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Enteric methane emission of lactating Holstein and Jersey cows fed two levels and two sources of forage neutral detergent fibre

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BACKGROUND

- In the Midwest of United States (US), increasing herd size without concomitant increase in the land-base has progressively led dairy farmers to increase the proportion of corn silage (CS) at the expense of alfalfa silage (AS) in their cropping and feeding systems.
- A previous study from our group showed that enteric methane (CH_4) per unit of digested neutral detergent fibre (NDF) decreased with increasing AS in the diet at the expense of CS (Arndt et al., 2015).
- Also, a Canadian group showed that total replacement of AS with CS reduces the enteric emissions expressed either per unit of dry matter intake (DMI) or milk yield (MY) (Hassanat et al., 2013).
- However, results of these studies may have been influenced by a possible confounding effect of dietary starch since starch level varied across treatments.
- Jersey (J) breed is gaining popularity in the US and greater NDF digestibility has been reported for J than Holstein (H) (Aikman et al., 2008). Furthermore, Capper and Cady (2012) reported about 20% lower milk carbon footprint and nitrogen (N) excretion from J than H to produce the same amount of cheese.

Objective

- Our objective was to determine the effects of replacing AS NDF with CS NDF at two levels of forage NDF (FNDF) on enteric CH_4 emissions of lactating H and J cows fed iso-nitrogenous and iso-starch diets.

MATERIALS AND METHODS

- Twelve H (mean ± SD, 606 ± 40 kg BW and 106 ± 17 days in milk) and twelve J (407 ± 43 kg BW and 112 ± 15 days in milk) lactating cows (all primiparous) housed in tie-stalls, fed once and milked twice daily, were fed four total mixed ration (TMR) in a 2×2 factorial arrangement with two levels of FNDF (18 and 23% of DM) and two sources of FNDF (70:30 and 30:70 ratio of AS NDF:CS NDF).
- Starch content was constant across diets (24% of DM) and crude protein averaged 16.5% of DM varying from 16.0 to 16.8% of DM (Table 1).
- The experimental design was a split plot triplicated 4×4 Latin Square in which breed and diet formed the main and subplots, respectively.
- Experimental periods were four weeks (wk) in length with wk 3 and 4 used for sampling. All data reported here were collected in wk 3.
- In each period, BW was measured twice, DMI, and MY were recorded daily, and milk samples were obtained from 6 consecutive milkings.
- Enteric CH_4 (g/d) was measured at 8 time points (5-min each), which covered every 3-hr of a 24-hr clock spread over 3 days using GreenFeed System (C-Lock Inc.).
- Daily enteric emission was calculated as the average of the 8 time point measurement.
- Data were analysed using proc Mixed of SAS (version 9.4) and the explanatory variables included in the model were breed, level of FNDF, source of FNDF, and all possible interactions as fixed effects whereas random effects were square-within-breed, and cow within-breed-and-square. Statistical significance was declared at $P \leq 0.05$.

Table 1. Ingredients and chemical composition of dietary treatments.

	Dietary Treatments (DM[1] basis)			
Forage NDF level	**18% (Low)**		**23% (High)**	
Forage NDF source (AS:CS)	**70:30**	**30:70**	**70:30**	**30:70**
Ingredient composition (DM basis)				
Forage	53.6	55.3	66.9	69.1
AS	36.6	15.7	45.7	19.6
CS	17.0	39.6	21.2	49.5
Corn grain	22.0	9.5	20.0	4.5
Soybean meal expeller	4.0	1.5	5.6	2.2
Soybean meal solvent extract	3.2	10.5	0	9.5
Soyhulls	12.7	18.7	3	10.2
Blood meal	0.7	0.7	0.7	0.7
GreenFeed bait mixture[2]	2.0	2.0	2.0	2.0
Vitamins & Minerals	1.75	1.75	1.75	1.75
Chemical composition (% of DM)				
CP[3]	16.8	16.3	16.5	16.0
NEL[4], Mcal/kg	1.54	1.52	1.54	1.52
NDF	29.0	31.5	28.0	31.3
FNDF	18.5	18.4	23.1	23.0
AS NDF	13.0	5.6	16.2	7.0
CS NDF	5.5	12.8	6.9	16.0
NFC[5]	45.0	42.4	45.8	42.5
Starch	24.0	24.0	24.0	24.0

[1] DM: Dry Matter; [2] GreenFeed bait mixture (60% Corn grain, 10% Soybean meal and 30% Molasses): It was added to the ration except days when it was fed as bait via GreenFeed for CH_4 measurement; [3] CP: Crude Protein; [4] NEL: Net Energy of Lactation, calculated based on NRC (2001) formula; [5] NFC: Non-Fiber Carbohydrate.

RESULTS

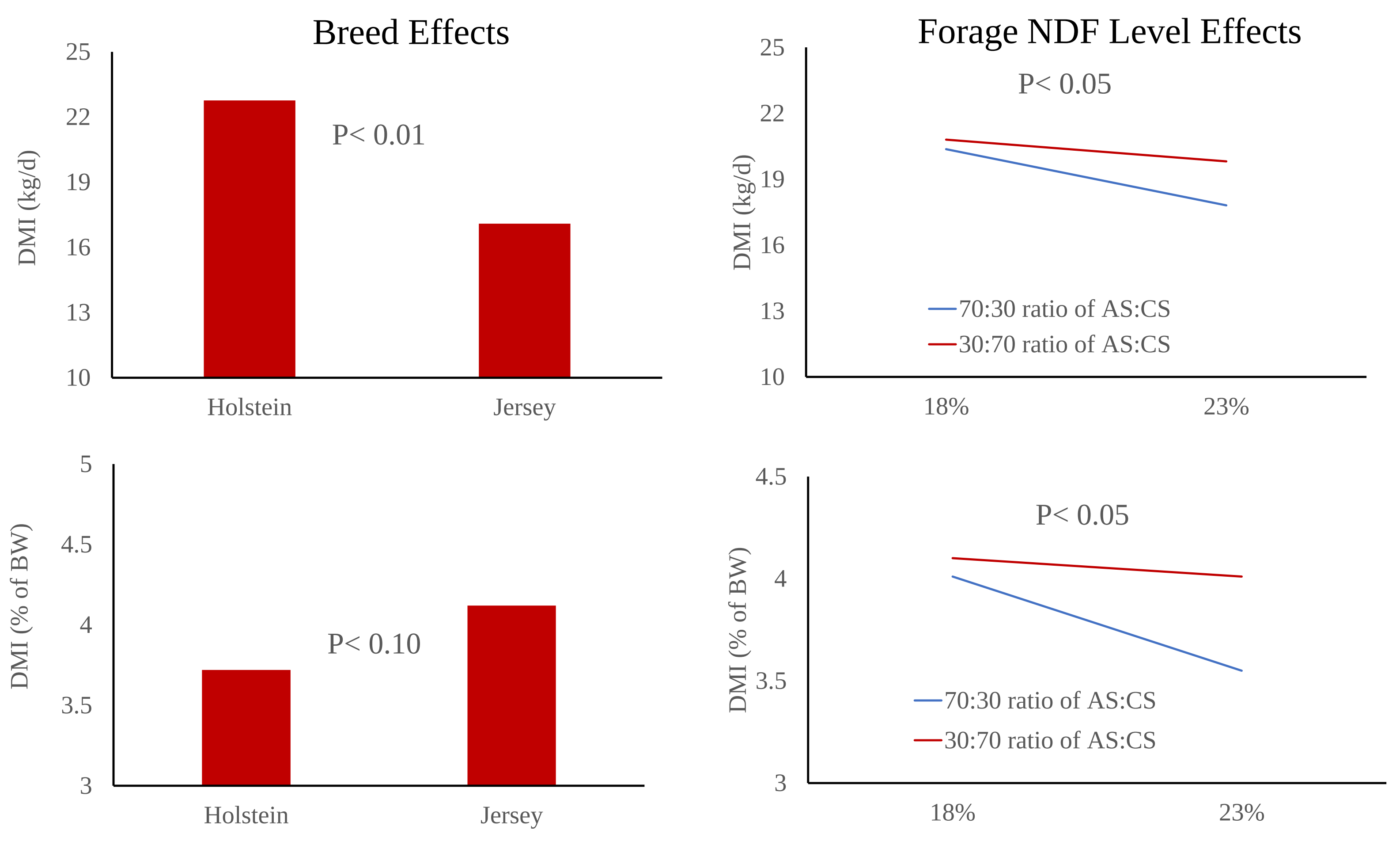

Figure 1. Effects of breed (Left), and interaction between FNDF level and FNDF source (Right) on DMI.

RESULTS

Table 2. Performances and enteric methane (CH_4) emissions.

FNDF level	**Dietary Treatments** **18% (Low)**		**23% (High)**			**Breed**			**P value**		
FNDF Source (AS:CS)	70:30	30:70	70:30	30:70	SEM	Holstein	Jersey	SEM	FNDF Level	FNDF Source	Breed
BW[1], kg	512	518	512	514	8.84	613	415	12.37	0.12	<0.01	<0.01
DMI[2], kg/d	20.5	21.0	18.0	20.2	0.61	22.8	17.1	0.71	<0.01	<0.01	<0.01
FNDFI[3], kg/d	4.08	4.2	4.69	5.27	0.14	5.20	3.92	0.16	<0.01	<0.01	<0.01
MY[4], kg/d	27.4	28.1	26.2	27.2	0.76	33.1	21.4	1.03	<0.01	<0.01	<0.01
FPCM[5], kg/d	29.2	29.5	27.1	28.7	0.83	32.4	24.9	1.08	<0.01	<0.01	<0.01
Feed Efficiency[6]	1.45	1.41	1.52	1.44	0.04	1.43	1.48	0.04	0.07	0.02	0.53
CH_4, g/d	440	439	413	418	16.2	471	385	21.0	<0.01	0.74	0.04
CH_4/BW, g/kg	0.88	0.86	0.82	0.83	0.03	0.77	0.93	0.34	<0.01	0.84	0.03
CH_4/MBW[7], g/kg	4.14	4.08	3.87	4.92	0.13	4.82	4.18	0.17	<0.01	0.96	0.21
CH_4/DMI, g/kg	22.1	21.1	23.4	21.3	0.79	21	23	0.86	0.22	<0.01	0.17
CH_4/FNDFI, g/kg	111	106	90	82	3.30	92	102	3.60	<0.01	<0.01	0.14
CH_4/MY, g/kg	16.7	16.2	16.4	16.0	0.59	14.3	18.4	0.73	0.42	0.17	<0.01
CH_4/FPCM, g/kg	15.3	15.0	15.4	14.8	0.50	14.7	15.6	0.62	0.84	0.09	0.34
CH_4/MFY[8], g/kg	355	352	359	343	13.00	354	351	16.00	0.73	0.19	0.91
CH_4/MPY[9], g/kg	509	492	518	504	18.60	497	515	21.20	0.40	0.23	0.60

[1] BW: Body weight; [2] DMI: Dry matter intake; [3] FNDFI: Forage NDF intake; [4] MY: Milk yield; [5] FPCM: Fat-protein corrected milk which is calculated as per IDF (2010) formula; [6] Feed efficiency calculated as [FPCM (kg/d)]/[DMI(kg/d)]; [7] MBW: Metabolic body weight; [8] MFY: Milk fat yield; [9] MPY: Milk protein yield.

DISCUSSION AND SUMMARY

- **Breed (H vs. J)**
  - H had greater DMI (25%), MY (35%), FPCM (23%) and daily CH_4 emission (18%) than J.
  - H had lower CH_4 emission per kg of BW (21%) and MY (28%) than J.
  - H and J had the same CH_4 emission per kg of FPCM, milk fat, and milk protein.
- **Dietary FNDF level (18% vs. 23% of DM)**
  - Low FNDF diet resulted in greater DMI (8.0%), MY (2.0%), and FPCM (3.5%) than high FNFD diet.
  - Low FNDF diet resulted in greater daily CH_4 (5.5%), CH_4 per kg of FNDFI (10%) and BW (5.0 %) than high FNFD diet. These results were likely associated with non-forage NDF effects of soy hulls (15.7 vs. 6.6 % of DM in FNDF diets of 18 and 23%, respectively, Table 1). Ruminal digestibility of soy hulls NDF (>90%) was substantially greater than other non-forage NDF sources (52-72%) and forage NDF (24-62%) (Nocek and Russell, 1988).
- **Source of FNDF (AS vs. CS)**
  - High CS diet resulted in greater DMI (7.0%), MY (3.0%), and FPCM (3.0 %) than high AS diet.
  - High CS diet resulted in lower feed efficiency (4%), as well as CH_4 per kg of DMI (7.0%) and FNDFI (6.5%) than high AS diet.
  - In agreement with our results, total (Hassanat et al. 2013) and partial (Arndt et al. 2015) replacement of AS with CS decreased CH_4 per kg of DMI. In these studies, dietary starch increased with increasing CS in the diet. In contrast, in our study dietary starch was constant but non-FNDF (mainly soy hulls) may have contributed to the observed difference in DMI (may be through increased rate of passage), which in turn may have influenced CH_4 per kg DMI. However, the study of Archimède et al., (2011) suggested greater emission of CH_4 per kg of DMI for C4 grass (e.g., CS) than for cold season legumes (AS is considered a cold season legume).
  - Although increasing feed efficiency should contribute to reduction in CH_4 per kg of milk (Knapp et al., 2014), in this study there was no change in CH_4 per kg of FPCM in spite of a reduction in feed efficiency with increasing CS in the diet.

IMPLICATIONS AND FURTHER RESEARCH

- **Breed:** If the goal is to produce a certain amount of FPCM or milk-derived products (e.g., cheese) with the lowest possible CH_4 emission, then each breed (H or J) will perform equally. Replacing H cows with the same number of J cows would reduce FPCM by 23% and CH_4 emission by 18%. If Jersey population was increased to yield the desired amount of FPCM, then CH_4 emission would increase by 6%. In a herd-level comparative study Capper and Cady (2012) reported a 20% reduction of cheese carbon footprint for J compared to H.
- **Dietary FNDF:** In this study, the 4.6% reduction in dietary FNDF accompanied by a 5.2% increase in non-FNDF led to increase in DMI, daily CH_4 emission, and CH_4 emission per kg FNDFI. The absence of a FNDF effect on CH_4 emission per kg of DMI supported the contention that NDF digestibility was more important than DMI in influencing emission results.
- **Source of FNDF:** In this study, increasing CS at the expense of AS resulted in greater FPCM, but lower feed efficiency. If the goal is to produce a certain amount of FPCM, then feeding CS at the expense of AS will tend to reduce enteric CH_4 emission per kg of FPCM. The magnitude of these effects, however, should be placed in a whole-farm context. Because of greater yield of DM per ha, growing CS would reduce the required land base to produce a given amount of DM (Powell et al., 2016), but there are also increasing evidence that perennial crops of legumes (such as alfalfa) result in considerably lower greenhouse gases emissions than N-requiring annual crops (such as corn) (Sanford et al., 2012).

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