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Inclusion of sainfoin (*Onobrychis viciifolia*) silage in dairy cow rations affects nutrient digestibility, nitrogen utilization, energy balance, and methane emissions

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ABSTRACT

Sainfoin (*Onobrychis viciifolia*) is a tanniniferous legume forage that has potential nutritional and health benefits preventing bloating, reducing nematode larval establishment, improving N utilization, and reducing greenhouse gas emissions. However, the use of sainfoin as a fodder crop in dairy cow rations in northwestern Europe is still relatively unknown. The objective of this study was to evaluate the effect of sainfoin silage on nutrient digestibility, animal performance, energy and N utilization, and CH_4 production. Six rumen-cannulated, lactating dairy cows with a metabolic body weight ($BW^{0.75}$) of 132.5 ± 3.6 kg were randomly assigned to either a control (CON) or a sainfoin (SAIN)-based diet over 2 experimental periods of 25 d each in a crossover design. The CON diet was a mixture of grass silage, corn silage, concentrate, and linseed. In the SAIN diet, 50% of grass silage dry matter (DM) of the CON diet was exchanged for sainfoin silage. The cows were adapted to 95% of ad libitum feed intake for a 21-d period before being housed in climate-controlled respiration chambers for 4 d, during which time feed intake, apparent total-tract digestibility, N and energy balance, and CH_4 production was determined. Data were analyzed using a mixed model procedure. Total daily DM, organic matter, and neutral detergent fiber intake did not differ between the 2 diets. The apparent digestibility of DM, organic matter, neutral detergent fiber, and acid detergent fiber were, respectively, 5.7, 4.0, 15.7, and 14.8% lower for the SAIN diet. Methane production per kilogram of DM intake was lowest for the SAIN diet, CH_4 production as a percentage of gross energy intake tended to be lower, and milk yield was greater for the SAIN diet. Nitrogen intake, N retention, and energy retained in body protein were greater for the SAIN than for the CON diet. Nitrogen retention as a percentage of N intake tended to be greater for the SAIN diet. These results suggest that inclusion of sainfoin silage in dairy cow rations reduces CH_4 per kilogram of DM intake and nutrient digestibility. Moreover, sainfoin silage improves milk production and seems to redirect metabolism toward body protein accretion at the expense of body fat.
Key words: sainfoin silage, digestibility, methane production, nitrogen utilization

INTRODUCTION

Methane (CH_4) is the second most important gas involved in global warming, with CH_4 from livestock accounting for 6.3% of the human-induced production of greenhouse gases when expressed in CO_2-equivalents (Gerber et al., 2013). Among livestock, ruminants are the main contributors, accounting for 65% of emissions. Ruminants typically lose between 2 and 12% of their ingested energy as eructated CH_4 (Johnson and Johnson, 1995). These energy losses are not only an environmental concern but also reduce efficiencies in ruminant production. Reducing the enteric CH_4 emissions of cattle would lessen the impact of livestock production on the environment and potentially decrease the costs of production by increasing feed efficiency. A decrease in CH_4 emissions from ruminants can be achieved by improving feed quality (Ominski et al., 2006), adding oils to the diet (Alexander et al., 2008; Castillejos et al., 2008), or including secondary compounds such as condensed tannins (**CT**) in the diets (Carulla et al., 2005; Waghorn, 2008).

Sainfoin (*Onobrychis viciifolia*) is a tanniniferous legume that is grown under different climatic conditions

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in Europe, Asia, and western North America, primarily in calcareous soils (Hayot Carbonero et al., 2011). Sainfoin can be grown as a pure stand or mixed with perennial ryegrass as companion crop (Moyer, 1985), and it is useful for grazing, hay-making, and for silage. Sainfoin is reported to support a similar animal performance compared with grass and grass-clover hay when offered as hay to dairy cows (Scharenberg et al., 2009). Additional ruminant health benefits of sainfoin include the prevention of bloat (McMahon et al., 1999) and parasitism (Hoste et al., 2015). These positive effects may be explained by the CT that are present in sainfoin (Hayot Carbonero et al., 2011). In addition, due to the CT in sainfoin (compared with alfalfa), N excretion is partially redirected from urine to feces in sheep and, therefore, could reduce ammonia (NH_3) volatilization from ruminant manure (Copani et al., 2015). Sainfoin CT have also been shown to reduce CH_4 emissions in vitro (Hatew et al., 2015a,b). Limited data, however, are available on the effect of sainfoin on CH_4 emission in vivo, and to the authors' knowledge, no data are available on the use of sainfoin silage in TMR typically fed to dairy cows. The hypothesis of this study was that inclusion of sainfoin silage at the expense of grass silage in a TMR for dairy cows would reduce CH_4 emission, alter N metabolism, and affect milk production. Therefore, the objective of this study was to compare enteric CH_4 emissions, diet digestibility, energy and protein utilization, and N excretions from dairy cows receiving TMR based on either sainfoin silage (a CT-containing forage) or grass silage (a CT-free forage).

MATERIALS AND METHODS

Experimental Design

The experiment was approved by the Institutional Animal Care and Use Committee of Wageningen University (Wageningen, the Netherlands) and executed in accordance with European Union directive 2010/63/EU implemented by the Dutch legislation on the use of experimental animals. The experiment was conducted from February to April 2014 at the Carus Research Facilities of Wageningen University. The experiment followed a crossover design with 2 dietary treatments and 6 rumen-cannulated (Type 1C; Bar Diamond Inc., Parma, ID) lactating multiparous dairy cows with a mean ± SD metabolic BW ($\mathbf{BW^{0.75}}$) of 132.5 ± 3.6 kg, 214 ± 72 DIM, and an average milk production of 23.1 ± 2.8 kg/d at the start of the experiment. Cows were paired based on parity and milk production; within pairs, cows were randomly assigned to receive either a grass and corn silage-based control (**CON**) diet or a sainfoin-grass and corn silage-based (**SAIN**) diet (Table 1) for an experimental period of 25 d (adaptation period from d 8–29 and subsequent measurement period from d 29–33), after which animals were changed to the other dietary treatment for a second 25-d period. Before both experimental periods, all animals received the CON diet for a 7-d period (d 1–7).

Table 1. Feedstuff and chemical compositions (g/kg of DM unless otherwise noted) of TMR containing grass silage (CON) or sainfoin silage (SAIN) used in the experiment[1]

	Dietary treatment	
Item	CON	SAIN
Ingredient		
Grass silage[2]	600.0	300.0
Sainfoin silage[3]	0.0	300.0
Corn silage[4]	100.0	100.0
Concentrate[5]	240.0	240.0
Linseed[6]	60.0	60.0
Chemical composition		
DM, g/kg of product	444.9	357.2
OM	918.9	891.3
CP	162.7	171.9
NDF	395.7	359.1
ADF	236.7	244.5
ADL	18.6	35.0
Crude fat	37.8	35.1
Starch	97.9	90.9
Gross energy, MJ/kg of DM	19.5	19.0
Condensed tannins	0.0	8.8

[1]Values are means for 2 successive measurement periods. For all components, NE_L was determined according to Van Es (1975).

[2]Grass silage: DM = 366 g/kg product; chemical composition (g/kg of DM): OM = 907.1, CP = 145.9, NDF = 508.6, ADF = 306.3, ADL = 14.3, gross energy (GE) = 19.2 MJ/kg of DM, NE_L = 7.4 MJ/kg of DM; pH = 5.4.

[3]Sainfoin silage was a mixture of cultivar 'Zeus' silage from clay soil and cultivar 'Esparcette' from sandy soil (ratio between silages from 'Zeus' and 'Esparcette' = 70:30 on DM basis). Sainfoin 'Zeus' silage: DM = 200 g/kg product; chemical composition (g/kg of DM): OM = 785.2, CP = 212.3, NDF = 346.0, ADF = 305.3, ADL = 67.0, GE = 17.1 MJ/kg of DM, NE_L = 4.3 MJ/kg of DM; condensed tannins (CT) = 24.0, pH = 5.5. Sainfoin 'Esparcette' silage: DM = 380 g/kg of product; chemical composition (g/kg of DM): OM = 923.5, CP = 96.5, NDF = 441.0, ADF = 336.5, ADL = 59.6, GE = 18.2 MJ/kg of DM, NE_L = 5.3 MJ/kg of DM; CT = 31.0, pH = 5.2.

[4]Corn silage: DM = 314 g/kg of product, chemical composition (g/kg DM): OM = 961.3, CP = 83.4, NDF = 354.9, ADF = 203.3, ADL = 7.4, starch = 328.5, GE = 19.0 MJ/kg of DM, NE_L = 6.9 MJ/kg of DM; pH = 3.8.

[5]Concentrate contained triticale 3.4%, palm kernel flakes 11.8%, stable rapeseed B 7.4%, rapeseed meal 7.2%, soybean meal 12.9%, beet pulp 7.5%, lime 1.53%, magnesium oxide 0.1%, mixing salt 0.42%, molasses 5%, sodium bicarbonate 0.25%, corn gluten middling 8.9%, corn 30.3%, PRX AR 202 Melkvee B Basis 0.6%, PRX AR 201 Melkvee A Prima (Agruniek-Rijnvallei, Wageningen, the Netherlands), 0.2% potato juice (protaminase). DM = 893 g/kg of product, chemical composition (g/kg of DM): OM = 916.3, CP = 209.9, NDF = 221.2, ADF = 122.5, ADL = 29.4, crude fat = 40.3, starch = 244.4, GE = 18.2 MJ/kg of DM, NE_L = 7.4 MJ/kg of DM.

[6]Linseed: DM = 922 g/kg of product; chemical composition (g/kg of DM): OM = 962.0, CP = 239.5, NDF = 201.3, ADF = 156.2, ADL = 29.1, crude fat = 417.9, starch = 14.3, GE = 27.8 MJ/kg of DM, NE_L = 11.7 MJ/kg of DM.