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IMPORTANCE OF INCORPORATING FEEDING RATE WHEN DEVELOPING PREDICTIONS OF FEED INTAKE

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SUMMARY

Obtaining individual feed intake data under pastoral grazing studies is important for work relating to feed efficiency and greenhouse gas emissions, but is nearly impossible to obtain. Accelerometer technology has been used to determine the duration of grazing events, but data from feed intake facilities suggests that between-animal variation in feeding rate makes duration alone a poor proxy for feed intake. This study explored in detail the trait of feeding rate (feed eaten/feeding duration) on data collected through a feed intake facility. Feeding rate was demonstrated to be a very consistent trait of an individual animal across their feeding events with a high heritability (0.60 ± 0.14) and considerable between-animal variation. Using feeding rate and feeding duration accurately predicted feed intake. Future accelerometer work to predict feed intake should therefore emphasise whether or not feeding rate can be accurately determined in addition to feeding duration.

INTRODUCTION

There is increasing interest in being able to accurately determine the individual feed intake for use within studies relating to feed efficiency and greenhouse gas emissions. Whilst this can be achieved in feed intake facilities through either cut and carry of feed, or the use of feed intake recorded against electronic identification tags, limited options are available when animals are grazing at pasture. One possible approach in which the feed intake of animals grazing at pasture could be estimated is through the use of accelerometer data that can be classified to describe the behaviour of the animal at any point in time. Smith *et al.* (2016) used "the head of the cow is tilted downwards and positioned near the ground. The cow is either taking bites of the pasture or searching for the pasture" to classify animals as grazing. This definition was used by Greenwood *et al.* (2017) to estimate the individual intake of animals by multiplying the length of time an animal was classified as grazing by a constant to estimate intake. However, such a model assumes that all individuals consume feed at a constant rate. In feed intake facility studies, significant between animal variation in the rate at which animals eat has been demonstrated (Durunna *et al.* 2011; Johnson *et al.* 2022). Johnson *et al.* (2022) estimated the heritability of feeding rate to be 0.29 ± 0.10. Utilising the data set described by Johnson *et al.* (2022), the question of whether feeding rate could be a useful metric, together with feeding duration, to predict feed intake is explored.

MATERIALS AND METHODS

All animal experiments were conducted to meet the guidelines of the 1999 New Zealand Animal Welfare Act and were approved by the AgResearch Animal Ethics committees. Specific approval numbers were AEC13563, AEC13892, and AEC14221.

Animals. The data used in this study is described in detail by Johnson *et al.* (2022). In brief, individual feed intake data over 42 days (after 14 days adaptation) was collected on 986 ewe lambs in a feed intake facility utilising automated feeders which captured the weight of individual feeding events and their duration through the feeders being fitted with RFID readers which recorded which animal was in the feeder during a feeding event. Five cohorts of lambs recorded over three years made up the data set, with the animals sourced from two progeny test flocks and the AgResearch methane selection line flock. The animals were fed a lucerne pellet *ad libitum*.

Data cleaning and analysis. In the study of Johnson *et al.* (2022), data cleaning was carried out at the population level. In this study, data editing was carried out at the individual animal level as follows. For each animal, intake was regressed on duration, the upper and lower bounds of the 95% confidence interval determined, and any values lying outside of the bounds were deleted and the regression step was repeated to estimate the model goodness of fit (R^2). Approximately 6% of the data was deleted. From this revised data set, an estimate of feeding rate (FR) was determined, calculated as feed eaten divided by the duration of the individual feeding event. The overall FR was calculated as the average of all FR data across the 42 days for each individual.

To determine the consistency and utility of FR, the data set was split into two equal time periods of 21 days (PER1 and PER2). The measured average daily intake in PER2 was calculated. The average FR was calculated for each time period independently. The FR value from PER1 was multiplied by daily feeding duration (FD) in PER2 to provide an estimate of intake in PER2. The derived trait data were subsequently analysed to determine their relationships.

The heritability of FR across all of the data was estimated using a model fitted as described by Johnson *et al.* (2022) including fixed effects of birth-rearing rank, age of dam, contemporary group (cohort*flock) and a covariate of birthday deviation.

RESULTS AND DISCUSSION

The potential for accelerometers to generate feed intake data has been explored but models to date have been limited to using grazing duration as a proxy for intake. Whilst the dataset used in this study is generated from a feed intake facility it allows the value of the inclusion of FR to better predict intake to be assessed. Figure 1 demonstrates that feeding event duration alone is not an accurate predictor of the intake.

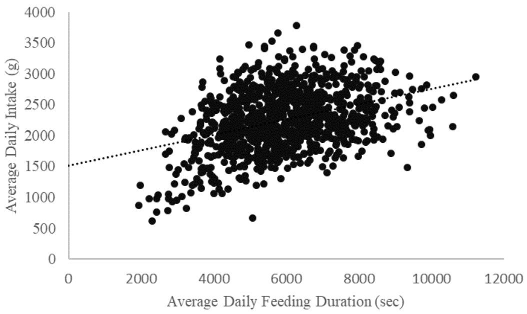


Figure 1. Average daily feeding duration for all animals plotted against their daily feed intake across full 42 day time period (R^2 = 0.14)

Figure 2 demonstrates between-animal differences in FR, and the consistency with which it presents for an individual animal. Contrasting between one animal which exhibited a low FR and as such for a FD of 500 seconds it only consumed 132g, compared with another animal exhibiting a high FR, consuming 327g of feed over 500 seconds. The R^2 of the associated regression models for these two animals was more than 0.86 indicating that the concept of rate is highly consistent across the 42 days of measurement for each animal. Across all animals, the average R^2 after one round of data cleaning was 0.89 with a range of 0.61 to 0.96, with the R^2 value greater than 0.80 for 96% of the animals. The average FR across all animals was 0.40 with a standard deviation of 0.11 and a coefficient of variation of 29%. Combined, these results indicate that for the majority of animals in the dataset, there is a very consistent relationship between the length of time that they are feeding and the amount of feed they are consuming within that time, but that individual animals feed at different rates such that some animals are “nibblers” with a very sow feeding rate and others are “guzzlers” with a very high feeding rate.

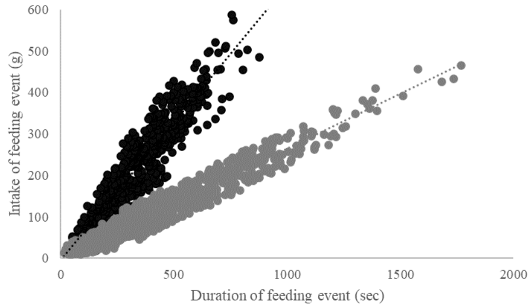
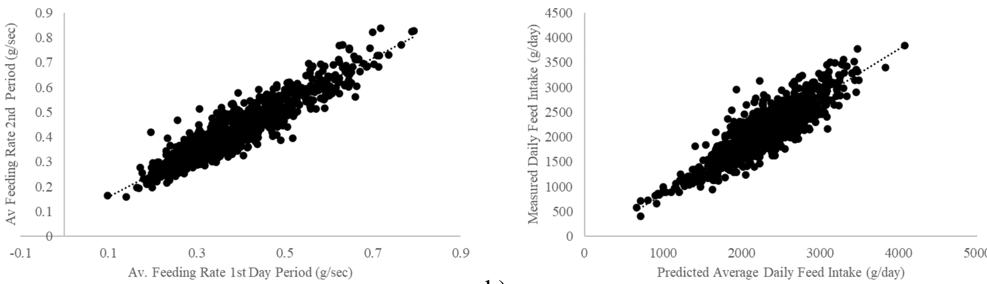


Figure 2. Examples of animals with high (black) feeding rate (model $R^2 = 0.87$) and low feeding rate (model $R^2 = 0.95$). Data points plotted are all feeding events across 42 days of individual feed intakes being measured, with outlier data points removed (beyond 95% confidence interval of original regression removed)

The next step was to explore the potential of FR to more accurately predict feed intake than FD alone. The dataset was split into two 21-day periods and FR was calculated for each period. Estimated feed intake in PER2 was calculated by multiplying the FR of PER1 trait by the daily FD. Figure 3 a) shows that FR for PER1 and PER2 were highly correlated. Although PER1 and PER2 were contiguous periods, it does demonstrate the consistency of the trait over 42 days. Figure 3 b) shows that by utilising the PER1 FR and FD an improved estimate of feed intake was obtained compared with using FD alone, and that FR at the individual animal level calculated on one data set was robust enough to be used with independent data.



a) b)

Figure 3. a) Average feeding rate calculated using data from the first 21-day time period plotted against the average feeding rate calculated using data from the second 21-day time period ($R^2 = 0.87$); b) Predicted average daily feed intake for the second 21-day period (using feeding rate calculated from the first 21 day period feeding rate multiplied by the average daily duration of feeding from the second 21 day period) plotted against the average measured feed intake for the second 21 day period (R^2=0.78)

The heritability estimate for FR was 0.60 ± 0.14. This value is considerably higher than 0.29 ± 0.10 reported for the same data set in Johnson *et al.* (2022), however, in that dataset rate data was cleaned at the population level, versus the individual animal level as was carried out in this current study, highlighting that whilst some values might be within population limits, they are inconsistent and anomalous for an individual animal.

Using the two animals in Figure 1 the intake predictions using FD or FD and PER1, FR are given in Table 1. Whilst both animals were measured to have eaten nearly identical amounts of feed, their FD were over two-fold different and as such a model only considering FD resulted in very different estimates of intake for the two animals, whereas the model incorporating FD and FR improved the estimates relative to their measured intakes.

Table 1. Predicting feed intake using feeding duration with and without feeding rate (FR) data for two animals with similar total measured intakes but very different durations and one animal exhibiting a high FR (Guzzler) and the other a low FR (Nibbler). FR was calculated on two consecutive 21-day subsets of the full dataset (PER1 and PER2)

Trait/Model Description	High FR	Low FR
PER1 Feeding Rate (g/sec)	0.65	0.27
PER2 Feeding Rate (g/sec)	0.63	0.26
Daily Feeding Duration (sec/day)	4540	11235
Model: Intake=Dur (g)	2079	2907
Model: Intake=Dur* PER1 Rate (g)	2951	3033
Actual Intake (g/day)	2950	2949

CONCLUSION

This work demonstrates that feeding rate is a unique attribute of an individual and is a highly heritable trait. As such future work on accelerometer, or other, technology used to predict feed intake should place a strong emphasis on determining whether or not the rate at which an animal is feeding can be determined versus just predicting feeding duration. If the accelerometer data can predict FR, models combining FD and FR will result in improved predictions of feed intake.

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