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Prediction of feed intake in growing beef cattle fed tropical forages

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Abstract

Prediction of feed intake in beef enterprises is important for feed budgeting, productivity, profitability and environmental outcomes (e.g. carbon and methane accounting). The objective of this study was to develop empirical prediction models for feed intake of growing beef cattle fed a range of tropical forages. Data were gathered from previous metabolism and pen trials (76 treatment diets) having live weight (LW), dry matter intake (DMI) and diet characteristics including in vivo DM digestibility (IVDMD), nitrogen (N), neutral (NDF) and acid (ADF) detergent fibre. Prediction equations of DMI were derived using mixed-effects linear regression models with LW and diet characteristic as independent variables and location of trial as a random factor. The models were later validated with an independent dataset from published literature related to tropical grazing trials. Results indicated that DMI could be predicted with similar accuracy using LW and any one measure of diet characteristic (R^2 from 73 to 81%) with the highest R^2 from the equation based on LW and ADF. However, validation against an independent dataset from grazing trials indicated that DMI was more accurately predicted from LW and IVDMD (R^2 = 75%), LW and N (R^2 = 71%), LW and NDF (R^2 = 61%), and least with LW and ADF (R^2 = 24%). The lower accuracy of the models to predict DMI from grazing trial may be due to diet selection and method used to measure it. The present models may be used with results from faecal NIRS as input to predict DMI more accurately.

Introduction

Prediction of feed intake is important in beef enterprises to predict profitability, productivity, and environmental outcomes (e.g. methane emissions and carbon balances). The need for accurate models may increase if cattle producers were to receive financial incentives for reducing the environmental footprint in beef production because of its close relationship between intake and methane emissions (Kennedy and Charmley 2012). However, most prediction models of feed intake in beef cattle were developed and validated under temperate conditions (forages and weather). Developing the prediction equations using data from specific feed types (e.g. tropical forages) could improve the precision of predictions (Poppi 1996). The objective of this study was to develop empirical models to predict feed intake of growing beef cattle fed a range of tropical forages based on simple measurements of LW, digestibility and diet composition.

Materials and methods

Data were gathered from previous metabolism and pen trials conducted in northern Australia and included animal live weight (LW), dry matter intake (DMI) and diet characteristics (i.e. vivo digestibility (IVDMD), nitrogen (N), neutral (NDF) and acid (ADF) detergent fibre. Treatment diets containing temperate forages (e.g. oats or lucerne) were excluded from analysis. Only diets fed ad-libitum were considered for analysis. Nitrogen concentration was considered as both N concentration of the forage consumed (**N forage**; urea was not accounted for even if it was added) and of the diet (**N diet**; added urea was added to the natural N concentration of the forage). The final database used for model development contained 76 treatment diets. Equations for predicting DMI were derived using mixed-effects linear regression models with LW and diet characteristic being independent variables and location of trial as a random factor. Only one measure of diet composition was included at a time because of the co-linearity among them, except for ADF and forage N which did not show high co-linearity. The models were later validated with a completely independent dataset constructed from published literature in grazing trials under tropical conditions. For this analysis, the dependent variable was the DMI predicted by the models developed in this study and the independent variable was the measured DMI in those published studies using linear regression. There were 11 published studies which generated 31 data points. Only 'control' treatments (e.g. treatments with feed supplementation were omitted) and number of observations varied because some studies did not measure one or more of the variables needed by the models presented herein.

Results and discussion

In the developed models, feed intake was predicted with similar accuracy using LW and any one measure of diet characteristic because the R^2 ranged only from 73 to 81% (Table 1). The models based on NDF and Diet N explained the lowest proportion of the variation in feed intake whereas the models based on ADF and Forage N concentration explained the greatest proportion. The regression coefficient for LW was on average 0.0177 kg DM/kg LW which indicates that animals consumed on average 1.77% of their LW. There was a linear decrease in DMI with increasing ADF and NDF whereas DMI increased linearly with increasing IVDMD (Table 1). However, N concentration had a quadratic effect on DMI because of a decreasing positive effect with increasing N (Table 1). Thus, N had a large positive effect on DMI when concentrations were below 1.2 % of DM but N concentration above 1.5% of DM did not seem to affect DMI to a large extent (Figure 1). The effect of increasing N concentration seemed to be slightly lower if this was added in the diet as urea because the regression coefficient was slightly lower for Diet N compared to Forage N (Figure 1 and Table 1).

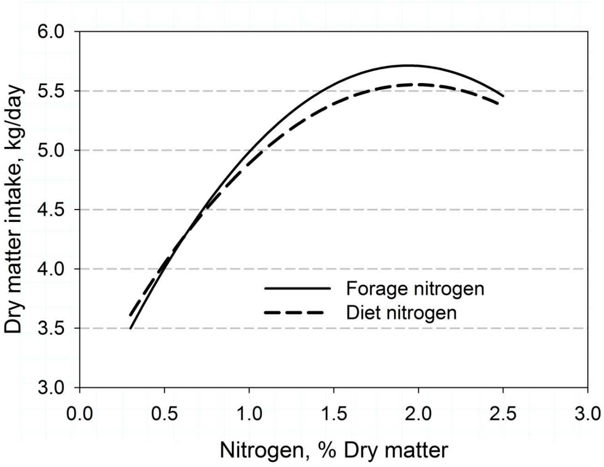

Figure 1. Predicted feed intake (kg DM/animal/day) with increasing forage (added urea omitted) and diet (including urea) nitrogen of cattle fed tropical forages in northern Australia. The live weight was considered at 300 kg for this figure but modelled as a continuous variable in the prediction equations.

Results were variable when the models developed in this study were used to predict DMI from the independent dataset constructed from published literature under grazing conditions. According to the coefficient of determination, DMI in grazing trials was more accurately predicted from IVDMD or N, while ADF was of no predictive value (Table 2). This does not agree with the values obtained from the model development where ADF yielded the highest R^2. Therefore, IVDMD and N concentration seem to be the best variables to predict DMI in growing beef cattle. This is interesting because both IVDMD and N are obtained from forage or faecal NIRS which could be a routine analysis for northern herds at a low cost and quick (Coates 2004). Thus it is possible that faecal NIRS could be used to predict DMI for feed budgeting and calculation of methane emissions as well.

Table 1. Intercept (β_0) and regression coefficients ($\beta_{1, 2}$) of models to predict DMI (kg DM/d) from cattle fed tropical forages in tropical regions of Australia.

Equation	Intercept			Body weight (kg/animal)			Forage component (% DM, linear)			Forage component (% DM, quadratic)			Pseudo-R^2
	β_0	SE	P-value	β_1	SE	P-value	β_2	SE	P-value	β_2^2	SE	P	
LW + ADF	6.52	1.05	<0.001	0.018	0.0014	<0.001	-0.159	0.0178	<0.001	NS	NS	NS	81.3
LW + NDF	4.64	1.41	0.001	0.019	0.0015	<0.001	-0.083	0.0176	<0.001	NS	NS	NS	73.8
LW + In Vivo DMD	-5.85	0.89	0.02	0.017	0.0016	<0.001	0.110	0.0194	<0.001	NS	NS	NS	76.1
LW + Forage N	-2.47	0.56	0.05	0.017	0.0016	<0.001	3.191	0.7654	<0.001	-0.822	0.316	0.011	77.4
LW + Diet N	-2.57	0.62	<0.001	0.018	0.0017	<0.001	2.712	0.8312	0.002	-0.683	0.343	0.050	73.7
LW +ADF + Forage N + Forage N^2	4.19	1.39	0.094	0.017	0.0014	<0.001	-0.122	0.0238	<0.001	1.610 -0.483	0.734 0.281	0.032 0.090	82.3

Pseudo-R^2 is calculated from mixed-effects regression models as the proportional decrease in the residual variance due to the fixed effects.

NS: quadratic term was not significant ($P < 0.05$).

LW: live weight, **ADF**: acid detergent fibre, **NDF**: neutral detergent fibre, **In Vivo DMD**: in vivo dry matter digestibility, **Forage N**: nitrogen content of the forage without accounting for any urea added, **Diet N**: nitrogen content of the diet after adding up the nitrogen coming from urea.

Ideally, the intercepts should be 0 and the slope should be 1 in those equations presented in Table 2. However, the fact that the intercepts were above 0 may indicate that the prediction equations overestimate DMI, whereas the regression coefficients indicate that an increase in observed DMI of 1 kg results in a 0.6 kg increase in DMI from prediction equations.

The lower proportion of the variation accounted for in DMI from grazing trials compared to the database for model development may be due to difficulties in measuring DMI under grazing conditions and the fact grazing trials did not account for diet selection, although diet composition in some of the studies were based on extrusa from fistulated animals. Further validation of the models is needed considering the diet consumed by animals (e.g. using faecal NIRS to account for diet selection with concurrent measurements of DMI).

Table 2. Regression between DMI (kg DM/d) predicted from equations developed using empirical data from pen studies against observed DMI from published literature in grazing trials under tropical conditions.

Equation	Intercept			Linear regression coefficient				Adj-R^2	N
	β_0	SE	P-value	β_1	SE	P-value	RMSE	(%)	
LW + ADF	4.72	3.377	0.20	0.600	0.374	0.15	2.2	14.9	10
LW + NDF	2.78	0.680	<0.001	0.516	0.088	<0.001	1.2	59.5	24
LW + IVDMD	2.89	0.575	<0.001	0.575	0.078	<0.001	1.0	73.9	20
LW + Forage N	2.43	0.524	<0.001	0.578	0.071	<0.001	1.6	70.1	29
LW + Diet N	2.26	0.541	<0.001	0.602	0.073	<0.001	1.1	70.5	29
LW +ADF+ Forage N	4.98	2.179	0.05	0.359	0.212	0.13	1.5	17.2	10

LW: live weight, **ADF**: acid detergent fibre, **NDF**: neutral detergent fibre, **In Vivo DMD**: in vivo dry matter digestibility, **Forage N**: nitrogen content of the forage without accounting for any urea added, **Diet N**: nitrogen content of the diet after adding up the nitrogen coming from urea.

Conclusions

There is a need to predict feed intake of grazing cattle in northern tropical Australia in order to predict productivity and environmental footprint, and to improve management such as feed budgeting. However, there is a limitation of empirical data that measured feed intake using comparable methodologies and that have accounted for factors such as diet selection in relation to diet available. A consistent method to measure both feed intake and to account for diet selection in relation to diet available under grazing conditions is needed to develop robust prediction models of feed intake of grazing cattle.

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