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Results of a mechanistic model estimating methane in relation to methane emissions measured in dairy cows

I.K. Hindrichsen[1,5], J.A.N. Mills[2], J. Madsen[3], M. Kreuzer[1] and J. Dijkstra[4]

[1]Institute of Animal Science, Animal Nutrition, Swiss Federal Institute of Technology (ETH) ETH Centre/LFW, CH-8092 Zurich, Switzerland
[2]University of Reading, Centre for Dairy Research, Department of Agriculture Earley Gate, P.O. Box 236, Reading RG6 6AT, UK
[3]Department of Animal Science and Animal Health, Royal Veterinary and Agricultural University (KVL) Grønnegårdsvej 2, DK-1870 Frederiksberg, Denmark
[4]WIAS Animal Nutrition, Wageningen University P.O. Box 338, Marijkeweg 40, 6700 AH Wageningen, The Netherlands

ABSTRACT

This investigation determines the accuracy of estimation of methanogenesis by a dynamic mechanistic model with real data determined in a respiration trial, where cows were fed a wide range of different carbohydrates included in the concentrates. The model was able to predict ECM (Energy corrected milk) very well, while the NDF digestibility of fibrous feed was less well predicted. Methane emissions were predicted quite well, with the exception of one diet containing wheat. The mechanistic model is therefore a helpful tool to estimate methanogenesis based on chemical analysis and dry matter intake, but the prediction can still be improved.

KEY WORDS: methane, carbohydrate, mechanistic model

INTRODUCTION

Methane emission in the rumen is a significant energy loss for dairy cows and there have been repeated attempts for reduction for many years. In the wake of the Kyoto Protocol of 1997, the interest in improving the ability to estimate and reduce methane emissions has increased. It has generally been accepted that fibre (hemicellulose and cellulose) has a major effect on methane production, due to acetate production, while non-fibrous carbohydrates have a less pronounced effect on methane. The

[5] Corresponding author: e-mail: ida.hindrichsen@inw.agrl.ethz.ch

effect of non-fibrous carbohydrate on methane has rarely been differentiated for individual carbohydrates, even though stoichiometry suggests that hydrogen (essential for methanogenesis), is also produced along with butyrate production, which is increased when feeding sugar-rich diets. The production of propionate by the ruminal microorganisms increases first of all when starch-rich diets are fed and this process utilizes hydrogen and therefore it reduces methane production in the rumen. The influence of different non-fibrous and fibrous carbohydrates in concentrate on methane production were therefore tested in an *in vivo* trial.

The aim of the present study was to examine how the mechanistic model by Mills et al. (2001) correlated with results of an *in vivo* trial on actual methane emission from dairy cows, by including detailed feed composition and dry matter intake from the *in vivo* trial in the model.

MATERIAL AND METHODS

The *in vivo* trial included 12 Brown Swiss dairy cows, which were fed six different concentrates varying in the carbohydrate composition over three experimental periods. The diets were aligned to meet maintenance and milk production of the cows. The cows were fed forage (0.45 grass silage, 0.22 maize silage and 0.33 hay) to concentrate in a ratio of 1:1 in equal portions four times a day. The six concentrates contained specific carbohydrate sources by including either 50% of dry matter of oat hulls (OH), 70% soyabean hulls (SBH), 54% apple pulp (AP), 68% Jerusalem artichoke tubers (JA), 18% molasses (M) or 46% wheat (W). These feedstuffs were rich in either lignified fibre, non-lignified fibre, pectin, fructans, sugars or starch, respectively. The chemical composition of the diets is shown in Table 1. More details on the experiment are given in Hindrichsen et al. (2003).

Table 1. Chemical composition of the experimental diets offered to dairy cows, g kg^{-1} DM

Nutrient	OH	SBH	AP	JA	M	W
Composition of dry matter, g kg^{-1}						
organic matter	923	912	917	908	915	914
crude protein	139	149	160	169	151	144
ether extract	54	49	42	22	23	51
starch	96	54	151	59	181	204
total sugars	37	38	55	114	91	44
neutral detergent fibre	513	518	401	319	355	405
acid detergent fibre	304	365	291	205	223	238
acid detergent lignin	55	44	73	30	37	42
fructan and pectin[1]	84	104	108	225	114	66

[1] calculated as OM-CP-EE-starch-total sugar-NDF

The tested dynamic mechanistic model was described in detail by Mills et al. (2001) and estimates both ruminal and post-ruminal methane production and is based on hydrogen production and utilization. The calculation assumes that lipogenic VFA and microbial growth on amino acids (MgAA) produce hydrogen, while glucogenic VFA and microbial growth on nonprotein nitrogen (MgNPN) utilize hydrogen. Furthermore, biohydrogenation of ingested lipids also utilizes hydrogen and is calculated from the proportion of feed lipid (PLi; mol/d) subjected to lipolysis (Liferm; mol/mol), and the amount of unsaturated fatty acid is 1.805 mol per mol of feed lipid. The model predicts the production of acetate (Ac), propionate (Pr), butyrate (Bu) and valerate (Vl) (all mol/d), as well as the quantity of microbial matter produced from growth on amino acids or ammonia (both in kg microbial DM/d) as source of N. The relationship between hydrogen and methane in the rumen is described in the formula below, in which the coefficients describe the amount of mol H_2 per mol VFA or microbial matter produced or utilized. For the production of 1 mol methane 4.0 moles of hydrogen are required.

$$CH_4 \text{ (mol/d)} = (2\times Ac + 2\times Bu + 0.58\times MgAA - Pr - Vl - 0.41\times MgNPN - 2\times 1.805\times (PLi\times Liferm))/4$$

RESULTS

The NDF digestibility (Figure 1) of the two fibre-rich diets (OH and SBH) was overestimated by the model, resulting in a correlation (r) of 0.622. The ECM was quite well predicted by the model (r=0.817), as shown in Figure 2. The total methane emission measured and the percentage of methane emission from GE were well estimated by the model (r=0.664 and r=0.609, respectively) (Figures 3 and 4), except for the W diet, where methanogenesis was predicted by the model to be much lower than actually measured. The model estimated that between 7.9% (SBH diet) and 10.4% (W diet) of the total methane was produced in the hindgut.

DISCUSSION

The low NDF digestibility of the OH diet, resulting from intensive lignification of the fibre, resulted in a low methane emission, even though the model overestimated the NDF digestibility. The model predicts that the W diet also has a low methane production, because of the high contribution of rapidly degradable starch that gives rise to propionate formation. The reason why methane actually was not low in the *in vivo* trial compared to the other diet could maybe be related to the facts that the diet in total only contained 20.4% starch.

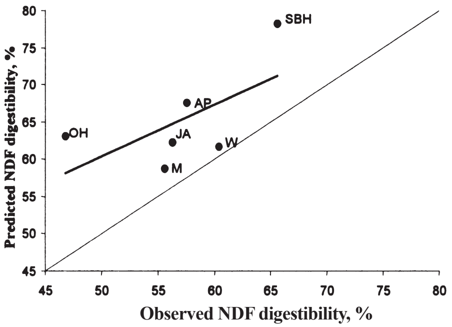

Figure 1. Observed vs predicted NDF digestibility

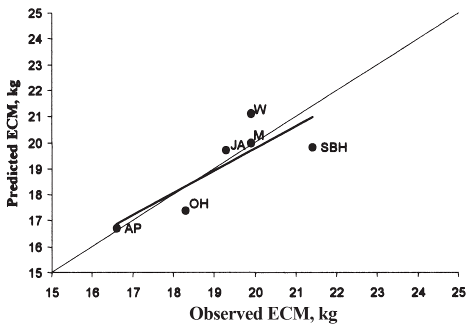

Figure 2. Observed vs predicted ECM

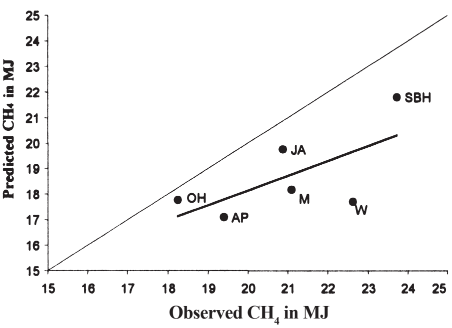

Figure 3. Observed vs predicted methane emission

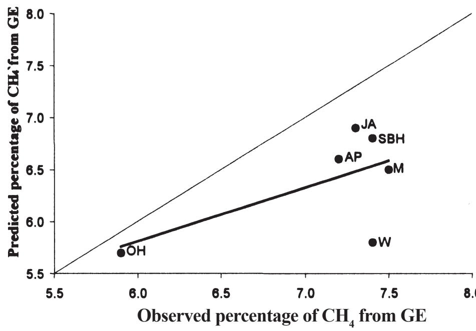

Figure 4. Observed vs predicted pct. of methane emission per GE intake

CONCLUSIONS

Based on detailed chemical analysis of the diet and dry matter intake the model was able to satisfactorily predict methane emission from most of the diets with the exception of diet W, even though some of the diets contained rarely fed feedstuffs.

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