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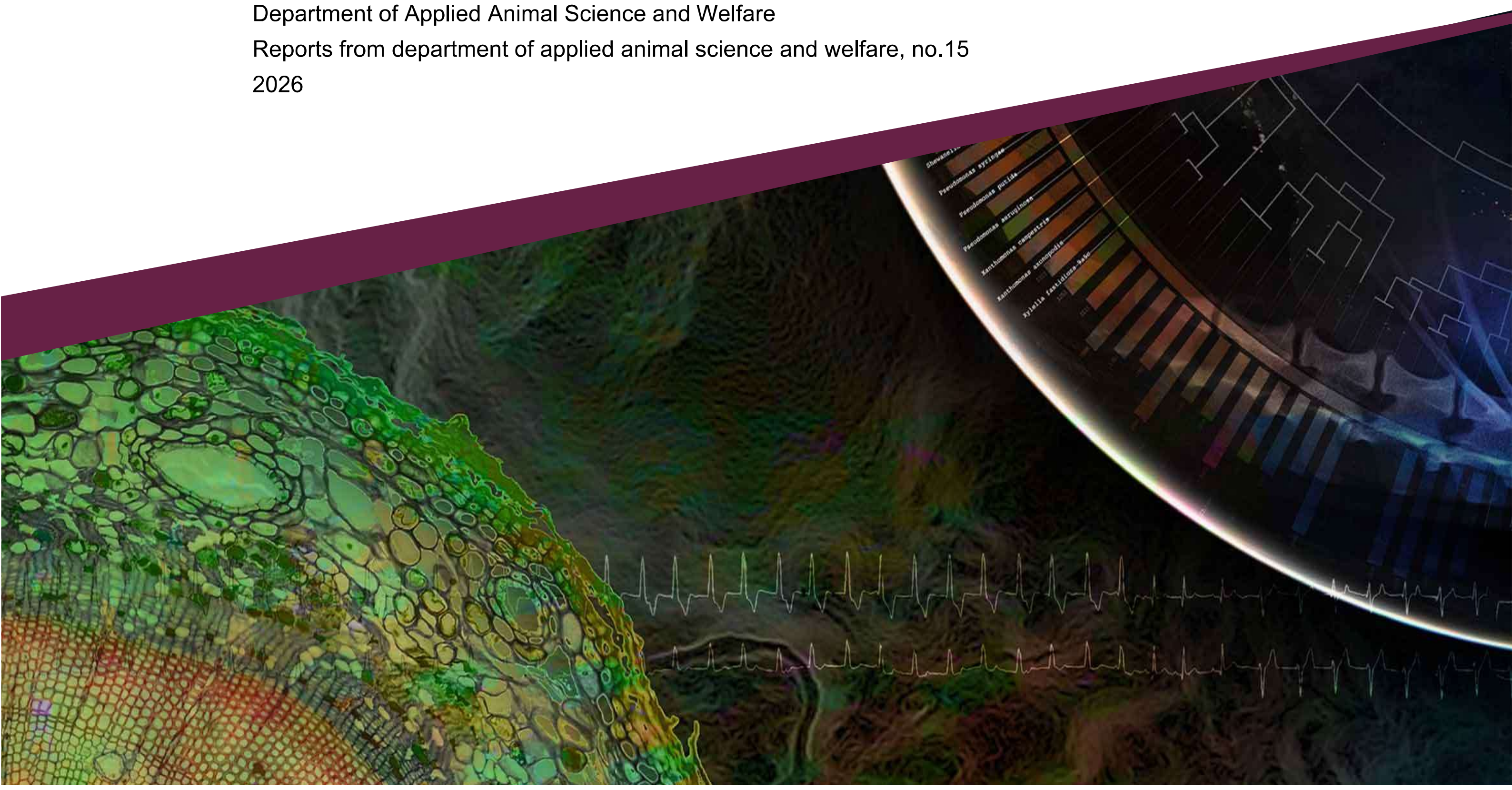

Predicting enteric methane from growing cattle

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Introduction

Some dairies and slaughterhouses have introduced incentive schemes that provide additional payments to milk and beef producers who calculate and achieve low climate impact of the production on farm. In parallel, countries that have signed the Paris Agreement are required to report their national greenhouse gas inventories to the United Nations every second year. These calculations rely on equations for predicting enteric methane from cattle, making it essential that such equations are both based on available data and provide accurate estimates. In recent years, a substantial amount of new research on methane production in growing cattle has become available. Therefore, updated models to predict enteric methane production in growing heifers and bulls based on dietary information have been developed, for implementation within the NorFor model.

Materials and Methods

A literature search with "methane OR enteric OR CH4 OR GreenFeed OR "respiratory chamber*" OR chamber*" in title was carried out in the "Web of Science" database. Articles with growing heifers and bulls (Bos taurus) fed indoors or in feedlots, written in English, were selected. Treatment means were excluded if diet contained methane reducing additive such as 3-NOP, nitrate or tannins.

The dataset used for development and evaluation contained 101 treatment means from 32 studies including heifers (n = 73) and bulls (n=34), with publication year ranging between 2003 and 2025. Descriptive statistics of the data is presented in Table 1.

Table 1 Descriptive statistics of dataset for heifers (73 treatment means) and bulls (34 treatment means)

	Heifers				Bulls			
Variable	mean	std	min	max	mean	std	min	max
Body weight (kg)	488	131.2	220	732	308	105.7	78.6	621
Live weight gain(g/d)	1004	404.2	100	2070	1314	289.8	810	2100
Age (days)	404	155.1	198	718	262	79.2	63	427
Roughage intake (kg DM/d)	6.00	2.705	0.73	12.0	4.23	1.827	0.67	8.03
Concentrate intake (kg DM/d)	2.42	2.826	0.00	10.8	2.61	1.956	0.52	8.93
Crude fat (g/kg DM)	32.7	11.30	16.1	75.1	34.5	8.606	22.6	59.2
NDF (g/kg DM)	388	98.6	164	675	368	82.58	218	506
Starch (g/kg DM)	205	162.1	0.5	564	212	97.03	38.2	408

A linear mixed model was fitted to predict methane production (CH4, g/d) using the mixedlm function from the statsmodels package in Python. The model included a set of independent variables as fixed effects, while study was included as a random effect to account for study-level variation. All models included an intercept term. Forward selection was applied.

Statistical significance for variables was declared at P ≤ 0.05. Models were evaluated on Bayesian information criterion (BIC), root mean square error (RMSE), and concordance correlation coefficient (CCC).

Results and Discussion

Some of the models developed for predicting the production of enteric CH_4 in growing heifers and bulls are presented in Table 2.

Table 2 Evaluation of models predicting enteric CH4 production in growing heifers and bulls. Numbers in grey indicate non-significant (p-value >0.05) variables in model for selected dataset

Dataset	Total	Heifers	Bulls	Total	Heifers	Bulls	Total	Heifers	Bulls
Model	BIC			RMSE			CCC		
DMI	750	539	254	38.3	36.8	35.8	0.635	0.472	0.753
DMI + CFat	753	540	257	38.0	35.8	35.8	0.644	0.514	0.752
DMI + conc_share	717	514	255	31.7	30.0	34.7	0.767	0.667	0.765
DMI + NDF	708	522	241	30.4	31.7	28.0	0.789	0.652	0.851
DMI + NDFr	701	514	244	29.4	30.0	29.5	0.804	0.680	0.831
DMI - ST	712	515	240	30.9	30.2	27.7	0.783	0.697	0.854
DMI - STc	703	504	245	29.7	28.0	29.9	0.794	0.712	0.830
DMI - CFat - STc	706	505	249	29.5	27.4	29.9	0.800	0.730	0.830
DMI + NDF - STc	694	506	242	27.7	27.6	26.9	0.826	0.733	0.862
DMI + NDFr - STc	698	507	246	28.3	27.8	28.6	0.818	0.724	0.843
DMIr + DMIc	719	511	258	32.1	29.4	36.1	0.764	0.685	0.743
DMIr + DMIc + NDF	705	511	256	29.2	28.7	33.5	0.810	0.715	0.779
DMIr + DMIc + NDF - STc	701	511	248	28.0	27.8	28.0	0.823	0.731	0.850
DMI - CFat - STc + NDF	700	508	244	27.9	27.3	26.6	0.825	0.741	0.866

Dry matter intake (DMI, kg DM/d), roughage intake (DMIr, kg DM/d), concentrate intake (DMIc, kg DM/d), crude fat (CFat, g/kg DM), concentrate share (conc_share, % of DM), neutral detergent fibre (NDF, g/kg DM), NDF from roughage (NDFr, g/kg DM), starch (ST, g/kg DM), starch from concentrate (STc, g/kg DM), starch from roughage (STr, g/kg DM)

Dry matter intake is the major explanator for predicting enteric methane emissions in most ruminants, primarily by increasing the supply of fermentable organic matter in the rumen (Nielsen et al., 2013; Ramin & Huhtanen, 2013). Here DMI alone explained 24% of variance in the heifer dataset and 59% of variance in the bull dataset. Several of the developed models had non-significant variables with the bull dataset, which could be explained by a smaller dataset but also by the fact that the bull dataset had lower variation for many variables compared to the heifer dataset.

The two models with similar and high performance (low BIC, low RMSE and high CCC) and having all variables being significant in all three datasets were:

1. CH4 (g/d) = 77.7 + 17.3 × DMI – 0.649 × CFat – 0.168 × STc

2. CH_4 (g/d) = - 28.4 + 18.4 × DMI + 0.159 × NDFr

A third model including more parameters and having relatively high performance for the total dataset were:

3. CH_4 (g/d) = 33.5 + DMI × 17.5 – CFat × 0.578 – STc × 0.133 + NDF × 0.088

here presented with coefficients from the total dataset including both heifers and bulls, with dry matter intake (DMI; kg DM/d), crude fat (CFat; g/kg DM), starch from concentrate (STc; g/kg DM), NDF from roughage (NDFr; g/kg DM), starch (ST; g/kg DM), and NDF (g/kg DM).

Dietary fat and the carbohydrates starch and NDF along with concentrate proportion have previously shown to influence enteric methane production (Arndt et al., 2022; Zhang et al., 2024). Fat reduces methane by inhibiting protozoa and methanogens, and providing alternative hydrogen sinks via biohydrogenation of unsaturated fatty acids. Increasing dietary starch or concentrate proportion has generally been associated with reduced enteric methane emissions, particularly when expressed per unit of intake or production, with meta-analyses demonstrating a negative relationship between starch content and methane output. This effect is primarily mediated by a shift in rumen fermentation toward propionate formation at the expense of hydrogen availability for methanogenesis. NDF on the other hand, enhance acetate formation during ruminal fermentation, which generates hydrogen that is subsequently utilized by methanogens to produce methane.

Conclusions

Several models for predicting the enteric CH_4 production in growing heifers and bulls were developed and evaluated. The best performing models included DMI and NDF from roughage or crude fat and starch from concentrate, where DMI and NDF increases methane and crude fat and starch from concentrate decreases methane

Supplementary Materials: List over studies included in the analysis

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