enhance the overall efficiency of their herds. Initially the sire and dam summaries were published twice yearly and only provided to Vytelle Network customers. Subsequently, Vytelle Network customers were given access to the LGS online web portal allowing them to have continuous access to the most up-to-date genetic evaluations on all animals in the data repository. In addition, the high accuracy sire and dam summaries were published for distribution to producers outside of the network group. The publication of sire and dam summaries, along with continuous access to updated genetic evaluations, provided a wide array of beef producers around the world with access to efficiency data. This data generated great interest in feed efficiency and allowed for it to be implemented across the industry, whether producers had their own cattle tested or not. The latest sire and dam summary is shown in Figure 5. The latest sire and dam summaries contained RFI EPDs ranging from -1.41 to 1.30 lbs., and -0.70 to 0.90 lbs., respectively. The reference sire and dam summaries also provide general information on how the data could be used to improve feed efficiency, and therefore reduce GHG emissions.





Angus

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SIRES

Registration Number	Animal Name	RFI EPD	RFI Accuracy	RFI Percentile Ranking	ADG EPD	ADG Accuracy	ADG Percentile Ranking	Progeny
		-1.15	0.49	1%	-0.05	0.40	82%	33
		-0.86	0.67	1%	0.10	0.58	17%	127
		-0.86	0.68	1%	0.04	0.60	43%	182
		-0.85	0.54	1%	-0.11	0.45	96%	33
		-0.83	0.42	2%	0.06	0.36	31%	29
		-0.78	0.71	2%	-0.03	0.64	78%	132
		-0.77	0.62	3%	0.06	0.53	32%	55
		-0.77	0.49	3%	-0.07	0.40	90%	29
		-0.77	0.60	3%	0.02	0.51	55%	67
		-0.76	0.44	4%	0.04	0.37	41%	14
		-0.72	0.58	5%	-0.02	0.50	75%	51
		-0.66	0.44	6%	-0.07	0.36	88%	35
		-0.62	0.60	6%	-0.00	0.52	65%	73
		-0.61	0.73	6%	0.08	0.65	25%	155
		-0.60	0.43	7%	-0.01	0.36	71%	13
		-0.60	0.68	7%	0.00	0.60	63%	112
		-0.60	0.74	7%	0.09	0.68	21%	562
		-0.60	0.62	7%	-0.03	0.53	79%	69
		-0.60	0.56	7%	-0.03	0.47	78%	123
		-0.59	0.47	8%	0.03	0.39	44%	18
		-0.57	0.42	8%	-0.02	0.36	75%	30
		-0.57	0.51	9%	0.03	0.44	47%	24
		-0.57	0.50	9%	0.02	0.43	54%	75
		-0.56	0.48	9%	0.02	0.40	50%	27
		-0.55	0.52	9%	0.04	0.43	39%	34
		-0.54	0.58	10%	0.02	0.50	55%	40
		-0.54	0.55	10%	0.03	0.47	49%	46
		-0.53	0.67	10%	-0.05	0.59	84%	144
		-0.52	0.55	11%	-0.05	0.46	83%	63
		-0.51	0.57	11%	0.04	0.50	42%	72
		-0.51	0.56	11%	-0.03	0.47	77%	45
		-0.51	0.43	11%	0.00	0.37	62%	30
		-0.50	0.61	11%	-0.11	0.53	96%	178
		-0.48	0.50	12%	-0.06	0.42	86%	38
		-0.48	0.42	13%	-0.05	0.34	82%	24
		-0.48	0.60	13%	-0.06	0.51	87%	186

GrowSafe Network Privileged Information — DO NOT COPY, DO NOT CIRCULATE 5

Figure 5. A portion of the 2019 Reference Sire and Dam Summary which was initially only published for Vytelle Network customers. A more public version was developed in 2020 for release to a wider audience. The names and registration numbers of the sires have been hidden for privacy purposes.

Greenhouse Gas Evaluations

Increasing pressure on the beef industry to reduce environmental impact by reducing GHG emissions, led Vytelle to not only develop a protocol to quantify GHG emissions, but it also provided an opportunity for Vytelle customers to file carbon offset credits. Although the existing equations in the *Selection for Low Residual Feed Intake in Beef Cattle and Reducing Greenhouse Gas Emissions from Fed Cattle* protocol were limited in their ability to calculate overall GHG emissions from beef production, the equations were accommodating to the limited data received from customer locations.

The existing RFI-based protocols to quantify GHG emissions were reviewed and accepted for the carbon offset protocol, *Offset Project Plan for Selection for feed efficiency to reduce environmental impact of beef cattle in Alberta*, and was used for quantification of GHG emissions in the simulation. Dr. Monty Kerley also reviewed CH_4 production equations from individual animals with respect to their diet compositions, which showed good correlations between methods in the protocols currently used. Although there were good correlations, many customer sites did not provide enough detailed ration and diet composition information for such thorough evaluation of GHG emissions.

The protocol allowing Alberta-based producers to file carbon offset credits, gave producers a greater incentive to select for feed efficiency; several new customers joined the Vytelle Network to file carbon offset credits. Vytelle's data repository has allowed for proper certification of efficient cattle and therefore also allowed for validation of the credits applied. Although the protocol currently recognizes four different locations within Alberta that are set up to file their carbon offset credits, additional locations have been identified that are well underway to having enough data to establish proper baseline emission values. Use of these protocols across all Vytelle test locations has been difficult, as it requires protocols to be recognized and accepted by governing bodies, and it requires extensive data from customers, that many customers do not have or are not willing to provide.

Greenhouse gas analyses of Alberta-based cattle in the data repository revealed a significant opportunity to reduce the industry's GHG emissions by selecting for feed efficiency. Selection for low RFI cattle reduces feed intake and therefore also reduces CH_4 and nitrous oxide (N_2O) emissions, both of which are considered GHGs. Table 1 summarizes the reduction in DMI, feed cost and carbon dioxide equivalent (CO_{2e}) emissions of an efficient bull, when compared to an inefficient bull. The simulation assumed that bulls were exposed to 25 cows each year and that they produced terminal steers and heifers for the feedlot, as well as replacement heifers. The bull efficiency metrics were pulled from the data repository, where an efficient bull had an RFI EPD of -0.43 and an inefficient bull had an RFI EPD of +0.43, both within one standard deviation of the mean.

Table 1. Dry matter intake, feed cost and emissions reductions for one bull, as a result of selecting for feed efficiency.

Savings	Per Year	Over 7 Years
DMI Savings (kg)	2,710.99	18,976.91
Feed Cost Savings ($)	$ 469.15	$ 3,284.05
CO_{2e} CH_4 Emissions Reductions (kg)	1,501.15	10,508.04
CO_{2e} N_2O Emissions Reductions (kg)	6,056.98	42,398.85
Overall CO_{2e} Emissions Reductions (kg)	7,558.13	52,906.89

Although the results expressed in Table 1 demonstrate a significant improvement in overall efficiency and sustainability, benefits can be increased significantly when applying the principles of feed efficiency to entire herds. Further analysis was done to demonstrate the potential impact that the data repository, and selection for feed efficiency, has had on the sustainability of Alberta's beef industry. Table 2 shows that over the past seven years, testing and selecting for feed efficiency in beef cattle has significantly increased. This is due to increased producer awareness, and due to the programs offered by Vytelle that allow producers to improve their efficiency and profitability. Expected progeny differences have been offered to customers since 2017. The opportunity to receive efficiency EPDs, and access other Network efficiency benchmarks, significantly increased the number of bulls tested in Alberta from 2017 to 2018, and even more so from 2018 to 2019. Furthermore, the ability to use the In-Pen Weighing Positions to shorten RFI trials, significantly increased the bull throughput at test facilities; test facilities in Alberta began running RFI trials using In-Pen Weighing Positions in 2018.

As noted by the results in Table 2, industry wide selection for feed efficiency has a significant impact on GHG emissions. With carbon priced at $30/tonne, each efficient bull has the potential to generate approximately $110 per year in carbon offset credits, when compounding the emission reductions from yearly offspring. Although the value in carbon credits is appealing to producers and

Vytelle customers, currently the biggest driver for using RFI is the ability to reduce feed costs and to maintain more cattle on the same, or fewer, resources.

Table 2. Number of Alberta-based bull phenotypes and expected progeny differences (EPDs) collected and calculated per year, along with associated dry matter intake (DMI) and carbon dioxide equivalent (CO_{2e}) emissions reductions. Not all bulls tested for efficiency had expected progeny differences (EPDs) calculated.

Phenotypes								
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Number of Bulls Tested in Alberta	315	266	209	306	535	949	762	**3,342**
Number of Efficient Bulls Tested in Alberta	158	133	105	153	268	475	381	**1,673**
Estimated DMI Savings (kg)	428,336	360,561	284,654	414,781	726,544	1,287,719	1,032,886	**4,535,480**
Estimated CO_{2e} Emissions Reductions (kg)	1,194,184	1,005,231	793,603	1,156,394	2,025,578	3,590,111	2,879,647	**12,644,748**
EPDs								
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Alberta-Based Bulls with RFI EPDs Added to Repository	-	-	-	150	1,634	952	886	**3,622**
Alberta-Based Bulls with Efficient RFI EPDs Added to Repository	-	-	-	54	1,281	541	544	**2,420**
Percent Efficient EPDs Added to Repository	-	-	-	36%	78%	57%	61%	-

Calculating EPDs requires both pedigree and performance data. The inclusion of pedigree data allows for estimates of feed efficiency to be provided for every animal in the pedigree. The EPDs provided to animals within a pedigree are estimated based on an animal's relationship to other animals in the repository, and the efficiency and performance metrics of those relatives. Providing EPDs to all animals in the pedigree provides feed efficiency metrics on animals well beyond those that had phenotypes collected, especially considering that each tested animal receiving EPDs must have a three-generation pedigree submitted to the pedigree database. Expected progeny differences allow for estimates of efficiency to be calculated and used on an industry wide basis.

Reports and Publications

- **Interim Report:** *Technical Note: Calculating Residual Feed Intake using High-Frequency Partial Body Weights* – finalized in early 2017. Results indicate that high-frequency partial body weight information allow for accurate calculation of RFI with fewer rejections due to errors associated with incorrect chute weight points and issues caused by nonlinearity in growth. This report was prepared as a technical document for Vytelle.

Authors: D. Benfield, K. Garossino, C. Huisma
Abstract: Values for residual feed intake (RFI) were calculated for comparison using conventional chute weighing techniques as well as partial body weight data collected with specialized data acquisition systems. For this analysis, per-second partial body weight and feed intake data was compiled for 3,743 animals which were separated into 49 contemporary groups. Analysis of these data show a small difference (R^2 = 0.024, $P < 0.01$) in the R^2 values calculated for each contemporary group using either chute or partial body weight information. In addition, it was shown that the use of high-frequency partial body weight information provided the ability to calculated RFI with better rejection of errors caused by incorrect chute weight points and issues caused by nonlinearity in growth.

- **Publication Preparation:** Measurement of feed efficiency traits and reduction of test duration periods in beef cattle using high-frequency partial body weights – prepared and submitted for publication in 2017. The results concluded that when using high-frequency partial body weight data, instead of chute weights, RFI trial lengths could be reduced from 70 days to 49 days in length, consistent with results. Additionally, the use of high frequency partial body weights reduced the incidence of rejection due to errors associated with chute weight points. This report was submitted for publication, but not accepted. It was maintained as a technical document for Vytelle.

Authors: D. Benfield, K. Garossino, M. Kerley, R. D. Sainz, and C. Huisma
Abstract: The objective of this research was to determine if high-frequency partial BW (PBW) of calves measured at drinking events could be used to reduce the number of test days required to accurately measure residual feed intake (RFI). Values for RFI were calculated for comparison using conventional chute weighing techniques as well as using PBW data collected with a specialized data acquisition system. For this analysis, per-second PBW and feed intake data were compiled for 1,874 animals which were separated into 27 contemporary groups from four different sites. Chute and PBW data produced similar results for RFI, RFI ranking, DMI, mid-test BW and ADG ($r2 > 0.84$, $P < 0.001$). The high-frequency data were also subdivided into duration intervals greater than 21 d in length. Results were consistent ($r2 > 0.71$, $P < 0.001$) between the full trial data and subsets of at least 49 d in length. In addition, the use of high-frequency PBW information enabled calculation of RFI with better rejection of errors caused by incorrect chute weight points and issues caused by nonlinearity in growth.

The same abstract was also submitted for an oral presentation at the 2017 ASAS-CSAS Annual Meeting and Trade Show from July 8-12, 2017, in Baltimore, Maryland. Dr. David Benfield gave the presentation during the *Production, Management, and the Environment I* oral presentation session on July 10, 2017.

Part A References

Archer, J. A., Arthur, P. F., Herd, R. M. and Richardson, E. C. 1998. Genetic variation in feed efficiency and its component traits. Proc. 6th World Congr. Gen. Appl. Livest. Prod. 25: 81-84.

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Basarab, J. A., Price, M.A., Aalhus, J. L., Okine, E. K., Snelling, V. M., and Lyle, K. L. 2003. Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. 83:189-204.

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Part B: Feedlot Demonstration

Feedlot Demonstration Overview

The objective of this project phase was to demonstrate how feedlot operations could be optimized using In-Pen Weighing Positions. The In-Pen Weighing Positions allowed hot carcass weights and feed intakes to be modelled for individual animals in the feedlot environment, allowing for continuous animal monitoring and predictions of optimal marketing dates on an individual animal basis. The In-Pen Weighing Positions have the potential to identify high and low performing animals, ultimately, reducing the overall number of days on feed and therefore also reducing GHG emissions.

Deviations from Original Work Plan

The initial selection of Alberta feedlots for installation of In-Pen Weighing Positions was delayed, which subsequently delayed the purchase and manufacturing of In-Pen Weighing Positions earmarked for the potential sites. This was again delayed by the addition of another potential feedlot site in early 2019. The completion date for the project was initially extended from December 31, 2017, to December 31, 2018, and once again extended to December 31, 2020. The extensions were required due to delays in finalizing partnerships with feedlot sites in Alberta, and due to lower-than-expected In-Pen Weighing Positions installed. Only about a third of the initially anticipated In-Pen Weighing Positions were installed, resulting in less overall data collected on a yearly basis. Extension of the project allowed for collection of more robust datasets with the objective of increasing producer confidence in the technology, particularly around its ability to track changes in animal weight and identify animals that are ready for harvest.

Feedlot Demonstration Final Analysis

Introduction

The feedlot industry is the largest sector of the beef industry to produce saleable beef for consumers. Although the production of specialty products, such as ‘grass-fed’ or ‘grass-finished’ beef is on the rise, much of North America’s beef is still produced in feedlots. Many industry experts argue that a controlled feedlot environment in which cattle are fed highly digestible, well balanced diets to achieve the highest level of gain, is the most efficient way to produce beef with the lowest GHG emissions (North American Meat Institute, 2015; Basarab et al. 2013). Although the feedlot sector only contributes about 20% of the GHG emissions of the entire beef production cycle (Beauchemin et al., 2010), it is still a contributor of emissions and has become a focal point for many consumers. Due to the relatively controlled nature of the feedlot environment, there is significant opportunity to reduce GHG emissions using innovative technologies.

Vytelle’s In-Pen Weighing Positions were designed to collect body weights automatically and continuously from cattle in a non-invasive manner. The technology is positioned in front of a water trough to collect weights from cattle every time they visit the trough. The In-Pen Weighing Positions allow for continuous monitoring of animal behavior and animal growth curves. The purpose of this study was to apply the In-Pen Weighing Positions’ monitoring capabilities to real-life feedlot environments to determine if the technology could be used to optimally market cattle, identify poor performing animals, and reduce total days on feed, all to reduce GHG emissions.

Methods and Materials

Selecting Partner Feedlots and In-Pen Weighing Position Installation

Two feedlot locations in Alberta were identified as partners in the project. The partnering locations were chosen based on their interest in participating, their use of the HerdTrax cattle data managing software, and their proximity to the Vytelle Calgary-Winsport office. Two feedlot sites located in south-central Alberta, referred to as Feedlot 1 and Feedlot 2 were chosen as partners in the feedlot demonstration. Although the initial plan of the project was to identify additional partners to install more In-Pen Weighing Positions, no other suitable partners were acquired. Approximately one third of the proposed In-Pen Weighing Positions were installed for the project; the Feedlot 2 site received two In-Pen Weighing Positions, each with six positions, while the Feedlot 1 site received eight four-position In-Pen Weighing units. The Feedlot 1 and Feedlot 2 pen layouts can be seen in Figure 6, and Figure 7, respectively.

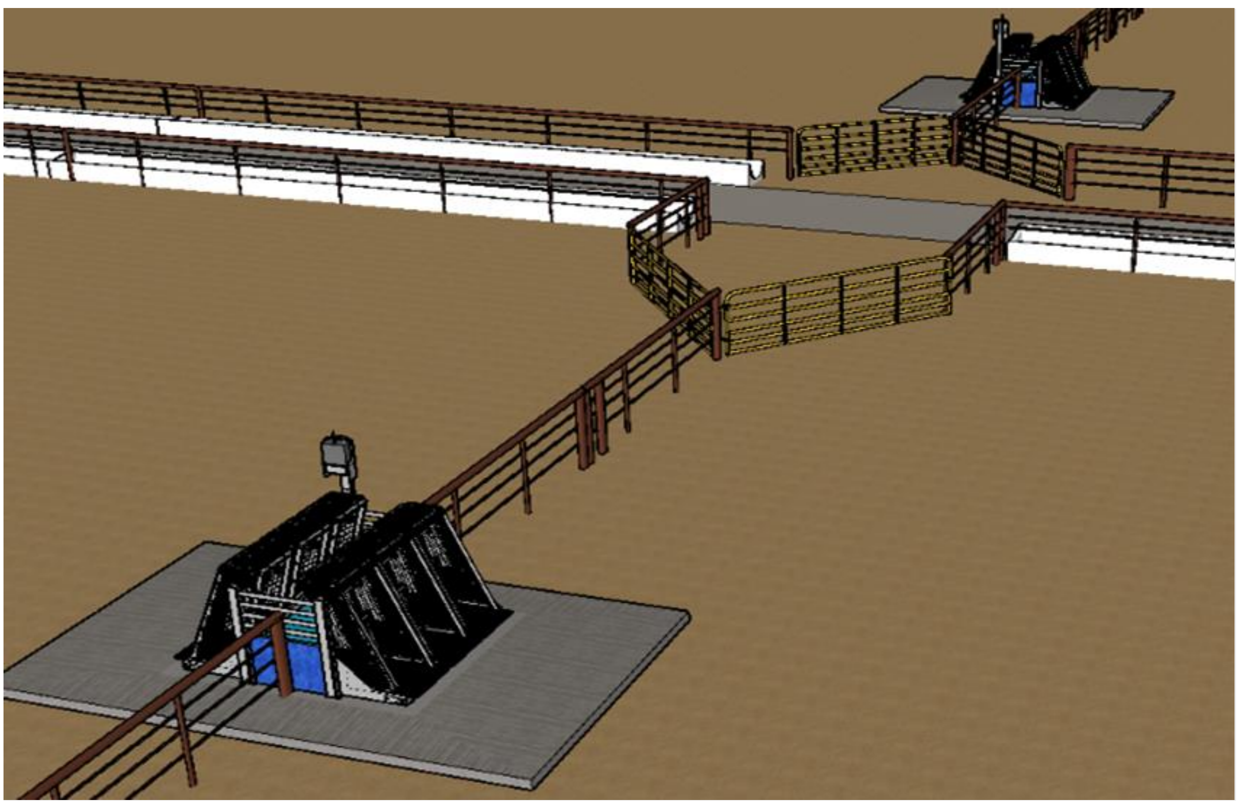


Figure 6. Birdseye view of Feedlot 2 and the In-Pen Weighing Positions within each pen. The site had four pens and each pen had 3 In-Pen Weighing Positions.

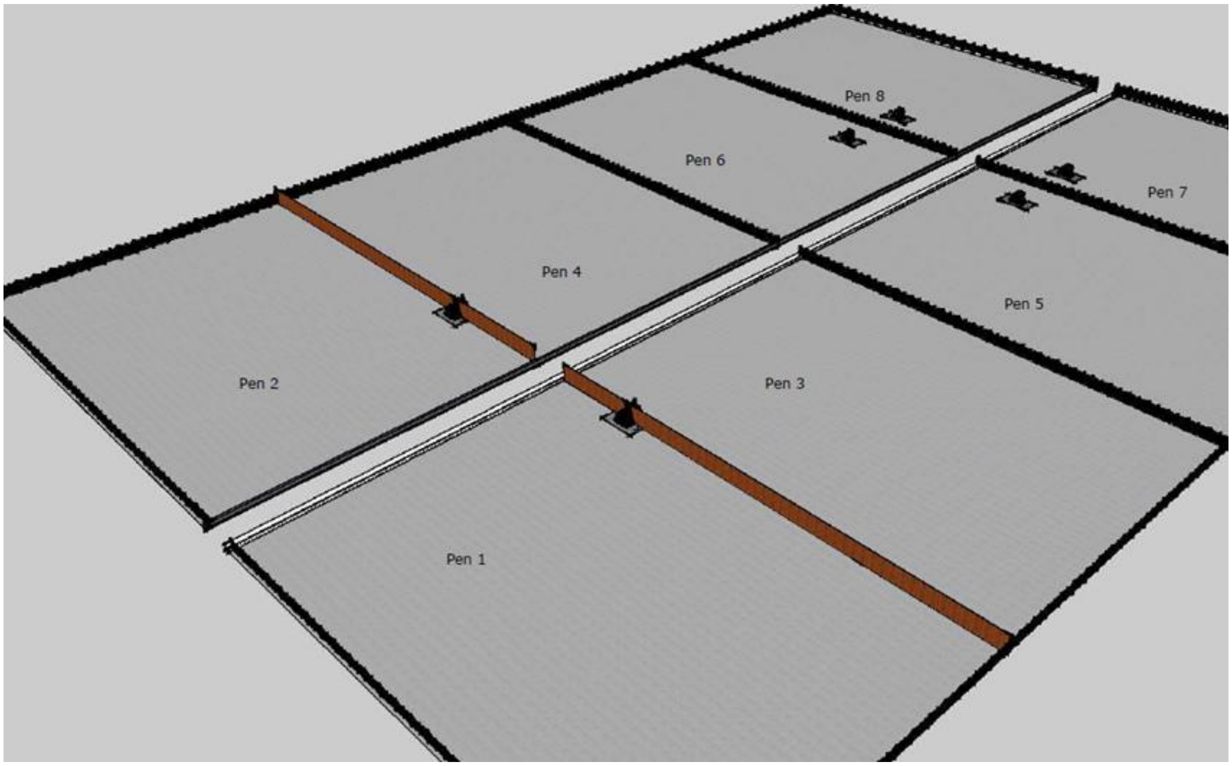


Figure 7. Birdseye view of Feedlot 2 and the In-Pen Weighing Positions within each pen. The site had eight pens and each pen had four In-Pen Weighing Positions. This site also had a sick pen with a single In-Pen Weighing Position (not shown in the figure).

Both sites had their In-Pen Weighing Positions installed in 2016, with the first groups of cattle accessing the systems in November 2016. The In-Pen Weighing Positions were maintained by Vytelle, with the partnering feedlots attending to emergency maintenance situations. Maintenance and part replacement were ongoing throughout the life of the project. Most maintenance tasks were related to ice buildup and freezing of the system positions, both impacting data quality. Metal brackets were added to the back of the In-Pen Weighing Positions to reduce the water pooling underneath the position, therefore also reducing ice buildup.

Data Collection and Auditing

Vytelle's In-Pen Weighing Positions were used to monitor feedlot heifers and steers automatically and continuously at Feedlot 1 and Feedlot 2 for cattle that finished in the spring and summer of 2017, 2018 and 2020. Data was not collected in 2019 as the project was waiting for the extension to be approved. Table 3 outlines the length of the monitoring periods, and the number of animals monitored at each site. The number of animals included in the analysis each year was dependent on the supply of cattle to the feedlots each year.

Table 3. Monitoring periods of all animals at Feedlot 1 and Feedlot 2.							
Feedlot 2				Feedlot 1			
Year	Start Date	End Date	# Animals	Year	Start Date	End Date	# Animals
2017:	2016-11-10	2017-06-07	700	2017:	2016-11-12	2017-09-12	1300
2018:	2017-11-12	2018-05-24	560	2018:	2017-10-23	2018-08-29	1881
2020:	2019-12-03	2020-07-10	359	2020:	2019-11-04	2020-09-02	937

Chute weights were collected from all animals upon entry to the feedlot. Not all animals entered the feedlot on the same day, even animals from the same monitoring group. Upon entry to the feedlot all steers and heifers were tagged with half duplex radio frequency identification (RFID) tags, and they had continuous access to the In-Pen Weighing Positions. Most animals visited the system several times each day and spent several minutes there with each visit. Because an animal's partial body weight is recorded each time its tag is read by the system, which is usually every second, each animal had many partial body weights collected per day. Proprietary Vytelle algorithms were applied daily to calculate daily partial body weight values. Partial body weights were converted to full body weights using proprietary algorithms. The data was audited automatically and manually daily using Vytelle's proprietary auditing software and Vytelle's technical support team, respectively. Only valid data was used in further analyses. The processing routines developed and used throughout the data validation process include the following routines:

- **Process Animal Weights:** combines scale files and behavior files.
- **Process IPW Frequency and Duration:** used to process raw behavioral data to determine the frequency and duration of each In-Pen Weighing Position for each individual animal.
- **Process DW RunAvg:** calculates a daily weight value for each animal based on all In-Pen Weighing Position weights collected over 24 hours.
- **Process IPW Audit:** verifies the status of the hardware and is used identify suspicious data or the need for hardware maintenance.
- **Process IPW Scales Audit:** verifies that each of the scales sending data to the DAQ panel are weighing properly. This auditing routine is used to identify suspicious data or flag the need for hardware maintenance.
- **Process Scales Validation:** calculates the differences in weights among the scales within the same pen to identify which scales are weighing properly and which are showing discrepancies.
- **Process Pen Averages:** calculates the pen average weight as well as the average In-Pen Weighing Position visit frequency and duration.
- **Process Norm IPW Data:** monitors and evaluates individual animal weights and allows for flagging of animals on an individual animal basis.

The feedlot operators at Feedlot 1 and Feedlot 2 utilized Vytelle's *View Animal Weights* program to monitor their cattle daily. The *View Animal Weights* program allows the user to see which animals are in each of the pens, how much they currently weigh, their body weight trend, their gain and how much they weigh in comparison to the rest of the pen. It also shows animals that have been flagged for weight loss, and the kind of flag they have been assigned. All the information in the program allows feedlot managers and operators to identify poor performing cattle that require treatment, poor doing cattle that should be removed from the feedlot, as well as cattle that have plateaued in their growth and are ready for market. Figure 8 shows the *View Animal Weights Program*.

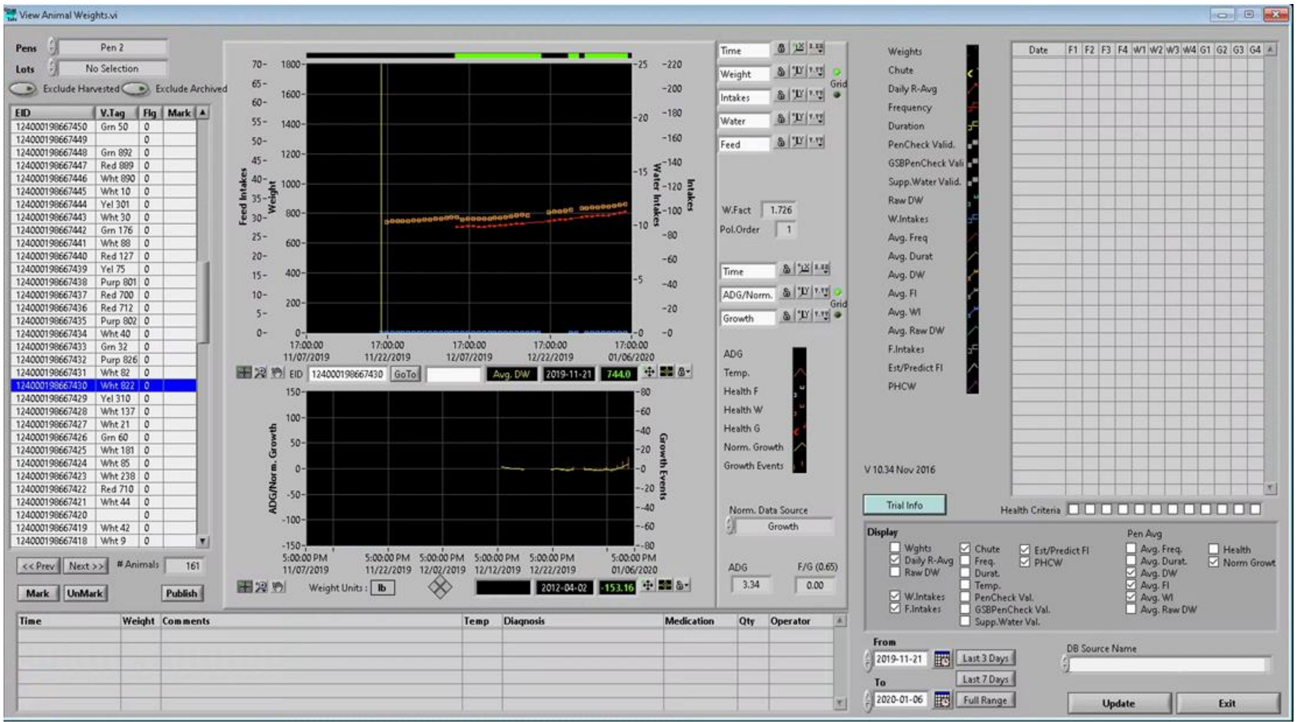


Figure 8. View Animal Weights program. The top graph in the program compares an individual animals' trend in body weight (red line) to the average weight of the pen (orange line). The table on the right of the program displays the weight-related flags assigned to each animal. The program allows animals to be marked by selecting the animal in the table on the left of the program. And then selecting the *Mark* button.

The *View In-Pen Weighing Position Data* (*View GSB Data)* program shows the distribution of animal weights and average daily gains within a pen. This allows for identification of poor performing animals, as well as market ready animals that are no longer growing. The *View In-Pen Weighing Position Data* (*View GSB Data)* program is shown in Figure 9. Both programs allow the user to select animals to be spray painted by the In-Pen Weighing Positions the next time they access it. Not only does this reduce labor associated with identifying and sorting animals in the pen, but it also reduces animal stress and enhances animal welfare. The *View Animal Weights* and *View GS Beef Data* programs are linked together, meaning that animals can be examined in both programs at the same time to make informed decisions. For additional insight, weight reports were developed that were utilized by the Feedlot 1 and Feedlot 2 sites to identify poor performing animals and animals that were ready for harvest. The weight report is show in Figure 10.

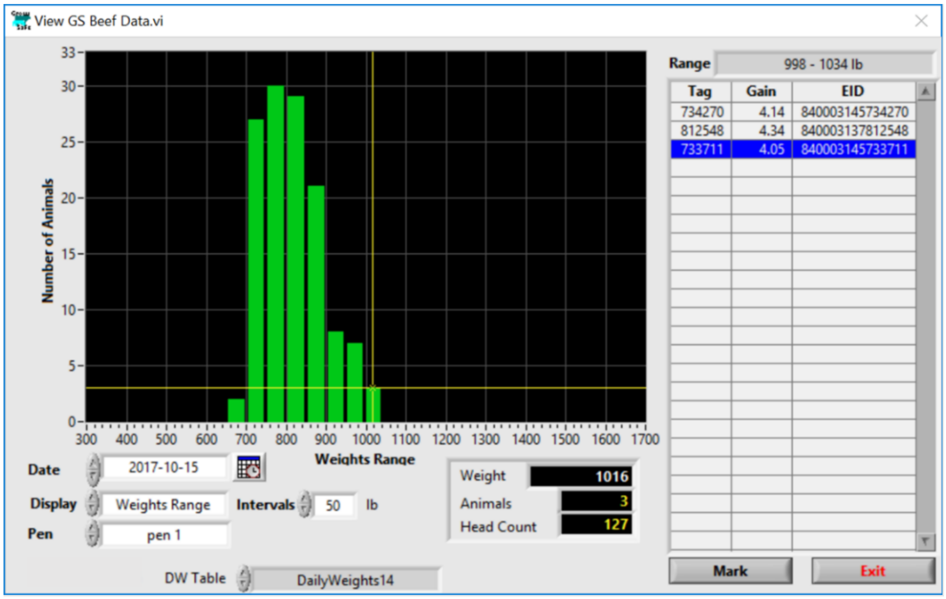
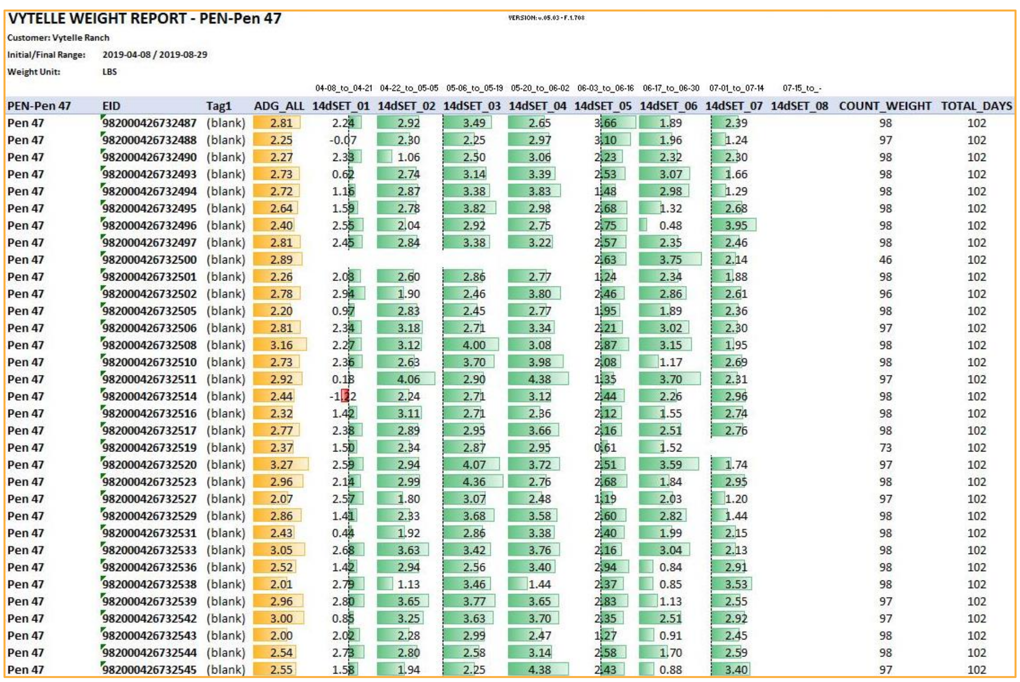


Figure 9. View In-Pen Weighing Position Data (View GSB Data) program. The histogram is displaying the weight range of the animals in the pen, the display can be adjusted to allow for the range in average daily gain to be displayed. By moving the yellow cursor on the graph, the table on the right displays the IDs of the animals found within each of the intervals.



VYTELLE WEIGHT REPORT - PEN-Pen 47   VERSION: v.05.03 - F.1.708

Customer: Vytelle Ranch
Initial/Final Range: 2019-04-08 / 2019-08-29
Weight Unit: LBS

				04-08_to_04-21	04-22_to_05-05	05-06_to_05-19	05-20_to_06-02	06-03_to_06-16	06-17_to_06-30	07-01_to_07-14	07-15_to_-		
PEN-Pen 47	EID	Tag1	ADG_ALL	14dSET_01	14dSET_02	14dSET_03	14dSET_04	14dSET_05	14dSET_06	14dSET_07	14dSET_08	COUNT_WEIGHT	TOTAL_DAYS
Pen 47	982000426732487	(blank)	2.81	2.24	2.92	3.49	2.65	3.66	1.89	2.39		98	102
Pen 47	982000426732488	(blank)	2.25	-0.07	2.30	2.25	2.97	3.10	1.96	1.24		97	102
Pen 47	982000426732490	(blank)	2.27	2.38	1.06	2.50	3.06	2.23	2.32	2.30		98	102
Pen 47	982000426732493	(blank)	2.73	0.62	2.74	3.14	3.39	2.53	3.07	1.66		98	102
Pen 47	982000426732494	(blank)	2.72	1.16	2.87	3.38	3.83	1.48	2.98	1.29		98	102
Pen 47	982000426732495	(blank)	2.64	1.59	2.78	3.82	2.98	2.68	1.32	2.68		98	102
Pen 47	982000426732496	(blank)	2.40	2.55	2.04	2.92	2.75	2.75	0.48	3.95		98	102
Pen 47	982000426732497	(blank)	2.81	2.45	2.84	3.38	3.22	2.57	2.35	2.46		98	102
Pen 47	982000426732500	(blank)	2.89					2.63	3.75	2.14		46	102
Pen 47	982000426732501	(blank)	2.26	2.08	2.60	2.86	2.77	1.24	2.34	1.88		98	102
Pen 47	982000426732502	(blank)	2.78	2.94	1.90	2.46	3.80	2.46	2.86	2.61		96	102
Pen 47	982000426732505	(blank)	2.20	0.97	2.83	2.45	2.77	1.95	1.89	2.36		98	102
Pen 47	982000426732506	(blank)	2.81	2.34	3.18	2.71	3.34	2.21	3.02	2.30		97	102
Pen 47	982000426732508	(blank)	3.16	2.27	3.12	4.00	3.08	2.87	3.15	1.95		98	102
Pen 47	982000426732510	(blank)	2.73	2.36	2.63	3.70	3.98	2.08	1.17	2.69		98	102
Pen 47	982000426732511	(blank)	2.92	0.18	4.06	2.90	4.38	1.35	3.70	2.31		97	102
Pen 47	982000426732514	(blank)	2.44	-1.22	2.24	2.71	3.12	2.44	2.26	2.96		98	102
Pen 47	982000426732516	(blank)	2.32	1.42	3.11	2.71	2.36	2.12	1.55	2.74		98	102
Pen 47	982000426732517	(blank)	2.77	2.38	2.89	2.95	3.66	2.16	2.51	2.76		98	102
Pen 47	982000426732519	(blank)	2.37	1.50	2.34	2.87	2.95	0.61	1.52			73	102
Pen 47	982000426732520	(blank)	3.27	2.59	2.94	4.07	3.72	2.51	3.59	1.74		97	102
Pen 47	982000426732523	(blank)	2.96	2.14	2.99	4.36	2.76	2.68	1.84	2.95		98	102
Pen 47	982000426732527	(blank)	2.07	2.57	1.80	3.07	2.48	1.19	2.03	1.20		97	102
Pen 47	982000426732529	(blank)	2.86	1.41	2.33	3.68	3.58	2.60	2.82	1.44		98	102
Pen 47	982000426732531	(blank)	2.43	0.44	1.92	2.86	3.38	2.40	1.99	2.15		98	102
Pen 47	982000426732533	(blank)	3.05	2.68	3.63	3.42	3.76	2.16	3.04	2.13		98	102
Pen 47	982000426732536	(blank)	2.52	1.42	2.94	2.56	3.40	2.94	0.84	2.91		98	102
Pen 47	982000426732538	(blank)	2.01	2.79	1.13	3.46	1.44	2.37	0.85	3.53		98	102
Pen 47	982000426732539	(blank)	2.96	2.80	3.65	3.77	3.65	2.83	1.13	2.55		97	102
Pen 47	982000426732542	(blank)	3.00	0.85	3.25	3.63	3.70	2.35	2.51	2.92		97	102
Pen 47	982000426732543	(blank)	2.00	2.02	2.28	2.99	2.47	1.27	0.91	2.45		98	102
Pen 47	982000426732544	(blank)	2.54	2.73	2.80	2.58	3.14	2.58	1.70	2.59		98	102
Pen 47	982000426732545	(blank)	2.55	1.58	1.94	2.25	4.38	2.43	0.88	3.40		97	102

Figure 10. Vytelle's weight report which can be used as a decision-making tool to identify poor-doing animals and animals that are ready for market. The report shows trends in individual animal weight gain, it also shows daily individual animal weights.

In addition to daily weights, daily feed delivery and ration information was captured at each feedlot site. This data was collected by the feedlot operators and managed using their HerdTrax online cattle record management software. This data was transferred to Vytelle daily via email; later in the project the online database was accessed directly by Vytelle. The daily feed delivery data was used by Vytelle's software and algorithms to estimate daily intakes using body weight, daily gain, pen feed delivery and In-Pen Weighing Position behavioral data. The estimated daily intakes were used by the original shipping software and to calculate daily methane (CH_4) and nitrous oxide (N_2O) emissions. The HerdTrax online software was also used to manage the carcass data on all harvested animals.

Cattle Management

The cattle at both feedlot locations were managed in accordance with each site's regular feedlot protocols. Feedlot induction protocols were followed at arrival, including the collection of chute weights, and assigning In-Pen Weighing Position compatible half-duplex RFID tags where necessary. All induction weights, treatments and tag changes were recorded in each site's HerdTrax account. Treatments that occurred throughout the feeding period were also maintained on HerdTrax. Some animals lost their half-duplex tags during the feeding period, in many cases the animals were not pulled from the pen for retagging, and therefore, were not monitored throughout the feeding period.

During the feeding period, cattle were fed twice daily, with daily feed deliveries and rations recorded in HerdTrax. Cattle were adapted to high energy feedlot rations through a phased approach with step-up rations that gradually increased the energy and decreased the protein content. The Feedlot 1 site transitioned through eight different rations each year while the Feedlot 2 site transitioned through six different rations. At both sites, the cattle were adjusted to the highest-energy rations within about a two-month period.

Cattle were selected for slaughter by the feedlot operators using Vytelle's proprietary shipping algorithms and weight reports. Weight reports were provided to the feedlots on a weekly basis, additionally, programs such as *View Animal Weights* and View In-Pen Weighing Position Data (*View GS Beef Data)* were utilized to identify animal weights and animals that had slowed in their growth. Feedlot operators identified the heaviest animals and the animals that had plateaued in their gain, as those that should be shipped. Animals that were identified as being ready for harvest were virtually selected to be marked by the system, with green paint, for easy identification and sorting prior to shipping. There were very few cases in which poor performing animals were shipped. In the case of Feedlot 1, animals that were identified as poor performers were moved to a separate pen for closer monitoring and specialized treatment. The shipping algorithms were only utilized for the 2017 feeding period. Following this feeding period, the algorithm was deemed to not be reliable and useful enough for active use by the feedlots as it required too many daily data inputs from the feedlot and proper application programming interfaces (APIs) were not in place. Following this, the algorithms underwent several revisions to be less dependent on data from external sources. Although the updated shipping algorithms were not used by the feedlot sites to select animals for harvest, the data collected during the 2018 and 2020 feeding periods was used to develop the revised shipping algorithms.

The 2020 shipping procedures were modified in response to COVID-19. Slaughter facilities were shut down and they reduced their kill capacity for an extended period which created a significant backlog for feedlot cattle entering the slaughter facilities. The slaughter facilities in Alberta were largely affected around the time in which both feedlot sites had cattle approaching their finishing weight. Because of this, both sites kept many animals for much longer than necessary and did not push them to perform to their fullest potential, as they did not know when the facilities would be accepting cattle for slaughter. Once the facilities had increased their capacity and were accepting cattle, both feedlot sites sent all their cattle for slaughter at one time, even if cattle had not reached their finishing weight.

Data Analysis

Data from both the Feedlot 1 and Feedlot 2 sites, from all three years of data collection, were combined into one dataset. The dataset included all animal specific data such as identification numbers, color, sex, and origin, along with feeding period-related data such as entry dates, entry weights, average daily gains, exit weights, estimated total dry matter intakes, estimated daily dry matter intakes and harvest dates. Carcass data, including carcass weight, carcass value, yield grade, quality grade, marbling score and fat thickness were also included. Other calculated data points were also included, such as carcass weight gain and GHG emission values. Greenhouse gas emissions were calculated daily for each animal, using the Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle (Alberta Government, 2016). Daily enteric CH_4 and N_2O emissions were calculated on a kg per head basis and on a carbon dioxide equivalent (CO_{2e}) per head basis. Emissions values were also totaled over the entire feeding period and reported on a CO_{2e} per kg of carcass weight gain basis. Carcass weight gain values were calculated for each animal using the animal's entry weight, assuming a dressing percentage of 60%. Feed to gain (F:G) efficiency measures, calculated using estimated intakes and average daily gains (ADG), were also included in the dataset for each animal. The data was also grouped into high and low categories for F:G, ADG, entry weight, days on feed (DOF), and carcass weight, based on their metrics with respect to the average of each site's metrics. Extreme ADG and F:G groups were also established with classifications based on the top and bottom 25% of gain and efficiency for each feedlot site. Animals with estimated daily dry matter intakes (DDMI) outside 3 standard deviations from the mean were removed from all further analyses.

Results

There were a total of 5,379 animals from both feedlot sites with In-Pen Weighing Position data, predicted feed intakes, carcass data and estimated GHG emissions. After the removal of animals with abnormal DDMIs, there were a total of 5,328 records, each from different animals included in the analyses. Table 4 shows the number of steer and heifer records collected from each site and on each year. As expected, each year there were more steers in the feedlot than heifers because many heifers tend to be kept as replacements for the breeding herd. A summary of the DOF at each feedlot site, for each year, is shown in Table 5. Feedlot 1 had more animals on feed than Feedlot 2 each year, each site also had significantly more steers than heifers on feed each year. The average DOF was lower at the Feedlot 2 site than Feedlot 1 and the standard deviation of the days on feed was also much smaller, indicative of a smaller range in the overall days on feed, likely resulting from differences in management practices, and potentially differences in entry weights of the cattle. Both feedlot sites had higher average DOF in 2020, which can be attributed to COVID-19 related slaughter facility shutdowns and capacity constraints.

Table 4. Number of steer and heifer records collected at each site on each year.					
Feedlot 1			**Feedlot 2**		
Year	**Steer**	**Heifer**	**Year**	**Steer**	**Heifer**
2017	890	399	2017	406	139
2018	1328	473	2018	343	97
2020	600	325	2020	215	115

Table 5. Summary of the days on feed (DOF) at each feedlot site for each year.					
Feedlot Site	**Analysis Year**	**Avg. DOF**	**Std.Dev. DOF**	**Min DOF**	**Max DOF**
Feedlot 2	**2017**	197.22	16.74	167	230
	2018	195.66	12.52	144	216
	2020	211.43	3.95	208	220
	Feedlot 2 Total:	**200.49**	**14.59**	**144**	**230**
Feedlot 1	**2017**	178.24	37.36	104	274
	2018	229.75	40.55	158	309
	2020	239.66	9.14	87	250
	Feedlot 1 Total:	**215.56**	**43.28**	**87**	**309**
	Overall Total:	**211.79**	**38.73**	**87**	**309**

Yearly carcass quality grade proportions for Feedlot 1 and Feedlot 2 can be seen in Figure 11 and Figure 12, respectively. Most of the carcasses each year and at each site were AAA, except for Feedlot 2 in 2018 where most carcasses were AA.

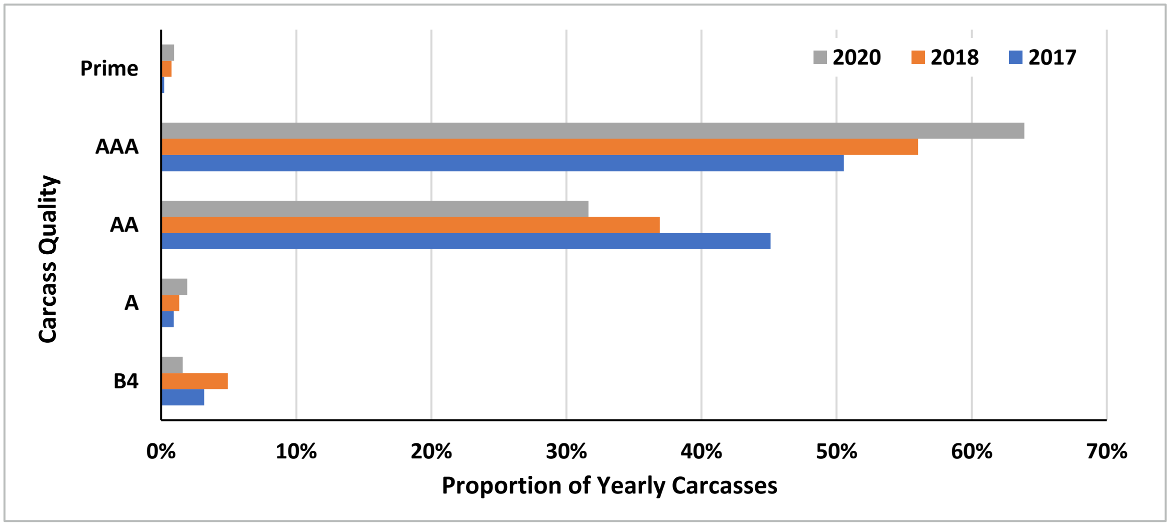


Figure 11. Feedlot 1 proportions of carcass quality classification by year.

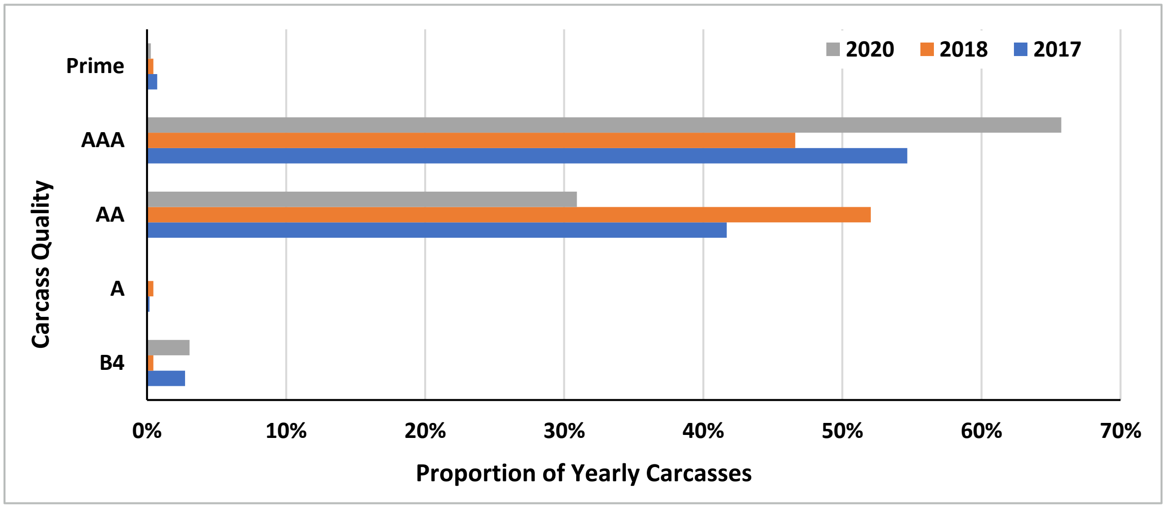


Figure 12. Feedlot 2 proportions of carcass quality classification by year.

Average ADG and F:G values for each site on each year are shown in Table 6. Additionally, Table 6 shows the average CH_4 and N_2O emissions per carcass weight gain. The emissions were reported with respect to carcass weight gain, as opposed to total emissions per day, as it standardizes emissions based on total beef produced. Total emissions per day do not consider whether animals are gaining or not.

Table 6. Summary of average daily gain (ADG), feed to gain (F:G), carbon dioxide equivalent methane emissions per kg of carcass gain (CH_4 CO_{2e}/kg carcass gain) and carbon dioxide equivalent nitrous oxide emissions per kg of carcass gain (N_2O CO_{2e}/kg carcass gain) at each feedlot site for each year.

Feedlot Site	Analysis Year	Avg. ADG (kg)	Std.Dev. ADG (kg)	Avg. F:G	Std.Dev. F:G	Avg. kg CH_4 CO_{2e}/kg carcass gain	Std.Dev. kg CH_4 CO_{2e}/kg carcass gain	Avg. kg N_2O CO_{2e}/kg carcass gain	Std.Dev. kg N_2O CO_{2e}/kg carcass gain
Feedlot 2	**2017**	1.57	0.21	7.73	1.04	6.94	0.94	6.59	0.74
	2018	1.49	0.18	7.37	0.87	6.62	0.78	6.02	0.76
	2020	1.32	0.20	10.02	1.35	9.00	1.22	7.68	1.04
Feedlot 2 Total:		**1.48**	**0.22**	**8.18**	**1.52**	**7.35**	**1.37**	**6.67**	**1.05**
Feedlot 1	**2017**	1.32	0.20	9.19	1.45	8.25	1.31	8.56	1.34
	2018	1.33	0.19	8.51	1.44	7.64	1.29	6.44	1.10
	2020	1.27	0.17	9.51	1.53	8.54	1.38	7.92	1.27
Feedlot 1 Total:		**1.31**	**0.19**	**8.96**	**1.52**	**8.05**	**1.37**	**7.46**	**1.55**
Overall Total:		**1.35**	**0.21**	**8.77**	**1.56**	**7.87**	**1.40**	**7.27**	**1.48**

The proportions of carcass yield grades for Feedlot 1 and Feedlot 2 can be seen in Figure 13 and Figure 14, respectively. Carcasses in Canada only qualify for yield grades if they are an A quality or better. A Grade 1 carcass has an estimated saleable carcass yield of at least 52.3%, Grade 5 carcasses have a saleable yield of less than 45.4% (BCRC, 2019). Carcass yield grades for 2017 and 2018 were similar for each site, while 2020 data saw many lower grading carcasses at each site, likely because of

COVID-19. Once the slaughter facilities re-opened in 2020, both feedlot sites shipped all their animals, whether they had finished a market-ready weight or not.

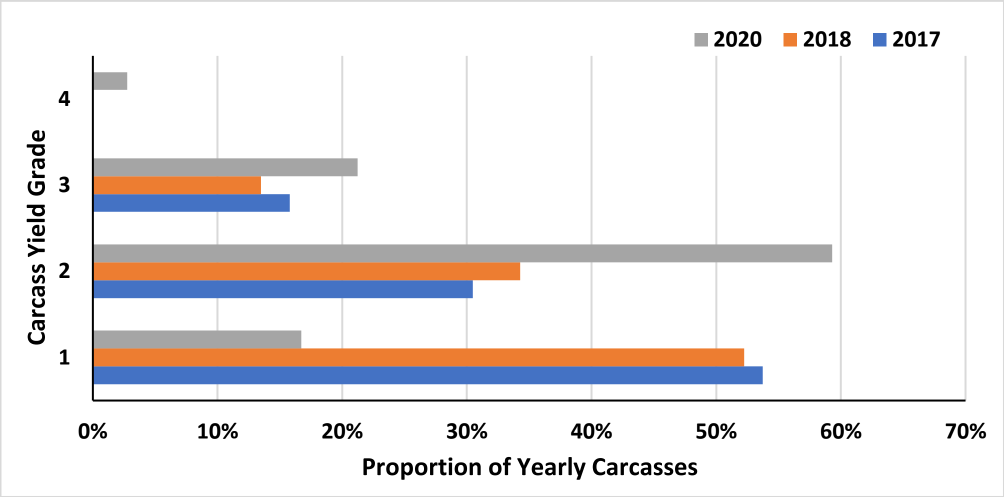


Figure 13. Feedlot 1 proportions of carcass yield grade classifications by year.

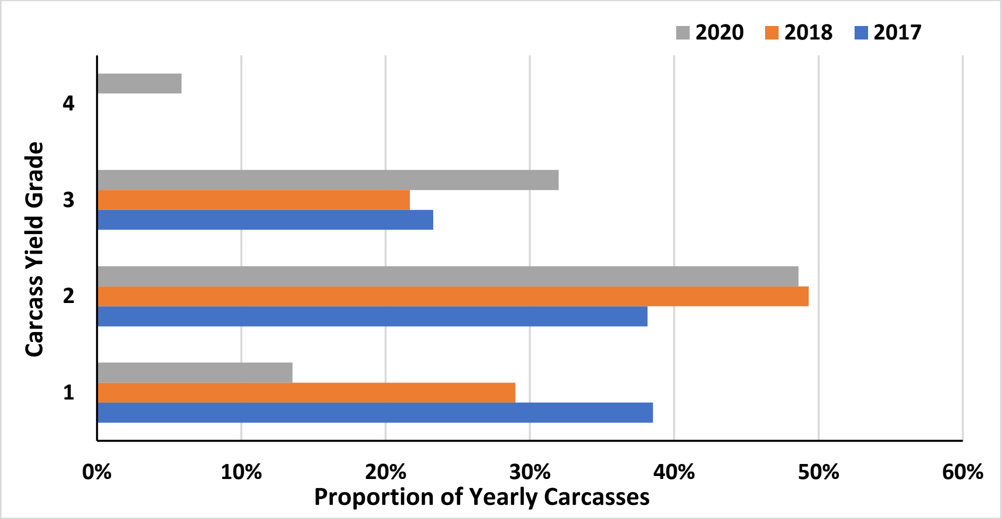


Figure 14. Feedlot 2 proportions of carcass yield grade classifications by year.

Mixed effects models determined that both CH_4 and N_2O emissions, on a CO_{2e} per kg of carcass gain basis, were significantly ($P < 0.05$) affected by management group, DOF, sex and feedlot site. Animal breed and origin (breeder) did not have a significant effect, likely because many animals were crossbred, and most origins contained an assortment of crossbred animals. Additionally, linear models indicated that each of the following metrics had a significant effect ($P < 0.05$) on CH_4 and N_2O emissions: F:G, ADG, entry weight and DOF. In the linear models, F:G and ADG had the most significant impact on CO_{2e} emissions per kg of carcass gain, while entry weight and DOF appeared to have a greater influence on overall CH_4 and N_2O emissions. This is likely because total emissions increase as animals spend more time on feed, and overall emissions per unit of beef produced are more highly influenced by the efficiency and performance of the animals. Table 7 summarizes the average CH_4 CO_{2e} emissions (kg/kg hot carcass weight gain) by trait group, for each customer during each year. Table 8 summarizes the same data for N_2O CO_{2e} emissions (kg/kg hot carcass weight gain).

Table 7. Average CH_4 CO_{2e} emissions (kg/kg hot carcass weight gain) by trait grouping for each site during each analysis year.

	Trait Grouping									
Customer	**F:G**		**ADG**		**DOF**		**Entry Weight**		**Carcass Weight**	
Feedlot 2	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***
2017	7.73	6.38	6.41	7.50	7.27	6.63	6.86	7.00	6.63	7.28
2018	7.25	6.09	6.18	7.05	6.60	6.64	6.84	6.43	6.44	6.81
2020	10.13	8.21	8.21	9.86	9.07	8.94	9.26	8.74	8.48	9.51
Feedlot 1										
2017	9.38	7.41	7.40	9.12	8.33	8.17	8.59	7.92	7.98	8.56
2018	8.73	6.81	6.79	8.55	8.30	7.20	7.84	7.48	7.48	7.80
2020	9.53	7.59	7.89	9.20	8.45	8.67	8.83	8.30	8.14	8.93

Table 8. Average N_2O CO_{2e} emissions (kg/kg hot carcass weight gain) by trait grouping for each site during each analysis year.

	Trait Grouping									
Customer	**F:G**		**ADG**		**DOF**		**Entry Weight**		**Carcass Weight**	
Feedlot 2	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***
2017	7.26	6.13	6.15	7.06	6.79	6.42	6.61	6.58	6.36	6.86
2018	6.60	5.53	5.62	6.41	5.98	6.06	6.26	5.81	5.87	6.17
2020	8.65	7.01	7.01	8.42	7.75	7.63	7.91	7.46	7.24	8.12
Feedlot 1										
2017	9.69	7.71	7.72	9.40	8.53	8.59	8.98	8.14	8.29	8.85
2018	7.36	5.73	5.73	7.20	6.95	6.09	6.65	6.27	6.31	6.56
2020	8.84	7.05	7.33	8.53	7.86	8.02	8.22	7.67	7.58	8.26

Because sex had a significant effect on emissions, the percentage of steers and heifers was calculated for the animals in the extremely high and low ADG and F:G groups. The same was done for the animals with the highest and lowest kg CO_{2e} emissions per kg of hot carcass gain, the results are reported in Table 9. Correlation coefficients of ADG, DOF and F:G and CO_{2e} emissions per kg hot carcass gain, as well as on a kg/day basis, are shown in Table 10.

Table 9. Percentages of steers and heifers in the high and low ADG groups, high and low F:G groups, and high and low emission groups (kg CO_{2e} emissions/kg hot carcass gain).					
Feedlot 2	**Heifer**	**Steer**	**Feedlot 1**	**Heifer**	**Steer**
Low ADG	61%	39%	**Low ADG**	60%	40%
High ADG	3%	97%	**High ADG**	7%	93%
Low F:G	9%	54%	**Low F:G**	10%	90%
High F:G	46%	54%	**High F:G**	51%	49%
Low CH_4 CO_{2e}	4%	96%	**Low CH_4 CO_{2e}**	7%	93%
High CH_4 CO_{2e}	41%	59%	**High CH_4 CO_{2e}**	51%	49%
Low N_2O CO_{2e}	11%	89%	**Low N_2O CO_{2e}**	12%	88%
High N_2O CO_{2e}	51%	49%	**High N_2O CO_{2e}**	45%	55%

Table 10. Correlation coefficients of DOF, ADG, F:G and CO_{2e} emissions, per kg of hot carcass gain and per day.												
	kg CO_{2e} emissions/kg hot carcass gain						**kg CO2e emissions/day**					
	DOF		**ADG**		**F:G**		**DOF**		**ADG**		**F:G**	
	CH_4	**N_2O**	**CH_4**	**N_2O**	**CH_4**	**N_2O**	**CH_4**	**N_2O**	**CH_4**	**N_2O**	**CH_4**	**N_2O**
Feedlot 2 2017	0.212	0.019	-0.533	-0.299	1.00	0.873	0.499	0.348	0.407	0.540	0.301	0.187
Feedlot 2 2018	0.447	0.136	-0.349	-0.246	1.00	0.677	0.630	0.512	0.432	0.645	0.543	0.225
Feedlot 2 2020	0.306	0.191	-0.718	-0.784	1.00	0.928	0.452	0.381	0.356	0.543	0.292	0.051
Feedlot 1 2017	0.395	0.341	-0.745	-0.685	1.00	0.885	0.913	0.899	-0.376	-0.342	0.540	0.472
Feedlot 1 2018	0.565	-0.150	-0.782	-0.151	1.00	0.454	0.915	0.751	-0.378	-0.104	0.558	0.336
Feedlot 1 2020	0.251	-0.144	-0.776	-0.618	1.00	0.858	0.916	0.857	-0.142	-0.029	0.210	0.105

Discussion

Results from the Feedlot 1 and Feedlot 2 sites indicate that there are opportunities to reduce GHG emissions in the feedlot through management practices involving sensor technology such as the In-Pen Weighing Positions. Although it was expected that GHG emissions would be most affected by a reduction in DOF, as outlined in the protocol (Government of Alberta, 2016) used to estimate GHG emissions, DOF had less of an impact than expected. Results indicate that managing groups of feedlot cattle based on their level of gain and performance will have the most significant impact on emissions; something which can be done using the In-Pen Weighing Positions. It is also important to recognize that GHG emissions, and factors affecting emissions, can vary widely depending whether they are reported on a total emissions per day basis, or on a per unit of beef or carcass gain basis.

The results from the mixed linear models indicated that the animal specific info such as management group, DOF, customer site and sex had a significant impact on GHG emissions while breed and origin did not have significant impacts. Breed likely did not have a significant impact because the breeds on trial were all rather similar, as most animals were crossbred. Additionally, not enough breed specific information was provided to tease apart breed related differences. It is possible that if most breeds were purebred, or if there was a clear indication of each animals' breed percentages, it may have had a more significant impact on GHG emissions. Origin likely also did not have a significant impact on GHG emissions because different origins contained many of the same cross breeds. Management groups were established based on animal sex, origin, and analysis year; the inclusion of sex and analysis year is likely what caused it to have a significant impact. Furthermore, the feedlot site had a significant impact on GHG emissions, which indicates that differences in management practices at each feedlot site had an impact on emissions. This is especially true considering that each site maintained its own feedlot protocols throughout the data collection periods. The feedlot site likely indirectly affected emissions by having a direct impact on ADG and F:G, this is confirmed by the fact that GHG emissions were lowest at the Feedlot 2 site. When comparing each site's emissions on a yearly basis, Feedlot 2 had the highest ADGs and the lowest F:Gs when compared to Feedlot 1 (Table 6). The exception to this is in 2020, where Feedlot 2 had greater CH_4 emissions per kg of hot carcass weight gain, likely resulting from animals remaining at the feedlot well past their finishing weight because of COVID-19 slaughter facility closures.

Although it was initially hypothesized that GHG emissions would be largely affected by DOF, as shown in Tables 7 and 8, emissions per kg of hot carcass gain were not always the lowest in animals in the low DOF group. Average CH_4 emissions were higher in the low DOF group during 2018 at Feedlot 2, and during 2018 and 2020 at Feedlot 1. Average N_2O emissions were higher in the low DOF group during 2018 at Feedlot 2, and during 2017 and 2020 at Feedlot 1. If DOF were such a significant contributor to GHG emissions, average emissions should be lowest in the low DOF group at both sites and for each year. The correlation coefficients reported in Table 10 show that there is a greater correlation between DOF and CO_{2e} emissions/day than CO_{2e} emissions per kg of hot carcass gain, which brings attention to the different metrics used to describe GHG emissions in the feedlot. Additionally, the negative relationships between ADG and CO2e emissions per kg of hot carcass gain, indicates that cattle with greater gain, and thus performance, had fewer emissions per kg of hot carcass gain.

It is important to consider which GHG metrics to report, as they can convey very different results and messages. When it comes to GHG emissions in the feedlot, it is important to think about total emissions emitted per product produced and in this case that product is beef. Although emissions produced per unit of saleable beef is likely the best way to describe emissions, this study did not go into that level of detail. Rather, this study focused on the emissions produced per unit (kg) of hot carcass gain which is directly related to the amount of marketable beef. Reporting emissions on a unit per animal per day basis does not factor in the amount of gain, or the amount of beef produced, in that given day. It only accounts for the feed consumed and the energy omitted to GHGs, it does not account for the energy allocated to growth. This means that high performing and low performing (poor doers) animals can both produce the same amount of GHG emissions daily, however the high performing animals will have much lower emissions per kg of carcass gain. Although Vytelle's In-Pen Weighing Positions can be used to identify high and low performing animals, it does not indicate how poor performing animals should be managed. It may seem logical to remove poor performing animals from the feedlot and to sell them directly for slaughter or through auction marts to other feedlot or farm locations, but these animals will continue to produce GHG emissions. If poor-performing cattle are sent to slaughter, they will likely have very high GHG emissions per carcass weight gain because their carcasses will not be close to their expected finishing weight. Using Vytelle's In-Pen Weighing Positions will allow for continuous monitoring of feedlot cattle, which in turn will allow for identification of poor performing animals so modified management practices can be applied to improve their performance.

Identifying and separating poor performing animals can allow for application of modified management practices to improve gain and performance. Vytelle INSIGHT™ turns data into knowledge and through this decision support tool, the program provides feedlot owners and operators with live animal weight and performance updates and flags. The system's software flags poor performing animals and allows them to be virtually selected for automatic marking in the pen, this is especially useful when identifying poor performing animals to be sorted and managed separately. Removing poor performing animals from a pen or grouping animals in the feedlot based on their performance, will allow for reduced competition and/or modified feeding practices. Performance of poor-doing animals can readily be enhanced by formulating and feeding special rations and/or using feed additives such as beta-adrenergic agonists (Avendano-Reyes et al., 2006). Previous studies have indicated that using efficiency enhancing feed additives, such as Monensin, also reduce GHG emissions (Beauchemin and McGinn, 2006), which may act as a potential solution for poor-performing animals. Additionally, measures such as animal sex, have an indirect impact on efficiency metrics which, therefore, will also impact GHG emissions. As shown in Table 9, the majority of high ADG and low F:G cattle were steers at both feedlot sites, while low CH_4 and N_2O CO_{2e} were also lowest in steers. Understanding the effects of indirect measures will allow for proper management of different animal groups, and ultimately reduce GHG emissions.

Residual feed intake (RFI), a measure of feed efficiency first described by Koch et al. (1963), has been used by cow-calf producers to enhance the efficiency of their cow herds. This trait is unique because it separates animal maintenance requirements from production and growth requirements and is therefore also independent of animal weight and growth rate (Koch et al. 1963; Crews 2005). In this study, the concept of RFI was not readily applied in the feedlot because it is an expensive trait to measure, and it is difficult to track the genetics of cattle entering the feedlot. Cow-calf and/or seedstock producers are more likely to utilize the concept because they are in the business of producing genetics and breeding stock, which is done on a more long-term scale than feeding cattle in the feedlot sector. Regardless, introducing RFI into the feedlot sector has the potential to improve F:G (Basarab et al. 2003), which will reduce GHG emissions. The cow-calf and feedlot sectors are relatively segregated areas of the beef industry, which means that feedlot operators are not often aware of the genetic selection that has gone into producing those cattle. Drawing a closer connection between the cow-calf and feedlot sectors can allow feedlot producers to source more efficient cattle.

Recommendations

Vytelle's In-Pen Weighing Positions can be readily used to monitor feedlot cattle for growth and efficiency which provides insight into GHG emissions. The system, and its reporting abilities, are able to identify high and low performing feedlot cattle and cattle that are ready for slaughter. The system is also able to keep feedlot inventory and record an animal's DOF. Although it was thought that reducing the number of days on feed would be the best way to use the In-Pen Weighing Positions to reduce GHG emissions, this study has discovered that it's better to use the In-Pen Weighing Positions to manage cattle to improve their rate of gain and enhance their efficiency (F:G). The system allows cattle to be managed as individuals, rather than applying the same management practices to all animals. Individual management of cattle will reduce GHG emissions in the feedlot. Identifying and separating poor-performing cattle will allow for overall reductions in GHG emissions per unit of marketable beef produced by a feedlot.

Conclusion

The three feedlot rotations completed at both partnering feedlot sites provided a large dataset of feedlot cattle metrics, including average daily gain, start and finishing weights, estimated daily feed intakes and carcass data. Ration information, and estimated intakes were used to estimate GHG emissions. Although it was hypothesized that the In-Pen Weighing Positions could best be used to reduce the number of days on feed, GHG emissions per unit of beef are most affected by animal rate of growth and animal efficiency. Average daily gain and feed to gain have the most significant effect on GHG emissions, and both have the ability to be monitored and managed using In-Pen Weighing Positions. When comparing overall GHG emissions of animals over their time spent in the feedlot, cattle with fewer days on feed did produce fewer overall emissions but the metric also did not account for beef produced during the time that cattle were on feed; therefore, a metric of emissions per unit of beef produced was most meaningful. Ultimately, the findings of this research identified that the In-Pen Weighing Positions can be used to identify differences in rate of gain and efficiency, and therefore, also differences in GHG emissions. This study was limited in estimating daily feed intakes based on the daily weight, gain, and watering frequency and duration data collected from the In-Pen Weighing Positions. It is possible that if daily intakes were measured using Vytelle's Feed Intake Nodes, results may have been different. Because rate of gain and efficiency had such significant effects on GHG emissions, future studies should consider the genetics of cattle entering the feedlot, and the effect it has on GHG emissions of those cattle. This study did not focus on sourcing genetics from efficient and inefficient cattle, which, in combination with optimizing management practices using In-Pen Weighing Positions, will likely the most significant impact on feedlot GHG emissions.

Part B References

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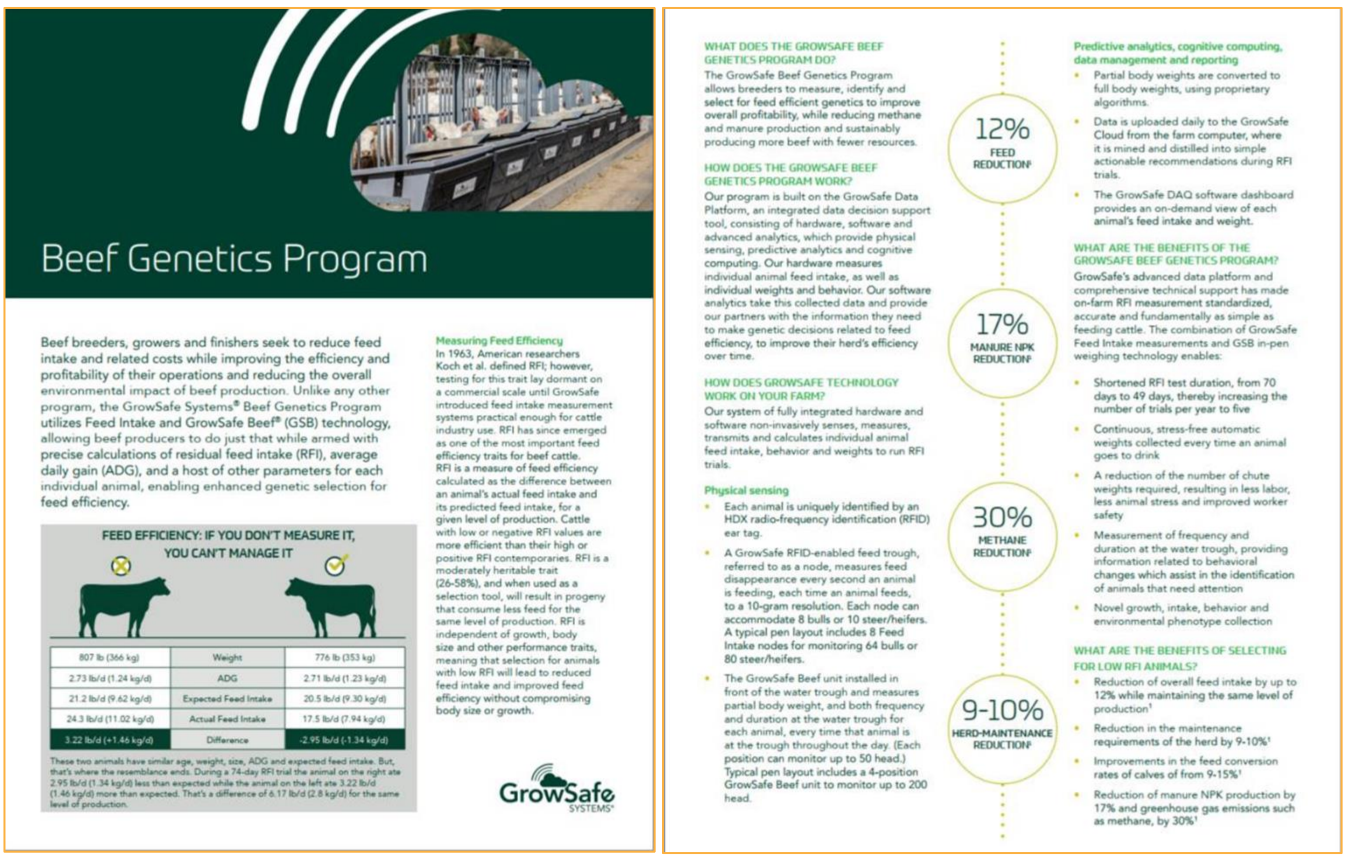
Part C: Commercialization

Part A Commercialization: Beef Genetics Program

The Beef Genetics Program was developed on the principles of the efficiency analytics platform established during Part A of this project. The Beef Genetics Program was launched in 2018 and several customers worldwide use the platform to make genetic selection decisions. The data provided in program reports gives customers insight into the feed efficiency of their breeding stock and allows them to use expected progeny differences (EPDs) to make informed breeding decisions. Although we do not instruct customers on how to make their breeding decisions, they are given the resources to understand feed efficiency and they are given the tools to make decisions that allow them to optimize production on their operations. The metrics developed for the Beef Genetics Program allow producers to make sustainable decisions that ultimately reduce GHG emissions and allow them to receive payment for their carbon offset credits. The Beef Genetics Program is a stand-alone program, separate from the Beef Marketing Program, and is described in more detail in its brochure in Figure 15.



Beef Genetics Program

Beef breeders, growers and finishers seek to reduce feed intake and related costs while improving the efficiency and profitability of their operations and reducing the overall environmental impact of beef production. Unlike any other program, the GrowSafe Systems® Beef Genetics Program utilizes Feed Intake and GrowSafe Beef® (GSB) technology, allowing beef producers to do just that while armed with precise calculations of residual feed intake (RFI), average daily gain (ADG), and a host of other parameters for each individual animal, enabling enhanced genetic selection for feed efficiency.

FEED EFFICIENCY: IF YOU DON'T MEASURE IT, YOU CAN'T MANAGE IT

807 lb (366 kg)	Weight	776 lb (353 kg)
2.73 lb/d (1.24 kg/d)	ADG	2.71 lb/d (1.23 kg/d)
21.2 lb/d (9.62 kg/d)	Expected Feed Intake	20.5 lb/d (9.30 kg/d)
24.3 lb/d (11.02 kg/d)	Actual Feed Intake	17.5 lb/d (7.94 kg/d)
3.22 lb/d (+1.46 kg/d)	Difference	-2.95 lb/d (-1.34 kg/d)

These two animals have similar age, weight, size, ADG and expected feed intake. But, that's where the resemblance ends. During a 74-day RFI trial the animal on the right ate 2.95 lb/d (1.34 kg/d) less than expected while the animal on the left ate 3.22 lb/d (1.46 kg/d) more than expected. That's a difference of 6.17 lb/d (2.8 kg/d) for the same level of production.

Measuring Feed Efficiency

In 1963, American researchers Koch et al. defined RFI; however, testing for this trait lay dormant on a commercial scale until GrowSafe introduced feed intake measurement systems practical enough for cattle industry use. RFI has since emerged as one of the most important feed efficiency traits for beef cattle. RFI is a measure of feed efficiency calculated as the difference between an animal's actual feed intake and its predicted feed intake, for a given level of production. Cattle with low or negative RFI values are more efficient than their high or positive RFI contemporaries. RFI is a moderately heritable trait (26-58%), and when used as a selection tool, will result in progeny that consume less feed for the same level of production. RFI is independent of growth, body size and other performance traits, meaning that selection for animals with low RFI will lead to reduced feed intake and improved feed efficiency without compromising body size or growth.

GrowSafe SYSTEMS®

WHAT DOES THE GROWSAFE BEEF GENETICS PROGRAM DO?

The GrowSafe Beef Genetics Program allows breeders to measure, identify and select for feed efficient genetics to improve overall profitability, while reducing methane and manure production and sustainably producing more beef with fewer resources.

HOW DOES THE GROWSAFE BEEF GENETICS PROGRAM WORK?

Our program is built on the GrowSafe Data Platform, an integrated data decision support tool, consisting of hardware, software and advanced analytics, which provide physical sensing, predictive analytics and cognitive computing. Our hardware measures individual animal feed intake, as well as individual weights and behavior. Our software analytics take this collected data and provide our partners with the information they need to make genetic decisions related to feed efficiency, to improve their herd's efficiency over time.

HOW DOES GROWSAFE TECHNOLOGY WORK ON YOUR FARM?

Our system of fully integrated hardware and software non-invasively senses, measures, transmits and calculates individual animal feed intake, behavior and weights to run RFI trials.

Physical sensing

- Each animal is uniquely identified by an HDX radio-frequency identification (RFID) ear tag.
- A GrowSafe RFID-enabled feed trough, referred to as a node, measures feed disappearance every second an animal is feeding, each time an animal feeds, to a 10-gram resolution. Each node can accommodate 8 bulls or 10 steer/heifers. A typical pen layout includes 8 Feed Intake nodes for monitoring 64 bulls or 80 steer/heifers.
- The GrowSafe Beef unit installed in front of the water trough and measures partial body weight, and both frequency and duration at the water trough for each animal, every time that animal is at the trough throughout the day. (Each position can monitor up to 50 head.) Typical pen layout includes a 4-position GrowSafe Beef unit to monitor up to 200 head.

12% FEED REDUCTION[1]

17% MANURE NPK REDUCTION[1]

30% METHANE REDUCTION[1]

9-10% HERD-MAINTENANCE REDUCTION[1]

Predictive analytics, cognitive computing, data management and reporting

- Partial body weights are converted to full body weights, using proprietary algorithms.
- Data is uploaded daily to the GrowSafe Cloud from the farm computer, where it is mined and distilled into simple actionable recommendations during RFI trials.
- The GrowSafe DAQ software dashboard provides an on-demand view of each animal's feed intake and weight.

WHAT ARE THE BENEFITS OF THE GROWSAFE BEEF GENETICS PROGRAM?

GrowSafe's advanced data platform and comprehensive technical support has made on-farm RFI measurement standardized, accurate and fundamentally as simple as feeding cattle. The combination of GrowSafe Feed Intake measurements and GSB in-pen weighing technology enables:

- Shortened RFI test duration, from 70 days to 49 days, thereby increasing the number of trials per year to five
- Continuous, stress-free automatic weights collected every time an animal goes to drink
- A reduction of the number of chute weights required, resulting in less labor, less animal stress and improved worker safety
- Measurement of frequency and duration at the water trough, providing information related to behavioral changes which assist in the identification of animals that need attention
- Novel growth, intake, behavior and environmental phenotype collection

WHAT ARE THE BENEFITS OF SELECTING FOR LOW RFI ANIMALS?

- Reduction of overall feed intake by up to 12% while maintaining the same level of production[1]
- Reduction in the maintenance requirements of the herd by 9-10%[1]
- Improvements in the feed conversion rates of calves of from 9-15%[1]
- Reduction of manure NPK production by 17% and greenhouse gas emissions such as methane, by 30%[1]

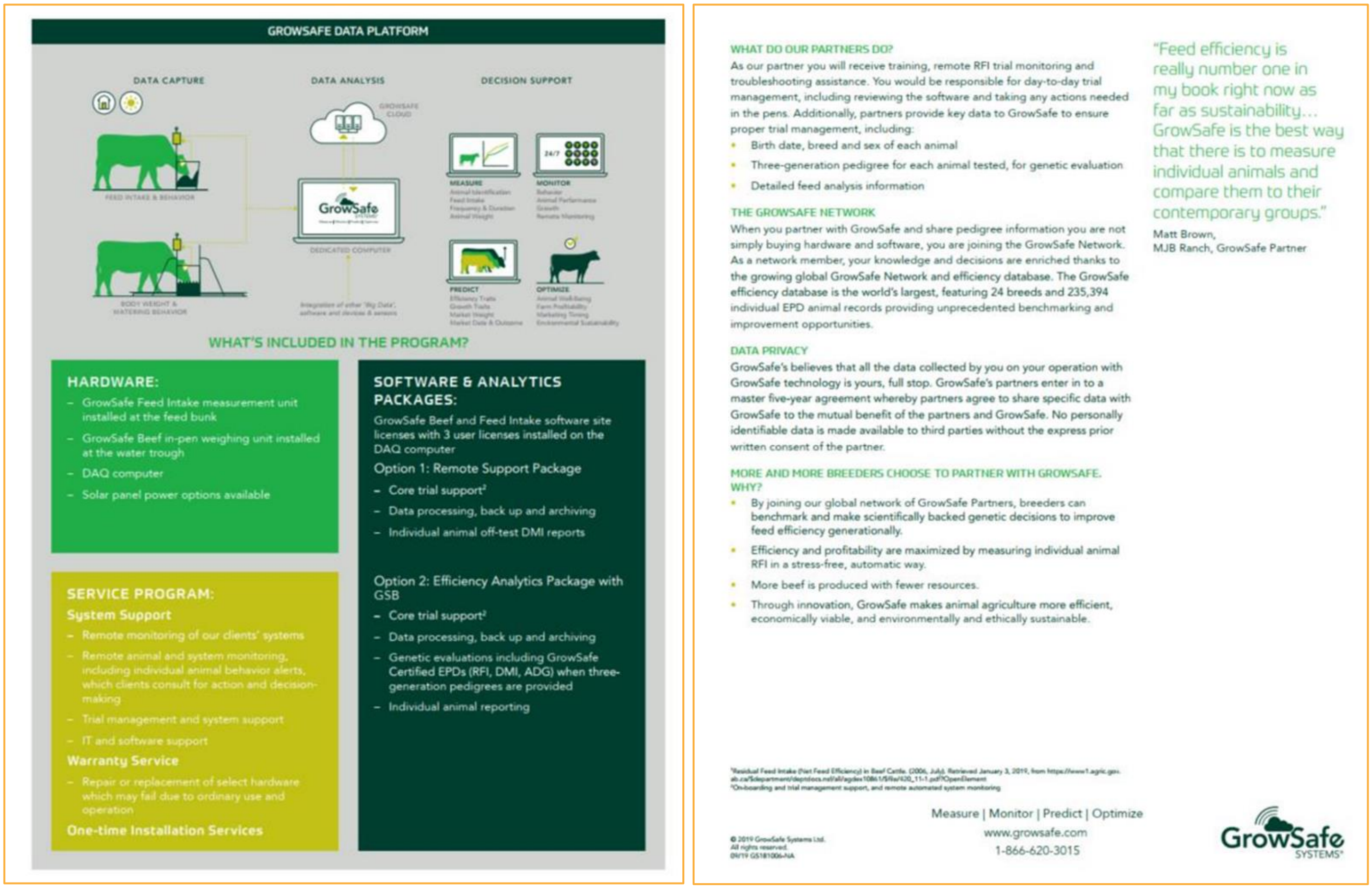


Figure 15. Beef Genetics Program commercial platform and details.

The Beef Genetics Program end of trial reports provide seedstock and cow-calf producers with different kinds of efficiency metrics that allow them to drive efficiency throughout their own programs. Because the beef industry is so divided, providing producers with a varying suite of phenotypic efficiency-related variables allows all producers to find a suitable metric to incorporate feed efficiency in their programs. Although EPDs provide the most valuable insight into progeny efficiency, the phenotypes alone also act as great indicators for feed efficiency. The EPD report, shown in Figure 16, provides percentile rankings to indicate how each animal's efficiency ranks among all animals in the efficiency database. This helps producers understand how their cattle compare to all other efficiency-tested cattle around the world, from several different breeds.

As part of the Beef Genetics Program, participating producers can join the Vytelle Network which gives them access to the entire efficiency database and allows them to see the most up-to date breeding values on all animals. This gives them the opportunity to source the most efficient genetics for inclusion in their breeding programs. It allows them to source feed efficient genetics from 25 different breeds worldwide. Additionally, the annual sire and dam summaries are published to provide a broad scope of producers with efficiency metrics on the high accuracy sires and dams in the database. The sire and dam summaries are far-reaching and give many producers opportunities to include feed efficient genetics into their programs, even if they have not had their own cattle tested. By publishing the sire and dam summaries, and giving network members access to the database, the concept of feed efficiency is spread much wider and more quickly.

Vytelle INSIGHT

BEEF GENETICS: Feed Efficiency Report

EPD

Customer:	Vytelle Ranch	**Sex:**	Bull
Start/End Date:	2021-01-19 / 2021-04-01	**Dry Matter %:**	76.00%
Units:	Lbs & Inches		
Trial Group:	Vytelle Ranch end 2021-04-01		

EPD REPORT

REGN. NO.	REGISTRY	ID	ALT ID	EID	DOB	ORIGIN	RFI EPD	RFI ACCURACY	RFI % RANK	ADG EPD	ADG ACCURACY	ADG % RANK	DMI EPD	DMI ACCURACY	DMI % RANK	SIRE REGN. NO.	SIRE REGISTRY	DAM REGN. NO.	DAM REGISTRY
1111	XYZ	XYZ1		840000000000000	2020-04-04	Vytelle Ranch	0.1096	0.2098	86	0.0412	0.1500	8	0.2045	0.2035	91	XYZ111	XYZ	XYZ2111	XYZ
1112	XYZ	XYZ2		840000000000001	2020-04-15	Vytelle Ranch	0.0296	0.2266	78	0.0060	0.1719	22	0.0223	0.2233	79	XYZ112	XYZ	XYZ2112	XYZ
1113	XYZ	XYZ3		840000000000002	2020-05-01	Vytelle Ranch	0.1851	0.1991	90	-0.0087	0.1417	35	0.0837	0.1930	85	XYZ113	XYZ	XYZ2113	XYZ
1114	XYZ	XYZ4		840000000000003	2020-04-16	Vytelle Ranch	-0.0762	0.2402	62	-0.0312	0.1833	50	-0.1713	0.2369	58	XYZ114	XYZ	XYZ2114	XYZ
1115	XYZ	XYZ5		840000000000004	2020-04-20	Vytelle Ranch	-0.2879	0.2267	11	-0.0611	0.1720	58	-0.4071	0.2234	20	XYZ115	XYZ	XYZ2115	XYZ
1116	XYZ	XYZ6		840000000000005	2020-04-27	Vytelle Ranch	-0.2695	0.2226	13	0.0287	0.1680	11	-0.0846	0.2190	66	XYZ116	XYZ	XYZ2116	XYZ
1117	XYZ	XYZ7		840000000000006	2020-04-16	Vytelle Ranch	0.0335	0.2212	79	0.0006	0.1668	27	-0.0041	0.2177	74	XYZ117	XYZ	XYZ2117	XYZ
1118	XYZ	XYZ8		840000000000007	2020-04-27	Vytelle Ranch	-0.0593	0.2280	64	-0.0488	0.1732	56	-0.2378	0.2247	50	XYZ118	XYZ	XYZ2118	XYZ
1119	XYZ	XYZ9		840000000000008	2020-04-14	Vytelle Ranch	0.1220	0.1800	86	0.0323	0.1245	10	0.1877	0.1731	90	XYZ119	XYZ	XYZ2119	XYZ
1120	XYZ	XYZ10		840000000000009	2020-04-21	Vytelle Ranch	0.0855	0.2042	84	-0.0022	0.1465	31	0.0484	0.1983	82	XYZ120	XYZ	XYZ2120	XYZ
1121	XYZ	XYZ11		840000000000010	2020-04-05	Vytelle Ranch	0.0819	0.2098	83	0.0304	0.1500	11	0.1516	0.2035	89	XYZ121	XYZ	XYZ2121	XYZ
1122	XYZ	XYZ12		840000000000011	2020-04-06	Vytelle Ranch	-0.0388	0.2098	67	0.0412	0.1500	8	0.1194	0.2035	87	XYZ122	XYZ	XYZ2122	XYZ
1123	XYZ	XYZ13		840000000000012	2020-05-17	Vytelle Ranch	0.0225	0.2206	77	0.0068	0.1663	22	0.0189	0.2171	79	XYZ123	XYZ	XYZ2123	XYZ
1124	XYZ	XYZ14		840000000000013	2020-04-20	Vytelle Ranch	-0.1016	0.2208	59	0.0045	0.1665	24	-0.0605	0.2172	68	XYZ124	XYZ	XYZ2124	XYZ

Figure 16. Feed efficiency report with EPDs provided to customers on the Beef Genetics Program.

Benefits

The Beef Genetics Program allows cow-calf and seedstock producers to make individual animal breeding decisions that drastically improve the feed efficiency of their herds. Through this research, the efficiency analytics platform evolved to allow for feed efficiency trials to be shortened using the In-Pen Weighing Positions. This improvement allows producers to run 49-day trials, instead of 70-day trials, reducing the cost of collecting efficiency phenotypes and allowing producers to test more animals per year. The reporting from the efficiency platform gives beef producers the knowledge to make strategic breeding decisions to accelerate their herd’s efficiency. Alongside the breeding values and phenotypes in the end of trial reports, benchmarking metrics provide perspective on where animals are ranked with respect to all other animals in the efficiency database. The network database, along with the sire and dam summaries, have distributed efficiency data across the industry. This has allowed many producers to incorporate feed efficiency into their breeding programs, regardless of whether they test their own cattle. Incorporating feed efficiency into breeding programs, reduces animal intakes, and decreases GHG emissions. An improvement in a sire’s RFI of 0.5 kg will result in progeny that consume 0.5 kg less each day, when bred to females of average RFI, which can reduce CO_{2e} GHG emissions by up to 3 kg per day. This reduction in GHG emissions can be amplified if selection pressures are applied across an entire herd, and improvements in RFI of more than 0.5 kg are highly probable. Information on the Beef Genetics program can be found on the Vytelle.com website, shown in Figure 17, which provides information regarding the program and resources for producers interested in improving the efficiency of their herds.

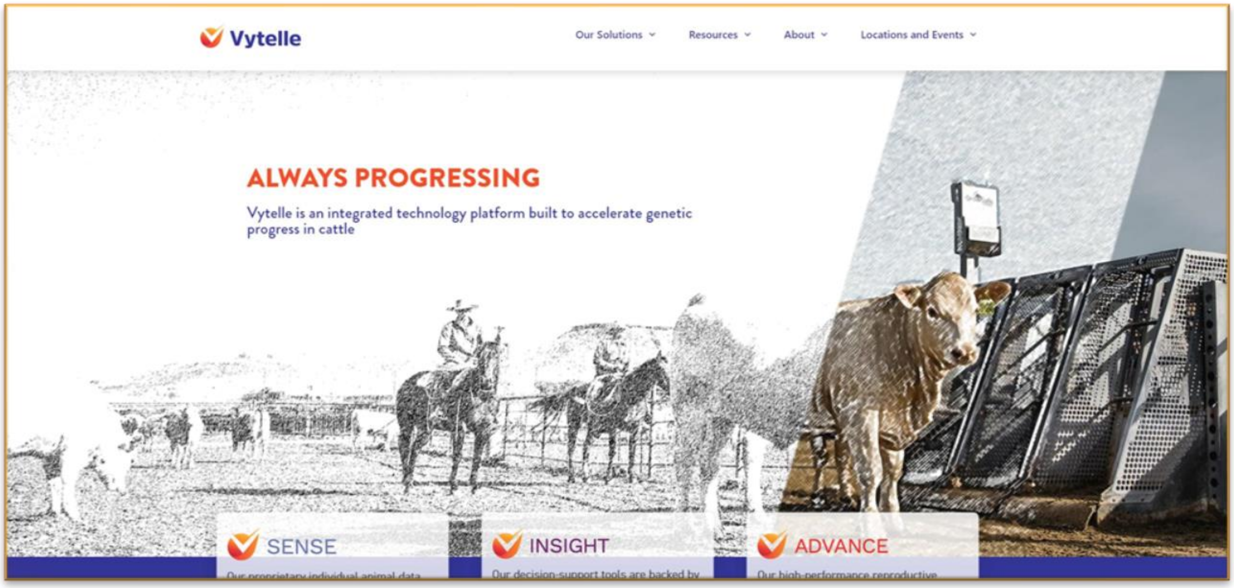


Figure 17. Vytelle website that provides producers with information on the Beef Genetics and Beef Marketing Programs, along with resources to help producers enhance the efficiency and sustainability of their herds.

Part B Commercialization: Beef Marketing Program

Findings from the Feedlot 1 and Feedlot 2 demonstrations were used to develop the Beef Marketing Program platform which was launched commercially in summer of 2020. The Beef Marketing Program is currently being used at several feedlot sites throughout North America. The platform provides feedlot owners and operators with daily insight into the performance, weights, and daily gains of cattle on feed. The program also accurately estimates the individual animal harvest weights of cattle on feed 30 days prior to slaughter, giving feedlot owners and operators additional insight into how best to manage their cattle on feed. Although the platform does not currently provide direct GHG metrics to producers, it allows them to manage their cattle so that they are gaining quickly and in the most efficient way possible, which ultimately reduces overall GHG emissions. The Beef Marketing Program is a stand-alone platform, separate from the Beef Genetics Program. The Beef Marketing Program is described in more detail in its brochure in Figure 18.

The technology that was installed at participant feedlots for the project was decommissioned at the end of the data collection period. Most feedlots currently using the program are very large operations, several magnitudes larger than the feedlots that participated in the project. It is possible that if the participating feedlots were larger, the program may have been more applicable and feasible for them. Both sites felt that the program was too expensive for the value they were receiving. The sites, however, did find some value in the continuous monitoring of their cattle over the period of the project.

MANAGE THE UNSEEN

GrowSafe SYSTEMS

BEEF MARKETING PROGRAM

A **data platform** that provides you with **precise individual animal information** to **support your daily decision making**

How does the data platform work?

Based around our industry leading GrowSafe Beef® technology, you receive daily weight and gain information, enabling you to manage animals as individuals, monitoring performance, predicting carcass weight and optimally marketing cattle.

How can I use the data platform?

Insights to increase your profit and the well-being of your animals, through:

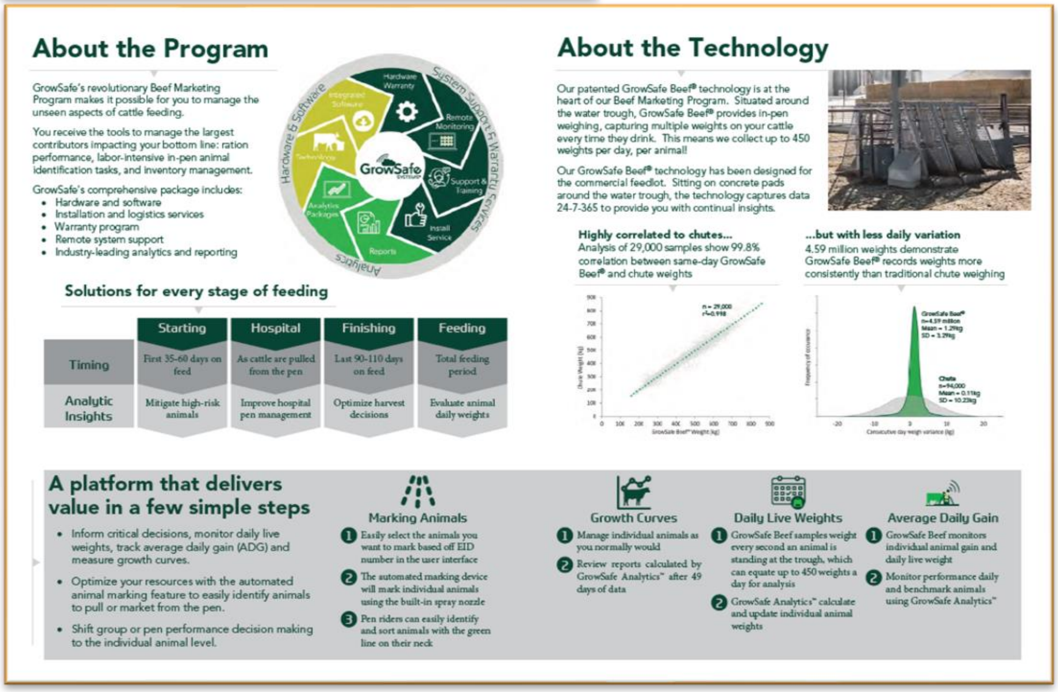
Performance Management
- Manage variation by individual animal and pen
- Rank animals or the pen for action

Animal Well-being
- Observe changes in individual animal behavior
- Reduce stress and injury related animal handling

Nutrition Insights
- Assess rations and performance of individual animals
- Feeding regimen verification

Labor Optimization
- Marking functionality reduces labor-intensive in-pen identification
- Decrease the number of trips through the chute

Marketing
- Market more uniform loads of cattle
- Reduce heavy- and light-weight carcasses
- Improve premiums for grid-based marketing



About the Program

GrowSafe's revolutionary Beef Marketing Program makes it possible for you to manage the unseen aspects of cattle feeding.

You receive the tools to manage the largest contributors impacting your bottom line: ration performance, labor-intensive in-pen animal identification tasks, and inventory management.

GrowSafe's comprehensive package includes:
- Hardware and software
- Installation and logistics services
- Warranty program
- Remote system support
- Industry-leading analytics and reporting

Solutions for every stage of feeding

	Starting	Hospital	Finishing	Feeding
Timing	First 35-60 days on feed	As cattle are pulled from the pen	Last 90-110 days on feed	Total feeding period
Analytic Insights	Mitigate high-risk animals	Improve hospital pen management	Optimize harvest decisions	Evaluate animal daily weights

About the Technology

Our patented GrowSafe Beef® technology is at the heart of our Beef Marketing Program. Situated around the water trough, GrowSafe Beef® provides in-pen weighing, capturing multiple weights on your cattle every time they drink. This means we collect up to 450 weights per day, per animal!

Our GrowSafe Beef® technology has been designed for the commercial feedlot. Sitting on concrete pads around the water trough, the technology captures data 24-7-365 to provide you with continual insights.

Highly correlated to chutes...
Analysis of 29,000 samples show 99.8% correlation between same-day GrowSafe Beef® and chute weights

...but with less daily variation
4.59 million weights demonstrate GrowSafe Beef® records weights more consistently than traditional chute weighing

A platform that delivers value in a few simple steps

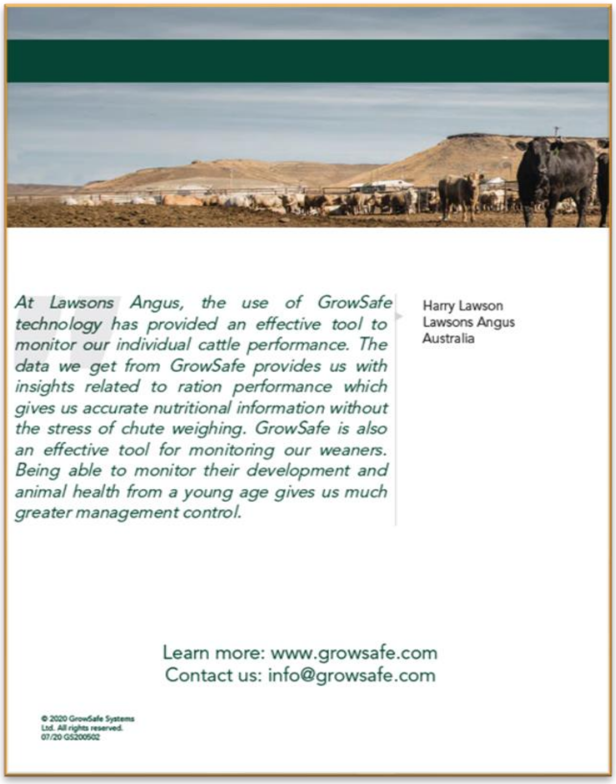
- Inform critical decisions, monitor daily live weights, track average daily gain (ADG) and measure growth curves.
- Optimize your resources with the automated animal marking feature to easily identify animals to pull or market from the pen.
- Shift group or pen performance decision making to the individual animal level.

Marking Animals
1. Easily select the animals you want to mark based off EID number in the user interface
2. The automated marking device will mark individual animals using the built-in spray nozzle
3. Pen riders can easily identify and sort animals with the green line on their neck

Growth Curves
1. Manage individual animals as you normally would
2. Review reports calculated by GrowSafe Analytics™ after 49 days of data

Daily Live Weights
1. GrowSafe Beef samples weight every second an animal is standing at the trough, which can equate up to 450 weights a day for analysis
2. GrowSafe Analytics™ calculate and update individual animal weights

Average Daily Gain
1. GrowSafe Beef monitors individual animal gain and daily live weight
2. Monitor performance daily and benchmark animals using GrowSafe Analytics™



At Lawsons Angus, the use of GrowSafe technology has provided an effective tool to monitor our individual cattle performance. The data we get from GrowSafe provides us with insights related to ration performance which gives us accurate nutritional information without the stress of chute weighing. GrowSafe is also an effective tool for monitoring our weaners. Being able to monitor their development and animal health from a young age gives us much greater management control.

Harry Lawson
Lawsons Angus
Australia

Learn more: www.growsafe.com
Contact us: info@growsafe.com

Figure 18. Beef Marketing Program commercial platform and details.

The feedlot monitoring reports, shown in Figure 19 provided to customers on the Beef Marketing Program, allow them to make informed management decisions that indirectly reduce GHG emissions in their feedlots. The reports display average daily gains (ADGs), current weights, start weights, feedlot entry dates, lot allocations, pen average weights and pen average gains. Additionally, the forecasted 30-day hot carcass weights are reported to provide insight into when animals may be ready for slaughter based on their current weight and past performance. Customers on the Beef Marketing Program can also receive the general weight report in Figure 20 which shows them their animals' current and previous weights, along with their current ADG and recent trends in ADG. It also flags animals that begin to lose weight. The data allows feedlot operators to individually manage cattle on feed to enhance their performance which will minimize GHG emissions.

Vytelle INSIGHT

BEEF MARKETING: Forecasting Report

Animal Performance Summary

Customer:	Vytelle Feeders
Units:	Lbs
Report Date:	2021-04-07

	System Performance Summary			Animal Performance Summary				Forecast Summary
Summary	First Valid IPW Dt	Last Valid IPW Dt	Days on System	First Valid IPW Wt	Current IPW Wt	Total Gain on IPW	IPW ADG	30d Forecast HCW
Min	2020-05-27	2021-03-10	46	438.45	543.32	41.70	0.08	841
Max	2021-02-24	2021-04-05	309	1458.31	1973.24	805.96	4.31	1140
Average	2020-10-03	2021-04-04	182	887.77	1278.33	390.56	2.19	963

Animal Information								System Performance			Animal Performance				Forecast
EID	VID	Lot	Lot Entrance Dt	Lot Entrance Chute Wt	Breed	Sex	Current Pen	First Valid IPW Dt	Last Valid IPW Dt	Days on System	First Valid IPW Wt	Current IPW Wt	Total Gain on IPW	IPW ADG	30d Forecast HCW
982000427405202	3240	466	2020-04-14	823.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	935.89	1734.55	798.66	2.62	1140
982000427404552	3320	466	2020-04-14	831.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	913.84	1719.80	805.96	2.63	1136
982000427404364	3336	466	2020-04-14	831.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	895.59	1691.97	796.38	2.63	1115
982000427404535	3273	466	2020-04-14	725.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	307	878.48	1637.52	759.04	2.56	1105
982000427405149	3229	466	2020-04-14	809.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	921.35	1707.84	786.48	2.56	1099
982000427404475	3289	466	2020-04-14	778.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	896.03	1657.51	761.47	2.44	1089
982000427405221	3409	466	2020-04-14	787.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	895.36	1680.80	785.44	2.57	1089
982000427404314	3219	466	2020-04-14	742.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	942.75	1634.30	691.55	2.46	1088
982000427404232	3366	466	2020-04-14	778.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	305	891.35	1653.91	762.56	2.43	1086
982000427404219	3249	466	2020-04-14	831.00	Wagyu	Heifer	Pen 47	2020-05-29	2021-04-05	308	934.89	1686.86	751.97	2.42	1086
982000426733331	3364	466	2020-04-14	767.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	305	897.82	1630.74	732.92	2.53	1085
982000427404627	3325	466	2020-04-14	836.01	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	929.12	1630.87	701.75	2.22	1082
982000427405251	3263	466	2020-04-14	756.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	911.94	1634.33	722.39	2.38	1075
982000427404081	3222	466	2020-04-14	811.01	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	307	933.45	1626.89	693.44	2.22	1070
982000427404082	3298	466	2020-04-14	801.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	908.82	1619.41	710.59	2.41	1070
982000427404703	3311	466	2020-04-14	770.99	Wagyu	Heifer	Pen 47	2020-05-28	2021-04-05	307	884.08	1601.75	717.67	2.43	1065
982000427404056	3174	466	2020-04-14	754.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	864.41	1587.75	723.34	2.42	1061
982000427404385	3307	466	2020-04-14	812.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	306	922.61	1620.55	697.94	2.27	1060
982000427404457	3193	466	2020-04-14	691.01	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	805.92	1604.79	798.87	2.53	1054
982000427404909	3351	466	2020-04-14	792.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	305	905.97	1610.76	704.80	2.28	1050
982000427405061	3341	466	2020-04-14	798.99	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	308	897.29	1603.19	705.90	2.28	1043
982000427404019	3245	466	2020-04-14	783.01	Wagyu	Heifer	Pen 47	2020-05-28	2021-04-05	308	861.17	1547.77	686.60	2.28	1034
982000427404046	3316	466	2020-04-14	767.99	Wagyu	Heifer	Pen 47	2020-05-29	2021-04-05	308	816.02	1560.59	744.57	2.42	1033
982000427404325	3218	466	2020-04-14	776.00	Wagyu	Heifer	Pen 47	2020-05-27	2021-04-05	307	851.46	1537.87	686.41	2.23	1023

Figure 19. Beef Marketing Report that provides insight into feedlot animal weight, gain and 30-day projected hot carcass weights.

VYTELLE WEIGHT REPORT - PEN-Pen 47

VERSION: v.05.03 - F.1.708

Customer: Vytelle Ranch

Initial/Final Range:	2019-04-08 / 2019-08-29
Weight Unit:	LBS

				04-08_to_04-21	04-22_to_05-05	05-06_to_05-19	05-20_to_06-02	06-03_to_06-16	06-17_to_06-30	07-01_to_07-14	07-15_to_-		
PEN-Pen 47	**EID**	**Tag1**	**ADG_ALL**	**14dSET_01**	**14dSET_02**	**14dSET_03**	**14dSET_04**	**14dSET_05**	**14dSET_06**	**14dSET_07**	**14dSET_08**	**COUNT_WEIGHT**	**TOTAL_DAYS**
Pen 47	982000426732487	(blank)	2.81	2.24	2.92	3.49	2.65	3.66	1.89	2.39		98	102
Pen 47	982000426732488	(blank)	2.25	-0.07	2.30	2.25	2.97	3.10	1.96	1.24		97	102
Pen 47	982000426732490	(blank)	2.27	2.33	1.06	2.50	3.06	2.23	2.32	2.30		98	102
Pen 47	982000426732493	(blank)	2.73	0.62	2.74	3.14	3.39	2.53	3.07	1.66		98	102
Pen 47	982000426732494	(blank)	2.72	1.16	2.87	3.38	3.83	1.48	2.98	1.29		98	102
Pen 47	982000426732495	(blank)	2.64	1.59	2.78	3.82	2.98	2.68	1.32	2.68		98	102
Pen 47	982000426732496	(blank)	2.40	2.55	2.04	2.92	2.75	2.75	0.48	3.95		98	102
Pen 47	982000426732497	(blank)	2.81	2.45	2.84	3.38	3.22	2.57	2.35	2.46		98	102
Pen 47	982000426732500	(blank)	2.89					2.63	3.75	2.14		46	102
Pen 47	982000426732501	(blank)	2.26	2.08	2.60	2.86	2.77	1.24	2.34	1.88		98	102
Pen 47	982000426732502	(blank)	2.78	2.94	1.90	2.46	3.80	2.46	2.86	2.61		96	102
Pen 47	982000426732505	(blank)	2.20	0.97	2.83	2.45	2.77	1.95	1.89	2.36		98	102
Pen 47	982000426732506	(blank)	2.81	2.34	3.18	2.71	3.34	2.21	3.02	2.30		97	102
Pen 47	982000426732508	(blank)	3.16	2.27	3.12	4.00	3.08	2.87	3.15	1.95		98	102
Pen 47	982000426732510	(blank)	2.73	2.36	2.63	3.70	3.98	2.08	1.17	2.69		98	102
Pen 47	982000426732511	(blank)	2.92	0.18	4.06	2.90	4.38	1.35	3.70	2.31		97	102
Pen 47	982000426732514	(blank)	2.44	-1.22	2.24	2.71	3.12	2.44	2.26	2.96		98	102
Pen 47	982000426732516	(blank)	2.32	1.42	3.11	2.71	2.36	2.12	1.55	2.74		98	102
Pen 47	982000426732517	(blank)	2.77	2.38	2.89	2.95	3.66	2.16	2.51	2.76		98	102
Pen 47	982000426732519	(blank)	2.37	1.50	2.34	2.87	2.95	0.61	1.52			73	102
Pen 47	982000426732520	(blank)	3.27	2.59	2.94	4.07	3.72	2.51	3.59	1.74		97	102
Pen 47	982000426732523	(blank)	2.96	2.14	2.99	4.36	2.76	2.68	1.84	2.95		98	102
Pen 47	982000426732527	(blank)	2.07	2.57	1.80	3.07	2.48	1.19	2.03	1.20		97	102
Pen 47	982000426732529	(blank)	2.86	1.41	2.33	3.68	3.58	2.60	2.82	1.44		98	102
Pen 47	982000426732531	(blank)	2.43	0.44	1.92	2.86	3.38	2.40	1.99	2.15		98	102
Pen 47	982000426732533	(blank)	3.05	2.68	3.63	3.42	3.76	2.16	3.04	2.13		98	102
Pen 47	982000426732536	(blank)	2.52	1.42	2.94	2.56	3.40	2.94	0.84	2.91		98	102
Pen 47	982000426732538	(blank)	2.01	2.79	1.13	3.46	1.44	2.37	0.85	3.53		98	102
Pen 47	982000426732539	(blank)	2.96	2.80	3.65	3.77	3.65	2.83	1.13	2.55		97	102
Pen 47	982000426732542	(blank)	3.00	0.85	3.25	3.63	3.70	2.35	2.51	2.92		97	102
Pen 47	982000426732543	(blank)	2.00	2.02	2.28	2.99	2.47	1.27	0.91	2.45		98	102
Pen 47	982000426732544	(blank)	2.54	2.73	2.80	2.58	3.14	2.58	1.70	2.59		98	102
Pen 47	982000426732545	(blank)	2.55	1.58	1.94	2.25	4.38	2.43	0.88	3.40		97	102

Figure 20. Weight report provided to customers on the Beef Marketing Program that shows changes in animal and pen average daily gain (ADG) for management purposes.

Benefits

The Beef Marketing Program, and its reports, allow feedlot producers to manage individual animals to ensure they are maximizing their performance, which, in-turn, reduces GHG emissions. The program also allows for the identification of poor performing animals that produce greater GHG emissions. Identification of these animals is important because it provides an opportunity to improve management practices which can improve performance and therefore reduce GHG emissions. A one-unit improvement in feed to gain (F:G) can reduce GHG emissions by 2 kg Co_{2e} emissions per kg of beef produced, on a regular 400 kg carcass that results in an 800 kg difference in CO_{2e} emissions. The Beef Marketing Program is unique because it allows for continuous, non-invasive monitoring of individual animals for management purposes. Future programs should consider how selection for feed efficiency in the cow-calf herd can impact F:G in the feedlot and reduce GHG emissions. Information on the Beef Marketing program can be found on the Vytelle.com website, shown in Figure 17, which provides information regarding the program and resources for producers interested in individually monitoring feedlot cattle for growth and performance to enhance the efficiency and sustainability of their operations.

Overall Conclusion

The purpose of this project was to deploy an advanced analytics platform to quantify livestock greenhouse gas (GHG) emissions and to monitor reduction strategies on individual animal and whole operation scales. The project was broken down into two components, Part A) the Data Repository and Part B) the Feedlot Demonstration. The data repository overview involved development of a robust database that would allow for calculation of individual animal efficiencies and emissions. Through the process of historical data curation, it was recognized that the external researchers who had been providing residual feed intake (RFI) analyses on data collected using the Vytelle SENSE system, were applying different models, and calculating RFI in an unstandardized manner. The lack of standardization forced Vytelle to re-calculate all historical records and provide further standardization protocols to ensure that all efficiency records included in the database were collected and analyzed in the same manner. Through the standardization process, it was also recognized that ration information could be further standardized through the addition of ration effective energy in RFI calculations. Although this may still be applied in the future, at the time it was not considered practical due to the inconsistent ration information received from customers, as only some would provide the extensive information required for the effective energy calculation. Following development of the efficiency database and EPD services, it was noted that customers using the feed efficiency EPDs, were making improvements in their estimated GHG emissions and sustainability. Following the establishment of the *Quantification Protocol for Selection for Low Residual Feed Intake in Beef Cattle* in Alberta, it was determined that although a 3-year baseline is required before credits can be filed, it may be advantageous to develop a protocol that allows customers to capture credits over a shorter timeframe, or establishing a baseline using the extensive data already available in the database. Requiring a shorter timeframe will potentially allow producers to see a benefit and payoff earlier, further incentivizing them to select for feed efficiency.

The Feedlot Demonstration was used to determine how the In-Pen Weighing Positions could be used to monitor feedlot cattle for performance and market readiness, and the direct impact this monitoring would have on the efficiency and sustainability of the cattle. Throughout the feedlot monitoring phases it was discovered that the In-Pen Weighing Positions' ability to monitor cattle weights was impacted by ice and manure buildup during cold winter months. Ice buildup was especially problematic between the In-Pen Weighing Positions and the water trough, which affected accurate weight collection. To combat this, metal plates were added to the back of the In-Pen Weighing Positions to prevent water from pooling and freezing underneath the weight platform. The addition of metal plates improved the quality of weight data collection. The shipping calculator which was expected to be used throughout the entire duration of the project, was only used for a single monitoring period as it was found that daily data points required from the customer were difficult to provide. Therefore, the calculator was not used during all the project, and the models behind the shipping calculator were modified to require as little data from the customer as possible, making it more applicable. Although selection for feed efficiency was being done in Part A of the project, the progeny of the cattle in Part A were not followed through to the feedlot so it was difficult to understand whether differences in efficiency in the feedlot were more dependent on management practices or animal genetics. Follow-up studies should be done to monitor animals with divergent efficiency in the feedlot to determine how a combination of continuous monitoring, using the In-Pen Weighing Positions, and individual animal feed efficiency can further reduce GHG emissions and improve the sustainability of beef production. Through commercialization of the Beef Genetics and Beef Marketing Programs, it has been found that over the years, producers are more interested in data, and using data to make informed breeding and management decisions. Although they are interested in using data to enhance their daily operations, we have discovered that not all producers understand how to use the data to optimize their operational efficiency and sustainability. Additionally, although we may design programs that target specific traits such as RFI, breeders use a multi-trait selection approach that places different emphasis on traits that meet their needs, which may not maximize their offspring's potential for efficiency. Therefore, it is difficult to estimate the improvement customers will make in efficiency and sustainability when receiving breeding values or when using the In-Pen Weighing Positions. Further report development should be done to assist customers in making management and breeding decisions to enhance their overall efficiency.