Prediction of individual variation in enteric methane production in lactating dairy cows

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Introduction There is increasing interest to identify ways to lower enteric methane (CH_4) emissions from ruminant livestock as part of an overall strategy to decrease greenhouse gases and global warming. Enteric CH_4 formation represents a loss of dietary energy with high CH_4 production reflecting a low efficiency of energy utilization from ingested feeds. Several dietary and animal factors are known to influence CH_4 emissions from cattle. Early pioneering studies reported that rumen fermentation pattern influences the amount of CH_4 produced in ruminants (Wolin, 1960). There is also evidence from studies involving respiration chambers of between-animal variation (CV 7-8%) in rumen CH_4 production (Blaxter and Clapperton, 1965). Changes in rumen microbial ecology can alter the stoichiometry of volatile fatty acid (VFA) production, and consequently the rate and extent of variation in CH_4 production between individual animals. The aims of the present study were to compare individual (cow) variance components of a set of animal variables and to establish relationships between more repeatable variables for the prediction of enteric CH_4 production estimated by stoichiometry.

Material and Methods A meta-analysis was conducted in order to evaluate between-animal differences in enteric CH_4 production in lactating dairy cows. The dataset used was derived from 35 experiments conducted in Finland (30 trials, 116 diets) and Sweden (5 trials, 15 diets) involving 126 individual cows and comprised 567 cow/period observations. Observations for individual cows were considered as an experimental unit. All studies were conducted according to change-over designs. Diets comprised principally grass silage and cereal grain concentrates with a mean forage: concentrate ratio (on a DM basis) of 60:40. Both enteric CH_4 and CO_2 production were calculated based on volatile fatty acid (VFA) stoichiometry (CH_4VFA) according to Wolin (1960): CH_4VFA (mol/ mol VFA) = 0.5 × acetate – 0.25 × propionate + 0.5 × butyrate. The MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) was used for variance component analysis and for estimating relationships between variables. Repeatability (R) was calculated as: $\delta^2_{Animal} / (\delta^2_{Animal} + \delta^2_{Residual})$.

Results and Discussion Intake and milk yield were more repeatable (>0.70) than rumen fermentation, nutrient outflow, diet digestibility or CH_4 production (Table 1). Overall, the coefficient of variation between cows within study ranged from 1.0% (CH_4VFA) to 14.8% (milk yield (Table 1). All animal (exp) variance components were significant. In previous investigations, variation in rumen fermentation patterns did not explain between-animal variability in CH_4 production measured in respiration chambers. Predictions of enteric CH_4 production based on between-animal variance components are presented in Table 2. As expected, increased total DM intake was associated with lowered digestibility and CH_4 which together with improved energetic efficiency of microbial nitrogen synthesis (EMNS) could explain the decrease in CH_4 emissions per unit of intake with increases in feeding level. However, improvements in organic matter (OM) digestibility can increase CH_4 emissions both by providing more fermentable substrate and altering fermentation pattern. Emissions of CH_4 per

unit of VFA were positively related with pdNDF digestion. Digestibility of OM was more strongly related to passage rate than the rate of pdNDF digestion. It appears that variability in OMD and EMNS makes a larger contribution to between-animal variability in CH_4 emissions compared with rumen fermentation pattern.

Conclusion Results suggest that selecting animals for low CH_4 emissions may lead to lowered digestion capacity. Our in vivo measurements with lactating dairy cows using the GreenFeed system (C-Lock Inc, Rapid City, South Dakota, USA) have indicated a high repeatability (>0.70) and moderate between-cow variation (8-9% CV) in CH_4 per kg dry matter intake, which suggests that in addition to variance in rumen fermentation pattern, diet digestibility and EMNS, other factors also contribute to between animal variability in CH_4 emissions.

Table 1 Summary of the analyzed dataset and description of individual (cow) variance components

	Overall				Cow variance component			
Item	n	Mean	SD	CV[1]	SD	P-value	CV	Rep[2]
DMI[3], kg/d	561	19.4	2.72	14.0	1.69	<0.01	8.67	0.71
Milk, kg/d	561	26.9	6.86	25.5	3.97	<0.01	14.8	0.79
pH	537	6.36	0.28	4.46	0.14	<0.01	2.17	0.48
Total VFA,mmol/L	560	115	15.4	13.3	5.90	<0.01	5.13	0.49
Acetate, mmol/mol VFA	560	678	23.6	3.48	8.22	<0.01	1.21	0.41
Prop. mmol/mol VFA	560	190	20.6	10.8	4.97	<0.01	2.62	0.13
Butyrate, mmol/mol VFA	560	132	18.8	14.3	6.48	<0.01	4.91	0.30
Microbial N, g/d	234	320	73.0	22.7	30.0	<0.01	8.96	0.50
EMNS[4], g/kg DOM	230	23.9	4.32	18.1	1.50	<0.01	6.30	0.39
pdNDF-kd[5], 1/h	96	0.049	0.023	47.3	0.007	<0.01	14.6	0.61
pdNDF-kp[6], 1/h	96	0.017	0.004	26.6	0.002	0.02	9.19	0.31
iNDFkp[7], 1/h	96	0.023	0.005	21.9	0.002	0.02	8.78	0.42
OMD[8], g/kg	479	736	33.9	4.60	10.8	<0.01	1.47	0.36
NDFD[9], g/kg	463	643	69.8	10.8	14.0	<0.01	2.17	0.24
CH_4VFA[10], mmol/mol	562	358	14.4	4.02	3.73	0.01	1.04	0.12

[1]CV = coefficient of variation, %, [2]Rep = repeatability, [3]DMI = Dry matter intake, [4]EMNS = Energetic efficiency of microbial nitrogen synthesis, [5]pdNDF-kd = degradation rate of pdNDF fraction, [6]pdNDF-kp = passage rate of pdNDF fraction, [7]iNDF-kp = passage rate of indigestible NDF fraction, [8]OMD = organic matter digestibility, [9]NDFD = NDF digestibility, [10]CH_4VFA = calculated CH_4 production by stoichiometry.

Table 2 Best models for predicting enteric methane production based on the repeatability of individual (cow) variance components

Item	X	Intercept	SE	Slope	SE	P-value	RSD[1]
CH_4VFA	OMD	272	25.1	0.099	0.032	0.003	9.80
CH_4VFA	DMI	365	7.9	-0.89	0.329	0.01	9.48
CH_4VFA	pdNDF-kd	359	6.1	232	95	0.02	7.10
CH_4VFA	pdNDF-kp	381	9.4	-562	363	0.14	6.82
EMNS	OMD	74	7.2	-0.075	0.011	<0.001	1.75
EMNS	DMI	18.9	2.68	0.236	0.128	0.07	1.93
OMD	DMI	820	14.1	-2.5	0.59	<0.001	14.2

[1]Residual standard deviation = square root of residual variance.