

Impact of the methane-suppressing feed additive myristic acid on energy and calcium balance of sheep

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ABSTRACT

The impact of feeding myristic acid (C14:0; 50 g/kg DM) to sheep was investigated in a 6×6 Latin square arrangement. C14:0 was supplemented to two control diets (forage:concentrate ratios of 1:1.5 and 1:0.5) which were adjusted to different dietary Ca contents (4.2 or 9.0 g/kg DM). In combination with the concentrate-based diet, C14:0 reduced methane energy loss by more than 50% but reduced Ca availability of the animals while the additional Ca supply improved Ca and energy retention. Supplementing C14:0 to the forage-based diet did not affect Ca availability and resulted in highest feed energy utilization.

KEY WORDS: medium-chain fatty acid, methanogenesis, ruminants, metabolizable energy, calcium retention, forage proportion

INTRODUCTION

The use of fats in ruminant nutrition has gained renewed interest since fat is an important energy source in the diet of high-yielding animals and might be a possible mitigation strategy to reduce the emission of the greenhouse gas methane. *In vivo*, the methane-suppressing effect especially was demonstrated for fats rich in the medium-chain saturated fatty acids (MCFA), lauric (C12:0) and myristic (C14:0) acid, such as coconut oil (Machmüller and Kreuzer, 1999), and was recently also demonstrated for dietary C14:0 (Machmüller et al., 2003). However, due to interactions among MCFA, fibre and Ca in the digestive tract the efficiency of C14:0 in methane suppression will depend on the dietary proportions of forage and Ca (Machmüller et al., 2003). Therefore, the objective of the present study was to evaluate whether these interactions with C14:0 also have an impact on energy and Ca balance of ruminants.

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MATERIAL AND METHODS

The present study was carried out with six castrated male Swiss White Hill breed sheep of 41 kg body weight in a 6×6 Latin square arrangement. Two basal diet types of different forage:concentrate ratio (1:1.5 concentrate-based diet type and 1:0.5 forage-based diet type) were fed, calculated to cover 1.3 times maintenance requirements. Both basal diets were supplemented with pure non-esterified C14:0 (0 and 50 g/kg DM) and two levels of dietary Ca (4.2 and 9.0 g/kg DM, the latter only in combination with the diets already supplemented with C14:0). The lower level of dietary Ca supply was still within the range recommended for sheep (2.4 to 3.0 g Ca/d; ARC, 1980).

In six experimental periods, each sheep received all six dietary treatments but in a different sequence. Experimental periods consisted of 14 d of adaptation to the respective experimental diet, 8 d of complete and separate collection of faeces and urine, and 2 d of quantitative measurement of gaseous exchange in respiratory chambers. On the last day of every experimental period, blood samples were taken from every sheep 5 h after the morning feeding.

Collection procedure, analyses and calculations were conducted as described by Machmüller and Kreuzer (1999). In feed, faeces and urine, Ca contents were determined photometrically (Naumann and Bassler, 1997). Serum Ca concentration was measured on a COBAS MIRA analyser (Roche Diagnostics, Basle, Switzerland) using a commercial test kit (Roche Diagnostics) and serum calcitriol (1,25-dihydroxyvitamin D₃) concentration by using a gamma counter (GAMMAmatic 1, Kontron Instruments, Zurich, Switzerland) and a commercial radioimmunoassay kit (Nichols Institute Diagnostic, San Clemente, CA, USA).

RESULTS AND DISCUSSION

Supplementing the basal diets with 50 g/kg DM of C14:0 increased daily intakes of gross energy (Table 1), digestible energy and metabolizable energy (ME; data not shown) by 8, 5 and 12% on average, respectively. C14:0 supplementation reduced gross energy loss *via* methane and urine. However, the improvement in energy retention (RE) by on average 34% was not significant, because gross energy loss *via* faeces numerically increased.

The calculated ME value of C14:0 was 24.5 MJ/kg when added to the concentrate-based diet type and 32.1 MJ/kg when added to the forage-based diet type. The present data highlight that there is no single value for the ME content of fat as it will be specifically determined by the composition of the basal diet used. Thus increasing the dietary Ca content resulted in an improvement in the calculated ME value for added C14:0 in the concentrate-based diet to 32.6 MJ ME/kg which is similar to the 33.3 MJ ME/kg C14:0 found for the Ca-supplemented forage-

based diet. Compared to the forage-based diet type, lower RE:ME ratios (data not shown) were found with the concentrate-based diet type, which further gives evidence that the effect of added C14:0 on the nutrient digestion of the basal diet and, along with that, on the energy utilization of the complete diet is depending on the basal diet type, specifically on its fibre and Ca content.

Table 1. Effect of C14:0 supplementation on gross energy (GE) intake and energy balance (n = 6)

C14:0, g/kg DM	Concentrate-based diet type			Forage-based diet type		
	0	50	50	0	50	50
Ca, g/kg DM	4.2	4.2	9.0	4.2	4.2	9.0
GE intake, MJ/d	13.43	14.10	14.94	15.68	17.22	17.43
<i>Energy balance, % of GE intake</i>						
Energy loss						
faeces	31.2	33.7	34.0	33.7	34.3	34.1
urine	3.9 ^a	3.2 ^{ab}	3.4 ^{ab}	3.8 ^a	2.7 ^b	2.9 ^b
methane	7.4 ^a	2.9 ^c	3.5 ^c	6.4 ^a	4.5 ^b	4.9 ^b
EE ¹	50.4 ^a	52.6 ^a	49.4 ^{ab}	46.0 ^{bc}	43.1 ^c	42.7 ^c
Energy retention	7.1	7.6	9.7	10.1	15.4	15.4

¹ EE: energy expenditure (heat production)

^{a,b,c} mean values with different lower case letters in the same row are significantly different

With regard to Ca balance, it is assumed that, due to formation of insoluble complexes between C14:0 and Ca ions in the rumen and in the large intestine, the addition of C14:0 resulted in a negative Ca retention in the concentrate-based diet, while there was no effect in the forage-based diet (Table 2). Increasing the Ca level of the diets from 4.2 to 9.0 g/kg DM increased the daily amount of Ca ingested, excreted *via* faeces, digested and retained on average to 2.2-, 1.9-, 4.0- and 4.7-fold values, respectively, but did not change the daily urinary Ca excretion (data not shown). With the concentrate-based diet type, the extra Ca resulted in a return to a positive Ca balance. Animals retained on average 1.0 g Ca/d, which was similar to that found in the diet not supplemented with C14:0. By contrast, serum Ca (data not shown) did not clearly respond to the changes in Ca retention and ranged around 2.4 mmol/L. Apparently, the metabolic Ca supply was always sufficient for homeostatic control. However, the need for extra Ca with the C14:0-supplemented concentrate-based diet was clearly visible from a response in the serum calcitriol level (data not shown). With this basal diet type, the addition of C14:0 significantly increased the mean serum calcitriol level from 53 to 82 pg/ml, an effect not occurring when simultaneously extra Ca was given.

Table 2. Effect of C14:0 supplementation on Ca intake and Ca balance (n = 6)

	Concentrate-based diet type			Forage-based diet type		
	0	50	50	0	50	50
C14:0, g/kg DM						
Ca, g/kg DM	4.2	4.2	9.0	4.2	4.2	9.0
Ca intake, g/d	3.18	3.05	6.74	3.74	3.74	7.87
<i>Ca balance, % of Ca intake</i>						
Ca loss						
faeces	69.4 ^b	104.7 ^a	84.4 ^{ab}	83.7 ^{ab}	78.2 ^{ab}	74.9 ^{ab}
urine	2.3	2.2	0.6	2.3	1.8	1.1
Ca retention	28.3 ^a	-6.9 ^b	15.0 ^{ab}	14.0 ^{ab}	20.0 ^{ab}	24.0 ^{ab}

^{a,b} mean values with different lower case letters in the same row are significantly different

CONCLUSIONS

The present study gives evidence, that specific dietary measures have to be applied when using diets enriched in medium-chain fatty acid (MCFA) for methane-suppressing and energetic purpose. A high methane-suppressing activity of MCFA can be achieved with diets where rumen interaction of MCFA with dietary compounds remains as low as possible. In turn, high dietary fibre and Ca contents partially inactivate the methane-suppressing MCFA. However, with regard to the Ca availability for the animal the present data show that the recommended Ca content of C14:0-supplemented concentrate-based diet types has to be increased. On the other hand, having the aim to maximize energy retention with MCFA-supplemented diets needs the use of feeding regimes less efficient in methane abatement, i.e. forage-dominated, Ca-supplemented diets.

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