EFFECTS OF CALCIUM SALTS OF LONG-CHAIN FATTY ACIDS ON RUMINAL DIGESTIBILITY, MICROBIAL PROTEIN YIELD AND LACTATION PERFORMANCE

W. J. Maeng[1], J. H. Lim and S. R. Lee

Animal Resources Research Center, College of Animal Husbandry
Kon-Kuk University, Seoul 133-701, Korea

Summary

Four sheep per treatment were fed either control or 3% calcium salts of long-chain fatty acids (Ca-LCFA) in a total mixed ration (TMR). Feed and free water intakes were not different, but digestibilities of crude protein and crude fiber were lower ($p < 0.05$) and that of crude fat was higher ($p < 0.05$) for sheep fed Ca-LCFA than for control sheep. Dry matter digestibility, ruminal pH and microbial protein yield were not different between treatments and ammonia-N concentration in the rumen was higher for sheep fed Ca-LCFA than for control sheep. A 60-day milk production trial was conducted with thirty lactating Holstein cows. Fifteen cows per treatment were fed TMR containing either control or 3% Ca-LCFA *ad libitum*. Feed intake was not different between treatments, but milk yield was significantly higher ($p < 0.05$) for cows fed Ca-LCFA than for control cows. Milk fat percentage was slightly higher and milk protein was lower for cows fed Ca-LCFA than for control cows. Lactose and total solid contents in milk were not different between treatments.
(**Key Words**: Calcium Salts of Long-Chain Fatty Acids, Digestibility, Milk Yield, Milk Composition, Ruminal pH, Ammonia-N)

Introduction

Adding fat to the diet of dairy cattle may increase milk production because of the increased energy intake. Many experiments have also shown that metabolizable energy in the form of fat is utilized more efficiently than that contained in cereals and forage (Palmquist and Jenkins, 1980). This improved energetic efficiency due to added dietary fat comes from providing long-chain fatty acids for direct incorporation into milk fat, but also from reducing the energy cost of metabolism (Baldwin and Smith, 1974; Baldwin et al., 1980). However, fat use may be limited due to its inhibitory effect of some unsaturated fatty acids on ruminal bacteria (Henderson, 1973; Palmquist and Jenkins, 1980).

Feeding ruminal-escape lipids or rumen inert fat can enhance energy density of lactation diets without adversely affecting fibre digestion (Jenkins and Palmquist, 1984; Grummer, 1988); thus effectively overcome the shortcomings of conventional fat being introduced in the rumen. Jenkins and Palmquist (1984) reversed fibre digestion depression caused by tallow fatty acids when the same fatty acids were fed as calcium soaps.

Others also observed that adding calcium salt of long-chain fatty acid (Ca-LCFA) to the ration did not affect dry matter and NDF digestibility (Burgess et al., 1987; Schaulff and Clark, 1989). But some researchers (Wu et al., 1989) suggested that Ca-LCFA were only partially protected from ruminal biohydrogenation because net biohydrogenation of unsaturated fatty acid of Ca-LCFA was approximately 50%.

Two trials were designed 1) to determine the effects of calcium salts of long-chain fatty acids supplementation on the rumen microbial protein yield and digestibilities of protein, fat and fibre, and 2) to estimate the effects of calcium salts of long-chain fatty acids on the feed intake, milk yield and milk composition of lactating dairy cows.

Materials and Methods

Sheep metabolism trial

Four mature sheep (45-55 kg of body weight)

[1]Address reprint requests to Dr. W. J. Maeng, Animal Resources Research Center, Kon Kuk University, Sungdong-gu, Seoul 133 701, Korea.
Received June 29, 1992
Accepted May 31, 1993

surgically fitted with ruminal fistula were randomly assigned to one of two treatments in a crossover design. They were fed each one of the experimental diets of 1) control, no calcium salt of long chain fatty acids (Ca-LCFA), or 2) 3% Ca-LCFA mixed in a total mixed ration (TMR) consisted in 27% corn silage, 27% Italian rye grass and 46% commercial concentrate (DM basis) *ad libitum*. Chemical composition of corn silage, Italian rye grass and commercial concentrate mixtures is shown in table 2. Free access to a mineral salt block and water were provided.

The trial was conducted in metabolism crates with a 12-day preliminary and a 7-day collection period for urine and feces. Rations offered and orts were weighed daily throughout the whole period. Rumen samples were collected at different times after feeding on the 7th day of the collection period.

Milk production trial

A milk production trial was conducted with thirty lactating Holstein cows in mid-lactation. After the cows were adapted to the same TMR fed in the sheep metabolism trial for two weeks, they were assigned to one of two groups (table 1) and were fed the same experimental diet used in the sheep metabolism trial (control or 3% Ca-LCFA mixed in a TMR) *ad libitum* for 60 days.

TABLE 1. ALLOTMENT OF EXPERIMENTAL ANIMALS

Treatment	Number of cow	Mean parity	Mean lactation day	Mean milk yield (kg/day)
Control	15	1.93	146.6	19.41
Ca-LCFA[1]	15	1.93	139.3	19.40

[1] Calcium salts of long-chain fatty acids.

TABLE 2. CHEMICAL COMPOSITIONS OF FORAGE, FAT AND COMMERCIAL CONCENTRATE MIXTURE

(As fed basis)

Chemical composition	Corn silage	Italian rye grass	Ca-LCFA[1] fat	Concentrate mixture
		(%)		
Dry matter	26.77	15.78	86.03	87.27
Crude protein	2.05	2.22	0.70	15.95
Ether extract	0.81	0.71	75.97	1.78
Crude fiber	6.06	3.87	1.15	5.56
Crude ash	1.33	1.03	11.92	7.52
Nitrogen free extract	16.53	7.95	–	56.46
Ca	0.35	0.19	8.07	1.12
P	0.01	0.04	0.01	0.76

[1] Calcium salts of long-chain fatty acids.

The experimental diets were fed individually and amount offered and refusals were recorded daily. Cows were milked twice daily and milk yield was recorded at each milking throughout the experimental period. Twenty four hour (a.m. plus p.m.) milk samples were collected from each cow just before feeding the experimental diet (pretreatment) and every two weeks throughout the trial. Corn silage, Italian rye grass and commercial concentrate were sampled weekly throughout the trial and combined for chemical analysis.

Chemical analysis

Rumen samples collected in sheep metabolism trial were analyzed for pH and ammonia-N (Chaney and Marbach, 1962), and microbial true proteins (Lowry et al., 1951). Feed samples were

analyzed for the content of dry matter, crude protein, ether extract and ash (A.O.A.C., 1990). Calcium and phosphorus content were determined by atomic absorption spectro-photometry.

Milk samples were analyzed for the content of fat, protein, lactose and total solid by infrared milk analyzer (Milkoscan 104A/SN, Foss Electronic, Denmark).

Statistical analysis

Differences between treatment means were evaluated using student t test (Steel and Torrie, 1980)

Results and Discussion

Sheep metabolism trial

The mean feed intake were 862 and 884 g DM/day for sheep fed control and Ca-LCFA, respectively, and were not statistically different. Grummer (1988) and Ohajuruka et al. (1991) also reported that supplementation of Ca-LCFA in the diet of lactating cow did not influence dry matter intake. Palmquist et al. (1989), however, observed that abrupt introduction of Ca-LCFA into the diets of lactating cows resulted in initial decreases in dry matter intake.

Apparent digestibilities of dry matter (DMD), crude protein (CPD), crude fiber (CFD) and crude fat in sheep fed control and Ca-LCFA are shown in table 3. DMD seems to be lower for sheep fed Ca LCFA than for control sheep even if it was not statistically significant. CPD and CFD were lower ($p < 0.05$) and the digestibility of crude fat was higher ($p < 0.05$) for sheep fed Ca-LCFA than for control sheep. Others reported that Ca-LCFA are essentially inert in the rumen and thus have not a negative effect on the fiber-digesting bacteria (Jenkins and Palmquist, 1984). However, Klusmeyer and Clark (1991) observed that Ca-LCFA were only partially protected from ruminal biohydrogenation, which may reduce fiber digestion in the rumen. Klusmeyer and Clark (1991) also reported that feeding Ca-LCFA to cows decreased the amount and proportion of gross energy apparently digested in the rumen, which resulted in somewhat more gross energy passing to the duodenum compared with cows that were not fed Ca-LCFA. High level of Ca-LCFA (6 to 9%) added to the basal diet (3.5%) in dairy cows has been reported to depress CPD and CFD in a metabolism trial of four Holstein steers (Filley et al., 1987). Supplementing Ca-LCFA decreased total tract apparent crude protein digestion, which is consistent with some reports (Boggs et al., 1987; Schauff and Clark, 1989) but not others (Ohajuruka et al., 1991; Palmquist and Conrad, 1978).

Nitrogen excreted to feces and urine, and retained nitrogen were not different between treatments (table 3).

TABLE 3. EFFECTS OF Ca SALTS OF LONG-CHAIN FATTY ACIDS SUPPLEMENT ON THE APPARENT DIGESTIBILITY AND N BALANCE IN SHEEP[1,2]

Item	Control	Ca-LCFA[3]
Digestibility (%)		
Dry matter	85.15±0.86	81.29±0.06
Crude protein	70.09±0.58[a]	64.26±0.42[b]
Ether extract	60.54±0.25[a]	73.05±1.58[b]
Crude fiber	73.13±0.52[a]	67.88±0.38[b]
N balance		
Intake (g/day)	24.34±0.50	25.52±0.30
Excretion (g/day)		
Feces	7.25±0.16	8.72±0.10
Urine	4.24±0.27	4.43±0.08
Retention (g/day)	12.86±0.43	12.38±0.19

[1] Mean of 4 sheep ± S.E.

[2] Means in the same row with different superscripts differ significantly ($p < 0.05$).

[3] Ca salts of long-chain fatty acid added 3% of total diet.

Ruminal pH, ammonia-N concentration and microbial true protein yields in sheep fed control and Ca-LCFA are shown in table 4.

Ruminal pH was not different but concentration of ammonia-N in the rumen was higher for sheep fed Ca-LCFA than for control sheep. Ohajuruka et al. (1991) reported that both ruminal pH and ammonia-N concentration were not influenced by source and amount of dietary fat. Other studies that have examined supplementation with Ca-LCFA have indicated no difference in ruminal pH between animals consuming the supplement of the basal diets (Grummer, 1988; Fielding et al., 1988; Hightshoe et al., 1991) and supplementation enhanced ruminal am-

monia-N concentration (Hightshoe et al., 1991) as shown our studies. Palmquist and Conrad (1978) fed diets that varied in ether extract content to dairy cows; concentrations of ammonia-N tended to increase as fat increased.

Microbial true protein yields in the rumen of sheep fed Ca-LCFA were not different between treatments. Bacterial N flow to the duodenum did not differ and apparent and true efficiencies of bacterial protein synthesis were not affected by Ca-LCFA supplements (Ohajuruka et al., 1991). However, in some studies, feeding unsaturated oils to ruminants increased the efficiency of bacterial protein synthesis due to the defaunating effect of oils in the rumen (Ikwuegbu and Sutton, 1982).

TABLE 4. RUMINAL pH, AMMONIA-N CONCENTRATION AND MICROBIAL TRUE PROTEIN YIELDS IN SHEEP FED CONTROL AND Ca SALTS OF LONG-CHAIN FATTY ACIDS[1]

Time after feeding (hour)	pH		Ammonia N (mg/100 ml)		Microbial true protein yield (mg/100 ml)	
	Control	Ca-LCFA[3]	Control	Ca-LCFA	Control	Ca-LCFA
0	6.71	6.70	5.20	5.55	45.85	52.04
2	6.48	6.51	12.24	19.55	68.66	69.60
4	6.45	6.40	6.37	15.24	68.45	72.50
6	6.56	6.37	5.23	9.74	91.90	96.55
8	6.69	6.45	6.17	7.33	81.71	84.61
Average[2]	6.58	6.48	7.04[b]	12.60[a]	71.31	75.06
± S.E.	±0.04	±0.05	±0.90	±1.39	±4.00	±6.29

[1] Mean of 4 sheep.
[2] Means in the same row with different superscripts differ significantly ($p < 0.05$).
[3] Ca salts of long-chain fatty acid added 3% of total diet.

Milk production trial

Feed intake and milk yield are presented in table 5. Feed intake was not different between control and treatment, which is in agreement with others (Ohajuruka et al., 1991). Milk production after Ca-LCFA supplement increased steadily and was higher ($p < 0.05$) for cows fed Ca-LCFA than for control cows. This is consistent with other reports (Hoffman et al., 1991).

Milk fat percentage was not significantly affected by treatments but was slightly higher for the Ca-LCFA supplement (table 6). Milk protein percentage was reduced 0.1 percentage units by feeding supplemental fat. Milk protein depression due to supplemental fat is well documented (Depeters et al., 1987; Hoffman et al., 1991).

Lactose content of milk was not changed for cows fed added Ca-LCFA diets. Although the solid contents in milk was not statistically different between treatments, cows fed the Ca-LCFA tended to have a numerically lower total solid

TABLE 5. EFFECTS OF Ca SALTS OF LONG CHAIN FATTY ACIDS ON FEED INTAKE AND MILK YIELDS IN LACTATING COW[1,2]

Item	Control	Ca-LCFA[3]
Feed intake (DM kg/day)	16.92±2.50	17.43±3.70
4% FCM yield (kg/day)		
Pretreatment	19.41±1.65	19.40±1.98
Posttreatment		
15 day	19.33±1.78	21.27±1.86
30 day	20.44±2.09	22.32±1.81
45 day	18.33±1.70	23.25±1.81
60 day	17.43±1.90	23.07±1.73
Average	18.88±0.56[a]	22.48±0.39[b]
Increase (%)	100.00	119.07

[1] Mean of 15 cows ± S.E.
[2] Means in the same row with different superscripts differ significantly ($p < 0.05$).
[3] Ca salts of long-chain fatty acids added 3% of total diet.

content which reflected the lower concentration of milk protein.

TABLE 6. EFFECTS OF Ca SALTS OF LONG CHAIN FATTY ACIDS SUPPLEMENT ON MILK COMPOSITION IN LACTATING COW[1]

Item	Control	Ca-LCFA[2]
Milk fat (%)		
Pretreatment	3.68±0.01	3.63±0.10
Posttreatment		
30 day	3.73±0.26	3.74±0.15
45 day	3.78±0.21	3.93±0.21
60 day	3.73±0.22	4.05±0.24
Average	3.73±0.08	3.85±0.24
Milk protein (%)		
Pretreatment	3.18±0.04	3.13±0.06
Posttreatment		
30 day	3.13±0.08	3.08±0.07
45 day	3.12±0.12	2.91±0.08
60 day	3.11±0.17	3.03±0.13
Average	3.12±0.01	3.02±0.03
Lactose (%)		
Pretreatment	4.75±0.05	4.73±0.03
Posttreatment		
30 day	4.78±0.05	4.79±0.04
45 day	4.81±0.04	4.83±0.04
60 day	4.82±0.06	4.74±0.08
Average	4.80±0.01	4.77±0.05
Total solid (%)		
Pretreatment	12.83±0.17	12.62±0.11
Posttreatment		
30 day	12.54±0.28	12.03±0.17
45 day	12.83±0.25	12.38±0.23
60 day	12.48±0.31	12.02±0.24
Average	12.61±0.09	12.26±0.24

[1] Mean of 15 cows ± S.E.

[2] Ca salts of long-chain fatty acids added 3% of total diet.

Literature Cited

A.O.A.C. 1990. Official methods of analysis. 15th ed. Washington, D. C.

Baldwin, R. L. and N. E. Smith. 1974. Molecular control of energy metabolism. In the control of Metabolism, J. D. Sink (ed.). The pennsylvania state Univ. Press. pp. 17-34.

Baldwin, R. L. and N. E. Smith, J. Taylor and M. Sharp. 1986. Manipulating metabolic parameters to improve growth rate and milk secretion. J. Animal Sci. 51:1416.

Boggs, D. L., W. G. Bergen and D. R. Hawkins. 1987. Effect of tallow supplementation and protein withdrawal on ruminal fermentation, microbial synthesis and site of digestion. J. Animal Sci. 64: 907.

Depters, E. J., S. J. Taylor, C. M. Finley and T. R. Famula. 1987. Dietary fat and nitrogen composition of milk from lactating cows. J. Dairy Sci. 70:1192.

Fielding, A. S., W. J. Miller, H. E. Amos, M. A. Froetshel, M. W. Neathery, J. L. Arnadoe and C. T. Crowe. 1988. Influence of calcium soaps on metabolism in ruminants. J. Animal Sci. 66 (Suppl. 1):476 (Abstr.).

Filley, S. J., A. Munoz, J. E. Trei, A. J. Kutches, J. Downer and W. Chalupa. 1987. Digestibility of Megalac and effects on other dietary components. J. Dairy Sci. 70:221.

Grummer, R. R. 1988. Influence of prilled fat and calcium salts of palm oil fatty acids on ruminal fermentation and nutrient digestibility. J. Dairy Sci. 71:117.

Henderson, C. 1973. The effects of fatty acids on pure cultures of rumen bacteria. J. Agric. Sci. (camb.) 81:197.

Hightshoe, R. B., R. C. Cochran, L. R. Corah, D. L. Harmon and E. S. Vanzant. 1991. Influence of source and level of ruminal-escape lipid in supplements on forage intake, digestibility, digesta flow and fermentation characteristics in beef cattle. J. Animal Sci. 69(12):4974.

Hoffman, P. C., R. R. Grummer, R. D. Shaver, G. A. Broderick and T. R. Drendel. 1991. Feeding supplemental fat and undegraded intake protein to early lactation dairy cows. J. Dairy Sci. 74: 3468.

Ikwuegbu, O., A. Ohajuruka and D. L. Palmquist. 1989. Ruminal and total digestibilities of fatty acids in Megalac and animal-vegetable blend at two levels of intake. J. Dairy Sci. 72 (suppl. 1):546 (Abstr.).

Ikwuegbu, O. A. and J. D. Sutton. 1982. The effect of varying the amount of linseed oil supplementation on rumen metabolism in sheep. Br. J. Nutr. 48:365-375.

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

Klusmeyer, T. H. and J. H. Clark. 1991. Effect of dietary fat and protein on fatty acid flow to the duodenum and in milk produces by dairy cows. J. Dairy Sci. 74:3055.

Lowry, O. H., N. J. Rosebrough, A. L. Farr and R. J. Randall. 1951. Protein measurement with the Folin reagent. J. Biol. Chem. 193-265.

Ohajuruka, O. A., Z. Wu and D. L. Palmquist. 1991.

Ruminal metabolism, fiber and protein digestion by lactating cows fed calcium soap or animal-vegetable fat. J. Dairy Sci. 74:2601.

Palmquist, D. L. and T. C. Jenkins. 1980. Fat in lactation rations. Review. J. Dairy Sci. 63:1.

Palmquist, D. L. and H. R. Conrad. 1980. High fat rations for dairy cows. Tallow and hydrolyzed blended fat at two intakes. J. Dairy Sci. 63:391.

Palmquist, D. L., S. C. Loerch, D. E. Grum, F. L. Fluharty, S. Hughes and T. F. Sweeney. 1989. Acceptability of diets after abrupt introduction of Megalac®. J. Dairy Sci. 72 (Suppl 1):443 (Abstr.).

Schauff, D. J., J. H. Clark. 1989. Effect of prilled fatty acids and calcium salts of fatty acids on rumen fermentation, nutrient digestibilities, milk production, and milk composition. J. Dairy Sci. 72:917.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of statistics, 2nd ed. McGraw-Hill Book Co., Inc. New York.