ENERGY METABOLISM OF FARM ANIMALS

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METHANE SUPPRESSION BY CALCIUM SOAPS OF STEARIC, OLEIC AND LINOLEIC ACID MIXTURES IN CATTLE

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Summary

Two types of calcium soaps of fatty acids (Ca-FA) were used; Ca-FA-1 (C18:0 17.0%, C18:1 65.0%) and Ca-FA-2 (C18:0 20.0%, C18:1 40.0%, C18:2 35.0%). In Expt 1 four dry cows were fed Italian ryegrass hay and concentrate as basal diet (BD). Treatments were BD, BD + Ca-FA-1 (300g), BD + Ca-FA-1 (600g) or BD + Ca-FA-2 (600g). In Expt 2 four lactating cows were fed bahiagrass hay and concentrates with or without the Ca-FA-2 supplements (500g). In Expt 1 there were no significant differences in NDF digestibility by feeding Ca-FA. Methane production per dry matter intake (DMI) in dry cows tended to decrease about 7-9% (17-23 litres/day) by feeding Ca-FA but no effects of degree of saturation and amount of Ca-FA fed were observed. In Expt 2 DMI and digestibilities of dry matter (DM) and crude protein (CP) were not affected by feeding Ca-FA. Methane suppression in lactating cows was about 4% (22 litres/day/kg DMI).

From the above results, it is concluded that feeding 300-600 g/day of Ca-FA is effective in suppressing methane production without reduction of productivity.

Key words: Methane production, calcium soaps, cows, digestibility.

Introduction

It is important now to reduce methane production from ruminants because it is recognized to be one of the major greenhouse gases. Methane excretion by ruminant animals is about 8% of total energy intake of the animal (Blaxter, 1967). The methanogenic bacteria produce methane in the rumen mainly from hydrogen and carbon dioxide. Hydrogenation of the double bonds of unsaturated fatty acids might share hydrogen with the methanogenesis process in the rumen (Blaxter & Czerkawski, 1966). Therefore, the addition of unsaturated fatty acids to the diet may result in an inhibition of methane production.

Increasing energy density by feeding supplemental Ca-FA can increase production, especially in high producing lactating cows (Schneider *et al.*, 1988, Sklan *et al.*, 1989, Andrew *et al.*, 1991). Preformed calcium soaps are easily mixed with rations and do not affect normal rumen fermentation (Jenkins & Palmquist, 1984) and digestibilities of most nutrients (Schauff & Clark, 1992). For that reason it is practical for use by farmers to suppress methane production from ruminants without reducing production performance.

The objectives of the experiments were to evaluate the effect of unsaturated Ca-FA supplementation on the methane production and digestion of nutrients in cattle.

Materials and Methods

Two experiments were conducted using 4 dry cows (Expt 1, average live weight 643kg) in one way classification and 8 lactating cows (Expt 2, average live weight 626kg) in one way classification with blocks (protein source). Two types of Ca-FA were used; Ca-FA-1 (C18:0 17.0%, C18:1 65.0%; Fine feed I, Miyoshi Oils and Fat Co., Ltd.) and Ca-FA-2 (C18:0 20.0%, C18:1 40.0%, C18:2 35.0%; Fine feed B). The chemical composition of the

hay, concentrate and Ca-FA used in the trial are shown in Table 1. In Expt 1 dry cows were fed a diet of 60% Italian ryegrass hay and 40% concentrate on DM basis to meet metabolizable energy (ME) requirement (AFFRC, 1994) as basal diet (BD). Treatments were BD (control), BD + Ca-FA-1 (300g, C18:1L), BD + Ca-FA-1 (600g, C18:1H) or BD + Ca-FA-2 (600g, C18:2H) with 14 days feeding period. Faeces and urine were collected for the last 4 days, and each cow spent 2 days of each collection period in open-circuit respiration chambers for the measurement of respiratory exchange (Iwasaki *et al.*, 1982). In Expt. 2 lactating cows were fed bahiagrass hay *ad libitum* and concentrates with or without the Ca-FA-2 supplement (500g, C18:2) to meet 80% of ME requirement (AFFRC, 1994) for 14 days. Faeces and urine collections were done for the last 7 days, and studies of energy balance were conducted during the last 5 days of the collection period using open circuit respiration chambers (Mukai *et al.*, 1989).

All data were analyzed by the GLM procedure (SAS, 1988) and treatment means were tested with Tukey's multiple range test if F tests were significant ($P<0.05$).

Table 1. Chemical composition of hay, concentrate and calcium soaps of fatty acids (Ca-FA) (g/kg or MJ/kg DM).

	DM	CP	EE	NDF	GE
Expt 1 (dry cows)					
Italian ryegrass hay	884	99	29	620	17.8
Concentrate[1)]	902	173	40	188	18.3
Ca-FA-1	971		870		33.3
Ca-FA-2	970		880		34.0
Expt 2 (lactating cows)					
Bahiagrass hay	888	73	15	709	17.9
Concentrate (CaFA2+)[2)]	888	148	63	171	16.9
Concentrate (CaFA2-)[3)]	886	178	29	193	16.4

DM: Dry matter, CP: Crude protein, EE: Ether extract, NDF: Neutral detergent fibre, GE: Gross energy.

1) Ingredients (ADM%): corn 30%, barley 25%, wheat bran 9%, defatted rice bran 7%, soybean meal 12%, molasses 3.7%, alfalfa meal 7%, beat pulp 5%, $CaCO_3$ 1.3%.

2) Ingredients (ADM%): corn 41.9%, barley bran 2.2%, soybean meal 18.2-6.8%, fish meal 0-6.8%, alfalfa meal 10.6%, soybean hull 7.1%, beet pulp 7.3-13.7%, molasses 7.1%, calcium soaps of fatty acids 3.5%, $Ca_3(PO_4)_2$ 0.9%, mineral suppl. 0.7%.

3) Ingredients (ADM%): corn 50.3%, barley bran 2.7%, soybean meal 17.5-7.1%, fish meal 0-7.1%, alfalfa meal 7.1%, soybean hull 7.1%, beet pulp 14.0-17.7%, $Ca_3(PO_4)_2$ 0.5%, $CaCO_3$ 0.5%, mineral suppl. 0.7%.

Results and Discussion

The least square means of BW, milk yield, milk fat, digestibility, methane production, nitrogen balance and energy balance with dry and lactating cows are shown in Table 2. Milk fat concentration was lower in the Ca-FA period, but milk fat yield was more (1.01 kg/day) than the control (0.99kg/day) because of increased milk production. There were no significant differences in DM, CP and NDF digestibilities by feeding Ca-FA with dry cows or in DM and CP digestibility with lactating cows. These results were similar to previous experiments (Klusmeyer *et al.*, 1991; Schauff & Clark, 1992). DMI was not affected by feeding Ca-FA. Methane production tended to decrease when Ca-FA was fed to dry cows, but was increased by feeding Ca-FA (552.9 litres/day) compared to the control diet (540.4 litres/day) in lactating cows. Methane production per DMI in dry cows was tended to decrease about 6.7-8.7% (17-23 litres/day) by feeding Ca-FA but no effect of the degree of saturation nor amount of Ca-FA was observed. Methane production per kg DMI in

lactating cows was reduced by feeding Ca-FA-2 (30.0 litres/kg) compared to the control (31.2 litres/kg), and methane suppression per DMI was about 3.8% (22.4 litres/day).

Table 2. Least square means of live weight (LW), milk yield, milk fat, digestibility, methane production, nitrogen balance and energy balance in dry and lactating cows.

	Expt 1 (dry cows)					Expt 2 (lactating cows)		
Treatment	Control	C18:1L	C18:1H	C18:2H	SE	Control	C18:2	SE
Number of cows	4	4	4	4		4	4	
LW (kg)	677	650	651	668	18	597	653	19
DMI (kg/day)	6.5	6.5^{ab}	6.5	6.5	0.1	17.4	18.4	0.9
Ca-FA intake(kg/day)		0.3	0.6	0.6			0.5	
Milk yield (kg/day)						25.6	27.3	1.2
Milk fat (%)						3.9	3.7	0.1
Digestibility (%)								
Dry matter	71.2	71.6	69.7	70.5	0.8	68.1	68.0	0.7
Crude protein	62.4	62.8	62.3	61.5	1.7	57.7	59.5	0.6
NDF[1]	66.9	66.9	66.4	67.0	1.1			
CH_4 (l/day)	263	240	245	243	5.1	540	553	22
CH_4/DMI (l/kg)	40.6	37.1	37.9	37.5	0.9	31.2	30.0	0.7
% of control	$(100)^a$	$(91.3)^b$	(93.4)	(92.4)		(100)	(96.2)	
CH_4/DDMI (l/kg)	57.0^a	51.8^b	54.3	53.2	1.0	46.0^a	43.1^b	0.7
N balance (g/day)								
Intake	134	134	134	134	2.6	402	436	21
Faeces	50.4	49.8	50.6	51.6	3.1	168	176	9.2
Urine	72.1	68.5	60.2	66.8	4.3	54.4	82.1	8.9
Milk						129	132	4.0
Retention	11.3	15.4	22.9	15.3	3.7	50.3	45.4	10
Energy balance ($kJ/kg^{0.75}$)								
ME intake	538^A	585^A	667^B	655^B	4.9	1580	1654	57
Milk						650	615	16
Heat production	488^A	512^A	546^B	529^B	11	862	913	21
Retention	50	73	121	127	23	69	126	30

[a, b]: Means in the same row within dry cows or lactating cows with different superscripts differ (P<0.05) by Tukey's multiple range test.
[A, B]: Means in the same row within dry cows or lactating cows with different superscripts differ (P<0.01) by Tukey's multiple range test.
1) NDF: Neutral detergent fibre.

Nitrogen balance was not affected by Ca-FA feeding in Expt 1 but urinary nitrogen excretion tended to increase with addition of Ca-FA in Expt 2. Metabolizable energy intake and heat production were significantly increased with dry cows and retention energy tended to increase when 500-600 g of Ca-FA were fed with dry and lactating cows.

From the results of these experiments we calculated the decrease of methane production C18:1-L; 1.36, C18:1-H; 0.80, C18:2-H; 0.86 and C18:2-H (lactating cows) 0.89 moles/mole Ca-FA given. Methane production per mole of Ca-FA was not affected by unsaturation of the acid 500-600 g of Ca-FA feeding periods. Blaxter & Czerkawski (1966) observed the effect of stearic, oleic and linolenic acid for methane depression were 3.1, 1.7 and 1.8 moles/mole respectively with sheep, but they reported loss of appetite and decrease of DMI and digestibility due to the effects on rumen microorganisms. In our study smaller

effects on methane suppression compared with their experiments were confirmed by feeding Ca-FA with cows but no negative effects of DMI, digestibility, milk production, nitrogen and energy balance were observed. This is probably because Ca soaps protect ruminal microbes from the adverse effects of fat (Chalupa *et al.*, 1986). However, they observed a reduction in methane production per mole of unsaturated fatty acid increased with increasing unsaturation of the acid at a rate of 0.24 ± 0.09 moles/mole double bond. In our experiments Ca-FA-2 contained only 35.0% unsaturated fatty acid (C18:2) so the effects of degree of unsaturation might not be observed clearly.

From the above results, it is concluded that feeding 300-600 g/day of Ca-FA is effective in suppressing methane production without reduction of productivity.

References

Agriculture, Forestry and Fisheries Research Council Secretariat (AFFRC) (1994). Japanese Feeding Standards for Dairy Cattle. AFFRC. Tokyo.

Andrew S.M., Tyrrell H.F., Reynolds C.K. & Erdman R.A. (1991). Net energy for lactation of calcium salts of long-chain fatty acids for cows fed silage-based diets. *J. Dairy Sci.* 74:2588-2600.

Blaxter K.L. (1967). Energy metabolism of ruminant. Hutchinson Scientific and Technical. London.

Blaxter K.L. & Czerkawski J. (1966). Modifications of the methane production of the sheep by supplementation of its diet. *J. Sci. Food Agric.* 17:417-421.

Chalupa W., Vecchiarelli B., Elser A.E., Kronfeld D.S., Sklan D. & Palmquist D.L. (1986). Ruminal fermentation in vivo as influenced by long chain fatty acids. *J. Dairy Sci.* 69:1293-1301.

Iwasaki K., Haryu T., Tano R., Terada F., Itoh M. & Kameoka K. (1982). New animal metabolism facility especially the description of respirational apparatus. *Bull. Nat. Inst. Anim. Indust.* 39:41-78.

Jenkins T.C. & Palmquist D.L. 1984. Effect of fatty acids or calcium soap on rumen and total nutrient digestibility of dairy rations. *J. Dairy Sci.* 67:978-986.

Klusmeyer T.H., Lynch G.L., Clark J.H. & Nelson D.R. (1991). Effects of calcium salts of fatty acids and protein source on ruminal fermentation and nutrient flow to duodenum of cows. *J. Dairy Sci.* 74:2206-2219.

Mukai A., Shibata M. & Kurihara M. (1989). Energy metabolism of dairy cattle under high environmental temperature 1. Description of the energy metabolism laboratory at the Kyushu National Agricultural Experimental Station. *Bull. Kyushu Natl. Agric. Exp. Stn.* 26:27-69.

SAS (1988). SAS/STAT™ user's guide, release 6.03 ed. SAS Inst. Inc. Cary, NC, USA.

Schauff D.J. & Clark J.H. (1992). Effects of feeding diets containing calcium salts of long-chain fatty acids to lactating dairy cows. *J. Dairy Sci.* 75:2990-3002.

Schneider P., Sklan D., Chalupa W. & Kronfeld D.S. (1988). Feeding calcium salts of fatty acids to lactating cows. *J. Dairy Sci.* 71:2143-2150.

Sklan D., Bogin E., Avidar Y. & Gur-arie S. (1989). Feeding calcium soaps of fatty acids to lactating cows: effect on production, body condition and blood lipids. *J. Dairy Res.* 56:675-681.