TECHNICAL NOTE

Feed prediction and management software for beef feedlots

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Dyck, N.D., Crowe, T.G., McKinnon, J.J. and Ingelby, H.R. 2007. **Feed prediction and management software for beef feedlots**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **49**: 7.11 - 7.16. A software package was developed to assist human operators with feed management at beef feedlots. Mobile computers were used to record quantities of feed delivered and of residual feed, along with the proportions of various feed components in each batch of feed delivered. The software thus provided an accurate historical record of feed intake patterns. The software also incorporated an algorithm for predicting required feed quantities, based on the feed intake history and on a set of management rules for cattle being fed step-up rations. Software performance was evaluated by comparing the feed quantity predictions made by the software with those made by feedlot staff. During this evaluation, the feed-prediction software did not increase feed predictions at a rate fast enough to match the appetites of the cattle. It also was found that the feed-prediction software reduced feed predictions too greatly in response to excessive residual feed levels. Further testing of the software will be required to improve the feed prediction accuracy and responsiveness to varying feed intake patterns. **Keywords**: cattle feeding, cattle nutrition, feed prediction software.

Un logiciel d'assistance à la gestion de l'alimentation des bovins en parc d'engraissement a été développé. Des ordinateurs portables étaient utilisés pour enregistrer les quantités d'aliments servies et les quantités résiduelles ainsi que la proportion des différents ingrédients utilisés dans chacun des mélanges servis. Le logiciel procurait ainsi un registre précis des patrons de prise alimentaire. Le logiciel comprenait aussi un algorithme de prédiction de la quantité des ingrédients requis basé sur l'historique de prise alimentaire et une série de règles de gestion pour des bovins alimentés à partir de rations évolutives. La performance du logiciel a été évaluée en comparant les prédictions des quantités d'aliments par le logiciel avec celles faites par les employés du parc d'engraissement. Durant cette évaluation, les prédictions d'ingrédients du logiciel n'ont pas augmenté à un taux suffisamment rapide pour satisfaire les besoins croissants des bovins. Il a aussi été observé que le logiciel de prédiction d'ingrédients réduisait les prédictions d'aliments de manière trop importante lorsque les quantités d'aliments résiduels étaient élevées. Il faudra donc continuer de tester le logiciel pour améliorer la précision de prédiction d'aliments et l'ajustement à différents patrons de prise alimentaire. **Mots clés**: alimentation des bovins, nutrition bovine, logiciel de prédiction de l'alimentation.

INTRODUCTION

In North America, beef cattle are fed high-grain diets to prepare them for market. Grain is fed to cattle because it is inexpensive, easy to transport, and easy to process. Feeding cattle a high-grain diet results in more rapid growth and reduces the quantity of feed required per unit of body-weight gain (Woody et al. 1983).

High-grain diets are not natural for cattle because their digestive systems are more suited for the digestion of forages. Careful management of high-grain diets is thus required to prevent digestive disturbances and to maximize feedlot productivity (Horton 1990).

Rumen acidosis is a digestive disturbance that can temporarily depress the animal's appetite, cause erratic feed intake, or even kill the animal (Owens et al. 1998). It can cause liver damage, resulting in reduced weight gain (Nagajara and Chengappa 1998) and may also result in bloat or laminitis, both of which can reduce animal performance (Cheng et al. 1998). Clearly, acidosis can have an economic impact at the feedlot.

An important tool in minimizing potential digestive disturbances resulting from high-grain diets, such as acidosis, is the use of step-up rations. Step-up rations are a series of rations that contain an increasing proportion of grain. Feeding step-up rations allows the rumen microbial population to adapt to the increasing proportion of grain in the diet (Horton 1990).

Effective usage of step-up rations requires careful management of the composition and quantity of feed delivered to cattle. Predictions of the amount of feed required on a given day are based on the amounts of feed delivered and consumed on previous days. This record of the feed that was consumed by the pens of cattle over the feeding period is called a feed-intake history. The feed-intake history is important because a digestive upset caused by an error in feeding may not be evident for several days afterwards. Without a record of how much the cattle have been consuming and how much feed has been delivered, it can be difficult to diagnose and correct the mistake (Pritchard 1993).

At many feedlots, the exact amount of feed delivered to pens of cattle is not recorded. Instead, only the target amount is

recorded. Actual amounts delivered to the pens, which may differ from the target, are not recorded. As a result, an accurate feed-intake history for the cattle is not available.

The hypothesis in this study was that a software application that created a more accurate feed-intake history could minimize the problems associated with feeding high-grain diets to cattle. Further, the software-based feed-management system could assist the feedlot operators by making more accurate feed predictions that were based upon actual feed delivery amounts. Some feedlots do use automated systems for recording the content and quantity of feeds delivered to pens of cattle. Further, most feedlots implement well defined strategies for advancing cattle from forage-based diets to grain based diets. However, the combination of these elements (data collection and feed quantity prediction) within a single computerized management system has not been reported. Computers could be used for all of the data collection and archiving, eliminating the need for manual data entry into paper-based records. This could save time and reduce the errors associated from paper-based record keeping.

Software-based feed prediction thus offers at least two potential benefits. First, making feed predictions based on an accurate feed intake history and using an established set of known rules may improve feeding consistency and thus assist in optimizing performance. Second, given the chronic lack of skilled labor in the cattle feeding industry, a software-based expert system may help busy feedlot staff to perform their jobs more efficiently.

OBJECTIVES

The objectives of this project were:

1. to develop a software package that recorded feed management data (feed-intake history) and used this information to provide predictions of required feed quantities, and
2. to monitor the feed quantity predictions made by the software, relative to typical recommendations by the feedlot staff.

MATERIALS and METHODS

The system developed for this project consisted of hardware and software. The system was installed and tested at the University of Saskatchewan Research Feedlot at Saskatoon, Saskatchewan. The hardware component of the system consisted of a network of three computers linked via wireless ethernet connection. The software component of the system consisted of proprietary software obtained from a commercial company (LV Controls, Winnipeg, MB) and feed quantity prediction (FQP) software created specifically for this project.

Hardware

Three portable computers (Toshiba America Information Systems, Irvine, CA) were connected through a wireless access point (Linksys, Irvine, CA) via an ethernet hub (3Com, Santa Clara, CA) and PCMCIA ethernet cards (Linksys, Irvine, CA). The first computer, called the mill computer, executed the FQP software and archived the feed history data. The second computer executed proprietary software that recorded the mass of ingredients used in each batch of feed and the amount of feed that was delivered to the pens. A digital scale indicator (Digi-Star, Ft. Atkinson, WI), located in the cab of the tractor was connected to load cells in the feed-mixer wagon. The digital scale indicator had a serial communication interface that allowed it to send information to the serial communication port on the computer in the feed wagon tractor. The third computer executed proprietary software that recorded the amounts of residual feed present in the bunks and the number of animals in each pen prior to feeding.

Feed quantity prediction software

The FQP software estimated the quantity of feed required by the cattle at each daily feeding. The software used the quantity of feed left in the bunk at 0800h, called the residual feed, to determine whether the quantity of feed delivered to each pen should be increased, decreased, or maintained at the same level, relative to the quantity of feed delivered on the previous day. A flowchart of the algorithm used to produce the feed quantity estimates is shown in Fig. 1.

The algorithm operated on data retrieved from a feed history database. These data included previously delivered feed quantities and residuals, the number and average mass of animals in each pen, and values for various FQP parameters as determined by feedlot staff. The output of the algorithm was the predicted amount of feed required for the pen for the current day on an as-fed basis ($PredictedAF_n$) in kilograms. This was calculated from the quantity of feed dry matter predicted for the current day ($PredictedDM_n$), the number of cattle in the pen ($NumHead_n$), and the feed dry matter concentration for the current day ($FeedDMc_n$).

A target range for the mass of residual feed present on each day of feeding was established by the feedlot staff. This target range was called the acceptable range for residual feed. When residual feed quantities were within this range, the quantity of feed delivered to the cattle on the previous day was assumed to match the animal's ability to consume it, and feed quantities for the current feeding should remain at the previous day's level.

When residual feed quantities were greater than the acceptable range, too much feed was delivered to the cattle on the previous day and the software predicted that feed quantities for the current feeding should be reduced, relative to the previous day's feed delivery.

When residual feed quantities were less than the desired range, it meant the quantity of feed delivered to the cattle on the previous day might be inadequate. Feed quantities for the current feeding might need to be increased.

The size and frequency of increases to feed predictions were determined using a management parameter called the dry-matter intake:body weight ratio (DMI/BW). The DMI/BW was the quotient of the average dry-matter intake per head and the average individual animal weight for all animals in a given pen. Five ranges of DMI/BW were used in this project. Each range had corresponding values for two parameters: *Increase* and *Rest Days*. The *Increase* parameter was the percentage increase in the quantity of feed dry matter delivered relative to that of the previous day. The *Rest Days* parameter was the number of days that had to elapse between feed increases. The DMI/BW ranges used for this project, along with the associated

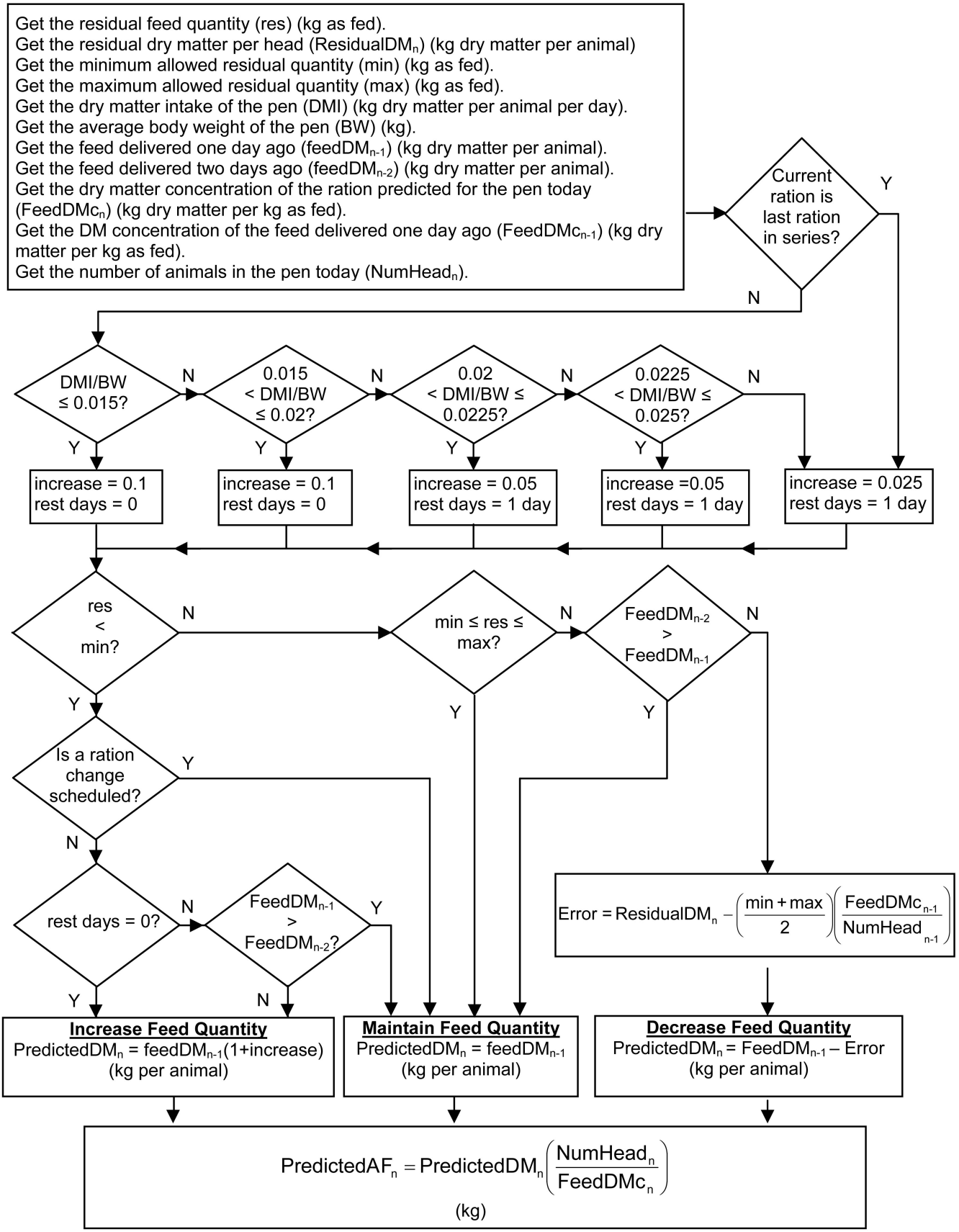

Fig. 1. Flowchart of the process for predicting feed quantities.

Table 1. Dry-matter intake to body-weight (DMI/BW) parameters.

DMI/BW (%)	Increase* (%)	Rest Days** (days)
0 to 1.5	10	0
1.5 to 2.0	10	0
2.0 to 2.25	5	1
2.25 to 2.50	5	1
> 2.5	2.5	1

* Size of dry-matter increases, relative to previous day's feed dry matter delivered.

** Number of days that must elapse between subsequent feed increases.

Increase and *Rest Days* values, are given in Table 1. The DMI/BW ratio was only used when the pens were fed step-up rations. When the cattle were fed the final ration in the series, increases were limited to 2.5% of the previous day's delivery on a dry matter basis, with one rest day between increases.

Feed increases occurred when no other feed increases had occurred within the specified number of *Rest Days* and a ration change was not scheduled. If previous feed increases had occurred within the specified number of *Rest Days* or a ration change was scheduled, the quantity of feed predicted for the pen was equal to the amount of feed delivered to the pen on the previous day.

Weight-prediction software

The DMI/BW ratio required the knowledge of animal body weight. However, animals at a commercial feedlot are not weighed on a daily basis. Thus, weight-prediction models were used to provide an estimate of average animal weight. The weight-prediction software was based upon equations published by the National Research Council (2000). These equations allowed animal body weight gain to be calculated based upon animal dry matter intake and the energy density of the diet.

Feed-intake history

A database (Access, Microsoft Corp., Redmond, WA) contained the feed intake history. The purpose of the feed-intake history was to create a record of the quantity of feed delivered to the pens of cattle so that their feed intakes could be determined. The database recorded the number of animals in the pens so that feed predictions could be adjusted if the number of animals in the pen changed.

The feed ingredient quantities used in the feed batches were also recorded, along with the portion of each batch delivered to the pens. This allowed the feed dry matter and the energy density of the rations delivered to the pens to be determined. The database also contained an ingredient inventory, which contained the dry matter and energy concentrations of each feed ingredient. A ration inventory defined the ingredients present in each ration, as well as the feeding order and feeding duration of each ration.

TESTING

Testing was conducted from November 7 to 23, 2001. Ten pens with 13 calves per pen and 10 pens with 14 calves per pen were used. The cattle in each pen were fed once per day each morning. The ration contained 40% barley silage, 25% hay, 27% barley grain, and 8% pelleted supplement, on an as-fed basis. The estimated residual feed levels and number of animals in each pen were recorded at 0800h each day. The amount of residual feed per pen was visually estimated by trained feedlot staff, and the animal count was determined by noting any changes (removal from or additions to the pen during the previous 24 hours) from the count on the previous day and applying this to the inventory on the previous day. The quantities of each feed ingredient used in batches of feed and the amounts of feed delivered to each pen were recorded.

Table 2. Limits of the acceptable range of residual feed.

Day of testing	Acceptable residual* (%)
1-11	0.0 - 5.0
12-14	2.5 - 10.0
15-17	5.0 - 10.0

* Percentage of previous day's feed delivered.

The mill computer executed the feed-prediction software. The DMI/BW parameters shown in Table 1 were used to determine the magnitude and frequency of increases to predicted feed quantities.

The pens of cattle were fed according to the software-based feed predictions, pending approval of the feedlot staff. The feedlot staff reviewed the software-based feed predictions, and if no changes were required, the pens were fed accordingly. If changes to the feed quantities were requested, these changes were used in place of the software-based feed predictions.

During the test, the acceptable range of residual feed was defined as a percentage of the feed delivered to the pen on the previous day. Over the course of the test, the feedlot staff suggested it would be beneficial to increase this limit. These changes are listed in Table 2.

During the test, the quantity of feed delivered was reduced by a quantity equal to 133% of the residual, when residual was present. This value was arbitrarily selected, after consultation with the feedlot staff. It was set at this value because it was believed that this would reduce the total feed delivered to the bunk, forcing the animals to consume the residual feed and helping to ensure that subsequent residuals would be within the desired range. Feed levels were reduced each day that residuals were too large.

RESULTS and DISCUSSION

Daily predicted feed quantities and residual feed levels were plotted for each pen. Two patterns occurred repeatedly in these plots. Figure 2 shows the plot for Pen 8, which displays the first of these two patterns. In this plot, and in plots for pens with similar behavior, the residual feed levels are initially somewhat high, but then become almost zero for a sequence of several days. This suggested that the FQP software was unable to increase the quantity of feed delivered to the cattle at a rate fast enough to match their appetites. If this is the case, the software should be modified so that it is able to increase feed at a faster rate. It must be noted, however, that this could increase the risk

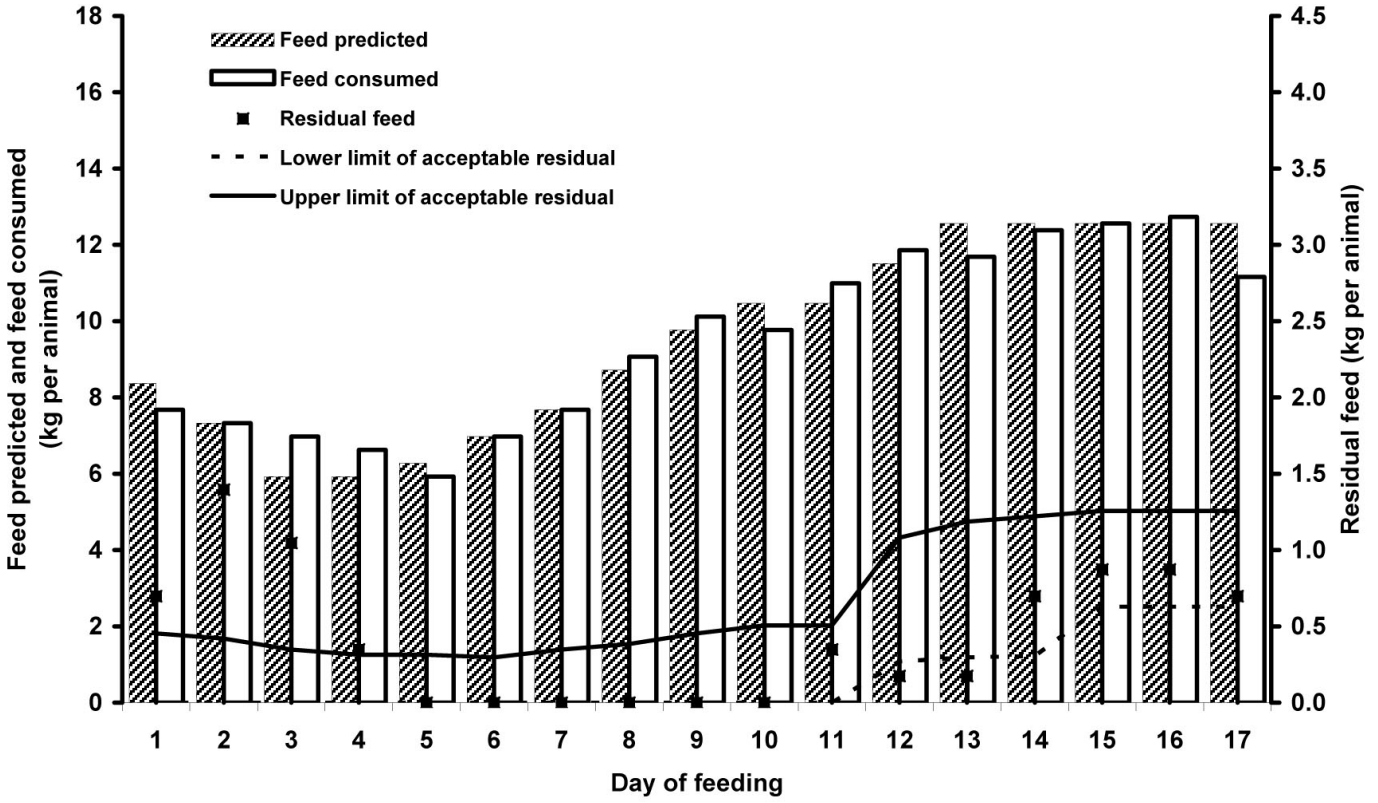

Fig. 2. Feed quantity predictions and residual feed levels for Pen 8.

of the cattle experiencing acidosis. A second option is to leave the increase sizes at the current values and accept that there will be a certain frequency of empty bunks during feeding.

Figure 3 shows the second dominant pattern, this time for Pen 18. In this and similar pens, a cyclical feed intake pattern is evident. The first cycle of this pattern occurred because the FQP software reduced the feed delivery on several consecutive days (days 1 to 6). On day 7, the feedlot staff suggested that the feed had been reduced too greatly and their predictions were used in place of the software-based feed predictions. This is what caused the increase in predicted feed on day 7. The second cycle of this pattern occurred between days 7 and 11. Again, the FQP software reduced the predicted feed quantities over several consecutive days. On day 12, the feedlot staff suggested again that the feed delivery had been reduced too greatly and their feed predictions were used in place of the software-based feed predictions. This is what caused the increase in predicted feed on day 12.

The cyclical intake patterns suggested that the FQP software reduced feed quantities too rapidly when residual feed quantities were too large. There are several possible reasons for this behavior. First, the feed reduction factor of 133% of the residual may have been too large. Second, allowing feed delivery quantities to decrease on consecutive days may cause feed levels to decrease too rapidly. Third, defining the levels of acceptable residual as percentages of the previous day's feed delivery may have contributed to the problem. When feed quantities were reduced, the level of acceptable residual decreased as well. When the upper limit of the acceptable residual was decreased, the FQP software became more sensitive to residual quantities. In other words, residual feed quantities that would previously have resulted in the FQP software maintaining, or even increasing estimates of the required feed, instead resulted in a decrease in these estimates.

Performance of the system hardware was also evaluated. No serious difficulties were encountered, and hardware performance was thus rated as very satisfactory.

CONCLUSIONS

In testing, the FQP software was observed to reduce feed quantities too rapidly. The software has subsequently been modified so that decreases in feed quantities cannot occur on consecutive days.

For this test, the acceptable range for residual feed was defined as a percentage of the previous day's feed delivery. This meant that when feed quantities were reduced, so too were the limits of the acceptable range. Consequently, when residuals were too large, the FQP software was more likely to reduce feed quantities instead of maintaining or increasing them. It was concluded that defining the limits of acceptable residual as fixed quantities, rather than percentages, should alleviate this problem.

In testing, the software was unable to increase feed quantities at a rate fast enough to match the appetites of the cattle. This indicated that the magnitudes of feed increases should be increased, or a certain frequency of empty bunks should be accepted as a normal part of the feeding process.

Overall, the FQP software provided estimates of required feed quantities that corresponded well with the

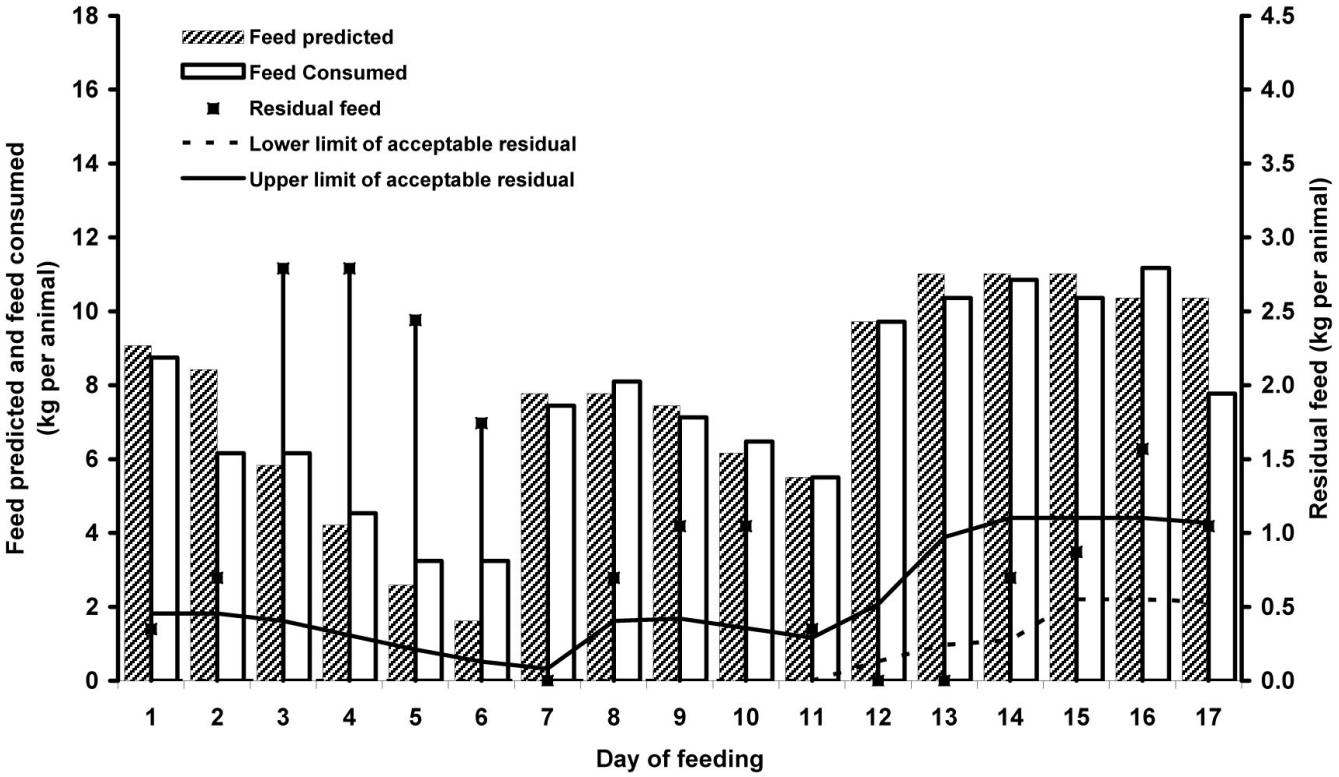

Fig. 3. Feed quantity predictions and residual feed levels for Pen 18. On days 7 and 12, feed predictions made by feedlot staff were used in place of those made by the feed-prediction software.

recommendations of the feedlot staff. However, in specific instances, particularly when cyclical feed patterns were apparent, staff recommendations were used instead of software-predicted values. Further testing is recommended in order to determine optimal values of feed prediction parameters for the FQP software.

ACKNOWLEDGEMENTS

This project was funded by Saskatchewan Agriculture and Food, Agriculture Development Fund. The authors thank the staff from the University of Saskatchewan Beef Research Centre for their cooperation and input during this project.

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