Dietary Starch Level and Rumen-protected AA: Effects on CH_4 Emissions and Heat Production in Lactating Dairy Cows

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INTRODUCTION

- Dairy practices account for about 1.9-2.2% of total greenhouse gas emissions and 24.8% of enteric CH_4 production in the US.
- The global warming potential of CH_4 is ~32 times that of CO_2, and CH_4 production also represents 2-12% energetic losses.
- There has been considerable interest in reducing CH_4 emission of dairy cattle.
- Addition of fermentable energy (e.g., starch) or rumen-protected (RP)-Met, Lys, and His to low-CP diets have been shown to improve milk and milk protein yield, while sustaining N efficiency of lactating cows.
- However, the effects of these dietary strategies (dietary starch level and RP-AA supplementation) on CH_4 emission and energy utilization have not been investigated.

OBJECTIVE

- **We aimed to explore the impact of dietary starch level and RP-Met, Lys, and His on CH_4 production and whole-body energy utilization in lactating dairy cows fed MP-deficient diets.**

METHODS

- Sixteen multiparous Holstein cows (138 ± 46 DIM, 46 ± 6 kg/d of milk, and 700 ± 55 kg of BW) were used in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments.
- Each period lasted 21 d, including 14 d for diet adaptation and 7 d for data and sample collection.
- Dietary treatments included high-starch (**HS**), high-starch + RP-Met, Lys, and His (**HS/MLH**), reduced-starch (**RS**), and reduced-starch + RP-Met, Lys, and His (**RS/MLH**).
- Both diets consisted of 50% forage and 50% concentrate (Table 1).
- Dietary starch level was varied by replacing 30% ground corn with 10% soybean hulls and 20% beet pulp (Table 1).
- Emissions of CO_2 and CH_4 were measured by the GreenFeed system (C-Lock Inc., Rapid City, SD) twice daily from d 15 to 18.
- Fecal, urinary, CH_4, milk, and tissue energy and heat production were calculated using equations.
- Data were analyzed using the MIXED procedure of SAS (SAS version 9.4).

Table 1. Ingredient and nutrient composition of high-starch (**HS**) and reduced-starch (**RS**) diets

	Experimental Diets	
Ingredient, % of DM	HS	RS
Corn silage	35.7	35.7
Haylage	14.7	14.7
Ground corn	30.0	-
Beet pulp	-	20.0
Soybean hulls	-	10.0
Soybean meal	8.71	8.71
Canola meal	2.76	2.76
BergaFat F100	3.00	3.00
Mineral mix	2.50	2.50
Sodium bicarbonate	1.00	1.00
DDGS	0.92	0.92
Urea	0.70	0.70

	Experimental Diets	
Nutrient composition	HS	RS
DM (%)	46.8	46.8
CP	16.0	16.4
aNDF	27.9	38.6
Forage NDF	23.4	23.4
ADF	16.4	24.6
NFC	47.0	35.2
Starch	34.4	12.3
Ether extract	6.40	5.70
NE_L, Mcal/kg DM	1.68	1.59
Ca	0.60	1.00
P	0.40	0.40

Table 2. NRC (2001) estimated NE_L, MP and AA balance of lactating dairy cows fed high-starch diet without (**HS**) and with RP-MLH (**HS/MLH**), and reduced-starch diet without (**RS**) and with RP-MLH (**RS/MLH**)

	Treatments			
Item	HS	HS/MLH	RS	RS/MLH
NE_L, Mcal/d				
Requirement	40.0	40.0	40.0	40.0
Supply	41.4	41.5	40.1	40.4
Balance	1.3	1.4	0.1	0.4
MP, g/d				
Requirement	2743	2747	2773	2780
Supply	2564	2612	2666	2727
Balance	-180	-135	-107	-53
RDP, g/d				
Requirement	2539	2548	2479	2497
Supply	2623	2633	2615	2634
Balance	84	85	136	137
RUP, g/d				
Requirement	1544	1541	1675	1669
Supply	1321	1366	1537	1590
Balance	-223	-175	-137	-79
dHis, g/d				
Requirement	60	60	61	61
Supply from the diet	55	55	58	59
Supply from RP-His	0	7	0	7
Balance	-5	2	-3	5
dMet, g/d				
Requirement	60	60	61	61
Supply from the diet	48	48	49	49
Supply from RP-Met	0	15	0	15
Balance	-12	3	-12	3
dLys, g/d				
Requirement	181	181	183	181
Supply	172	173	177	178
Supply from RP-Lys	0	16	0	16
Balance	-9	8	-7	13

Table 3. Dietary energy estimations and milk energy efficiencies in lactating dairy cows fed high-starch diet without (**HS**) and with RP-MLH (**HS/MLH**), and reduced-starch diet without (**RS**) and with RP-MLH (**RS/MLH**)

	Treatments					*P*-value		
Item	HS	HS/MLH	RS	RS/MLH	SEM	SL[1]	MLH[1]	SL × MLH
GE[2], Mcal/d	103	104	103	105	2.93	0.97	0.34	0.66
DE[3], Mcal/d	72.2	72.8	72.1	73.3	1.81	0.87	0.46	0.80
ME[4], Mcal/d	62.4	63.0	61.1	62.1	1.51	0.28	0.43	0.81
Fecal energy[5], Mcal/d	31.1	31.5	30.5	32.1	1.19	0.94	0.29	0.53
Urinary energy[6], Mcal/d	4.06	4.10	3.97	4.04	0.10	0.27	0.44	0.81
CH_4 energy[7], Mcal/d	6.13	6.13	7.71	7.70	0.30	<0.001	0.97	0.99
Heat production[8], Mcal/d	34.2	33.8	33.6	34.1	0.94	0.80	1.00	0.47
Milk energy[9], Mcal/d	27.8	28.2	27.3	27.2	0.80	0.08	0.80	0.59
Tissue energy[10], Mcal/d	0.34	0.99	0.16	0.93	0.40	0.76	0.07	0.88
Milk energy, % of GE	27.2	27.2	26.8	26.0	0.55	0.03	0.32	0.26
Milk energy, % of DE	38.6	38.8	38.0	37.2	0.77	0.02	0.53	0.25

[1]SL = starch level, MLH = RP-Met, Lys, and His. [2]GE = DE + fecal energy. [3]DE = ME + CH_4 energy + urinary energy. [4]ME = Heat production + milk energy + tissue energy. [5]Fecal energy = (DE ÷ in situ DM digestibility) − DE. [6]Urinary energy = ME × 0.065. [7]CH_4 energy = CH4 × 13.2 kcal/g. [8]Heat production = (4.96 + 16.07 ÷ respiratory quotient) × QCO2 (L/d) ÷ 1,000, RQ = 1.00. [9]Milk energy = [(0.0929 × milk fat%) + (0.0563 × milk true protein%) + (0.0395 × milk lactose%)] × milk yield (kg/d). [10]Tissue energy = (body fat% × 9.4 + body protein% × 5.55) × BW change.

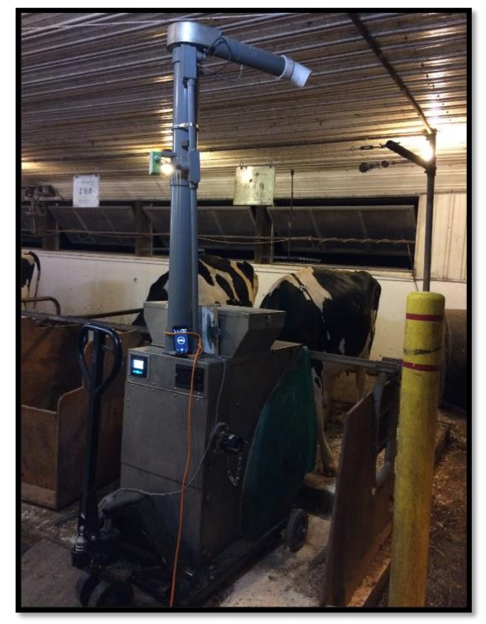

Figure 1. The GreenFeed system operates by automatically releasing a bait feed set to ~15 times per feeding event with 20 s apart triggered by a radio frequency ear tag after the cow's head is located inside the head chamber resulting in representative breath or eructation sampling and near real-time analysis of CH_4 and CO_2 emissions using built-in gas sensors

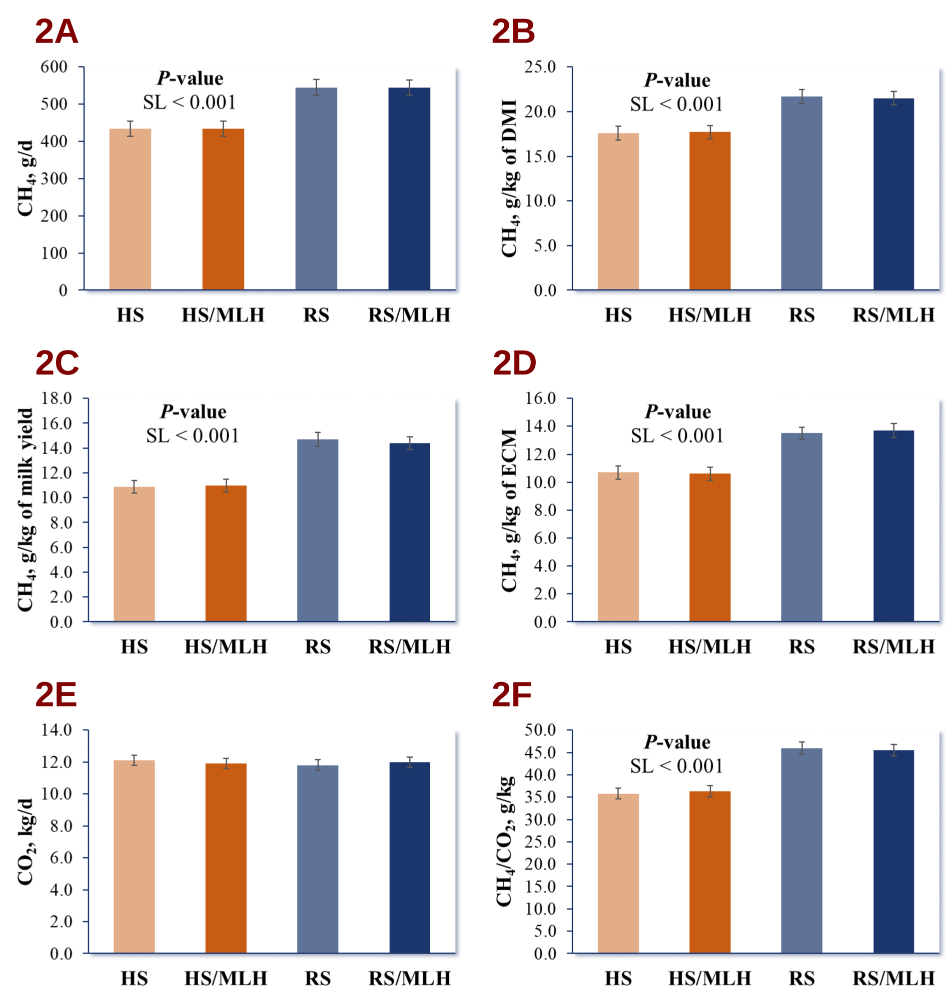

Figure 2. Enteric CH_4 production (**2A**), yield (**2B**), and intensity (**2C** and **2D**), CO_2 emission (**2E**), and CH_4 to CO_2 ratio (**2F**) in lactating dairy cows fed high-starch diet without (**HS**) and with RP-MLH (**HS/MLH**), and reduced-starch diet without (**RS**) and with RP-MLH (**RS/MLH**); SL represents dietary starch level.

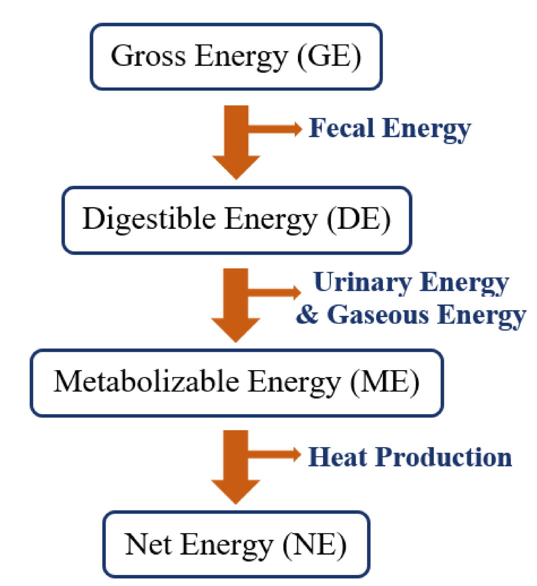

Figure 3. Energy flow diagram in dairy cows

RESULTS

- Daily CH_4 production (434 vs. 545 g/d; 605 vs. 760 L/d), yield (17.7 vs. 21.6 g/kg of DMI), and intensity (11.0 vs. 14.6 g/kg of milk yield; 10.7 vs. 13.6 g/kg of ECM) were lower with feeding HS vs. RS diets, respectively ($P < 0.001$; Figure 2A-D).
- CO_2 emission (mean = 12.0 kg/d or 6,043 L/d) did not differ significantly across diets (Figure 2E).
- HS diets had decreased CH_4 to CO_2 ratio than RS diets (Figure 2F).
- Treatments did not affect fecal and urinary energy (Table 3).
- Cows fed HS diets had reduced CH_4 energy than those fed RS diets (5.72 vs. 7.19 Mcal/d; Table 3).
- Heat production (mean = 33.9 Mcal/d) was not affected by treatments (Table 3).
- Milk energy tended to be higher with HS diets as compared with RS diets ($P = 0.08$; Table 3).
- Milk energy efficiencies (% of GE and % of DE) were elevated for HS diets, relative to RS diets (Table 3).
- No effect of RP-MLH supplementation on energy utilization was observed (Table 3).

CONCLUSIONS

- **Elevated starch supply by substituting fibrous byproducts with ground corn decreased energy losses as CH_4 without changing HP.**
- **Feeding high-starch diets improved milk energy utilization of lactating dairy cows.**

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