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The Role of Dietary Fats in Productivity and Health of Dairy Cattle

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The Role of Dietary Fats in Productivity and Health of Dairy Cows

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ABSTRACT

We proposed that dietary supplementation with calcium salts of long chain fatty acids [CaF] or with hard fats [HF] would improve milk production, lactational efficiency, reproductive performance and general health of highly productive dairy cows. These two forms of fat were found to be inert in the rumen, especially CaF. A series of studies in Pennsylvania and Israel demonstrated a consistent improvement in fat-corrected milk, due in some cases to increased milk volume, in others to increased fat content, and in some to both factors. The reason[s] for these difference responses in volume and fat were not determined. Reproductive performance improved in all trials except one in which the milk production response was exaggerated. We attribute the improvement in reproductive performance to the improved energetic efficiency of lactation in cows fed inert fats, and the exception to the negative effect on reproduction of high production that countered the positive effect of improved lactation efficiency. The metabolic and hormonal concomittants of these events have not been determined. We suggest the further need to study insulin and its antiagonistys, such as somatotropin, in this context.

In addition, we found that CaF and methionyl-somatotropin acted synergistically on milk production, and on plasma free fatty acids and acetoacetate.

Reports of our studies have had a major effect on the dairy industries in the USA and Israel. Protected or inert fats have been developed and marketed for dairy rations in both countries.

OBJECTIVES

From our proposal (23 August 1983): "Our overall objective is to the development of new feeding programs for high yielding dairy cows. We propose that fat is the dietary variable most likely to optimize production and efficiency while minimizing problems of reproduction, diegation and metabolism. This proposal is a continuation of BARD US-310-B0 (Termination: 30 Sept 1984). We plan to use ruminally inert forms of fat identified in US-310-B0 to formulate diets of high energy densities and optimal amounts of lipogenic nutrients.

"The main part of this proposal aims to investigate the effects of fats on productivity and health of dairy cows in trials that extend through the ascending, peak and early declining phases of lactation. We also propose to continue studies on digestion. Specifically we plan to examine the effects of dietary fats on:

- a. Production and production efficiency
- b. Composition of milk
- c. Ruminal fermentation
- d. Hormonal responses
- e. Reproductive performance
- f. Animal health
- g. Intestinal digestion"

In retrospect, these objectives have been met as follows:

a. Milk production improvement has been demonstrated consistently. Productive efficiency has been studied only in some of the trials in which feed intake was measured.

b. Milk fat content increases sometimes but not others. The reason[s] remain undetermined.

c. Ruminal fermentation is disturbed little by hard fats [HF, Dairy Fat Prills, BP Nutrition UK] and hardly at all by CaF [calcium salts of long chain fatty acids, Megalac, Chruch & Dwight Co, Princeto, NJ].

d. Hormonal responses were not significant in the one study where they were measured. We planned to measure the responses of insulin relative to its antagonists, such as somatotropin, should have been measured in other trials but failed to do so.

e. Reproductive performance was improved except when milk energy output was greatly increased.

f. Animal health was good in all studies, so that any latent differences were not measurable.

g. Efficiency of absorption was not different between fatty acids, contrary to previous studies of others.

SCIENTIFIC REPORT: UG-722-83C, [final report continued]

Trials of hard fats [HdF] and calcium salts of fatty acids [CaF] have continued and been completed in Pennsylvania and Israel. Data have been obtained on reproductive parameters and general health as well as milk production.

The studies with CaF have been the most promising. One company, Church & Dwight, Princeton, NJ, has introduced a form of CaF, "Megalac," to the USA market, with Dr Chalupa being involved in many of its production trials. Dr Chalupa has obtained Megalac gratis from the company for most of the CaF studies on the present project.

The main studies with CaF have been conducted by Dr P Schneider and Dr J Ferguson in the US, and by Dr D Sklan in Israel. Other studies of CaF have been conducted by Dr E Robb on a herd with a history of milk fat depression.

Digestion, absorption and milk responses to CaF

In order to determine absorption of CSFA and their effect on other dietary components, four cows 120 d post-partum were fed a diet of corn silage, corn and soybean meal (40:43:15 on dm basis) and supplemented with 0 or 4% Ca salts of palm oil (Megalac, Volac Ltd., Royston). A portion of the corn silage was treated with chromium oxide as described by (Van Soest, J.Sci. Fd. Agri. 31, 625, 1980) as a marker. Treatments were administered in a 4 x 4 latin square design with 21 d periods and data were collected from days 8 to 21. Rumen volatile fatty acids and long chain fatty acids were determined as previously described (Sklan et al, 1985) and calcium was determined as in (Sklan & Hurwitz, 1985).

The results of the 4 x 4 latin square CSFA absorption experiment are shown in Table 1. In these cows significant increases in milk, milk fat and FCM were observed as a result of feeding CSFA. No other changes in milk composition were observed. Dry matter and nitrogen digestion were not changed by feeding CSFA whereas the absorption of fatty acids increased from 60 to close to 70%. Percent Ca absorption decreased from 30% to 23% in cows fed CSFA. The dietary Ca increased by 36 g/d in these cows, thus absorption of Ca decreased by approximately 8 g/d.

Table 1. Responses of lactating cows to calcium salts of palm oil fatty acids.

Measurement	Control	LCFA	P<
Dry matter intake (kg)			
Dry matter intake	17.0	16.7	.37
Rumen volatile fatty acids (Mol/100 Mol)			
Acetate	56.5	58.3	.59
Propionate	28.5	24.9	.33
Butyrate	10.1	12.4	.40
Yield (kg)			
Milk yield	20.4	21.9	.01
4% FCM	17.9	20.0	.01
Fat production	.65	.75	.01
Milk composition (%)			
Fat	3.21	3.51	.04
Protein	3.19	3.16	.50
Digestion (%)			
Dry matter digestion	65.9	66.6	.57
N digestion	66.4	67.6	.78
Ca digestion	30.0	23.6	.05
Fatty acid digestion	60.1	69.7	.01

Cows were fed 0.5 kg/d CSFA (Megalac, Volac Ltd, UK).

The main studies on lactational responses to CaE

The objectives of these experiments were to evaluate supplementation of calcium salts of long chain fatty acids to lactating dairy cows in commercial dairy herds.

Two experiments were conducted to evaluate supplementation of calcium salts of long chain fatty acids (CSFA) to dairy cows in early lactation. One experiment was conducted in Pennsylvania with 4 small commercial dairy herds. The second study was conducted in Israel with 1 commercial dairy herd.

Pennsylvania experiment:

This study was conducted with 4 commercial dairy herds of the Hershey School Farms in Hershey, PA from September, 1985 to June, 1986. A total of 73 cows were randomly assigned two weeks postpartum to either a control (C; 0 kg CSFA/d) or fat grain mix (F; .45 kg CSFA/d) in a single reversal design. Periods were 7 weeks long.

The management system was the same in each herd. Cows were housed in tie stall barns and fed grain mixes individually. Weighbacks were not recorded. Forage was fed both in the barn and free choice outside. Milk was sampled and production recorded weekly.

Diets were periodically evaluated and modified during the study for each farm. Composition of control grain mix is presented in Table 2. Data in the table are means for all 4 farms. Experimental grain was formulated to be similar to control in all components except NE₁. The experimental grain mix was formulated to provide .45 kg Megalac to a cow producing 27 kg milk per day. Net energy of lactation and ether extract were higher in the fat diet compared to the control (Table 2). Blood samples were taken from the caudal vein the last week of each period. Somatotropin¹ and insulin² were analyzed by radioimmunoassay.

¹ Assay done by American Cyanamid Company, Princeton, NJ 08540.

² Serono Diagnostics, Inc., Norwell, MA 02061.

TABLE 2. Composition of Control Diet^{1,2} - PA experiment

Item	% of dry matter	
Corn silage	43.3	
Alfalfa hay	10.5	
Soybean meal	9.4	
Ground ear corn	16.5	
Molasses	3.9	
Distillers dried grain w solubles	13.8	
Limestone		.84
Dicalcium phosphate		.28
Trace mineral salt	.45	
Sodium bicarbonate	.73	
Magnesium oxide	.11	
Selenium	.11	
Vitamin A,D,E	.06	

¹ Average of reformulations over length of experiment and over 4 farms.

² Calculated to meet requirements for 27 kg milk/day.

TABLE 3. Analysis of Diets¹ - FA experiment

	% of dry matter
Crude protein	15.4
By-pass protein	5.5
ADF	21.7
Calcium	.58
Phosphorus	.44
Magnesium	.28

NE ₁ , Mcal/kg	1.53
Ether extract, %	4.6

¹Mean values for 4 farms.

Israel Experiment:

One hundred and eighteen Israeli-Friesian cows (including 32 primiparous cows) at varying stages of lactation were blocked according to previous lactation, age and calving date. Within each block, cows were randomly assigned to either a control (C; 0 kg CSFA/d) or a fat (F; .5 kg CSFA/d) diet from February 1986 for 110 days. Cows remained on the same dietary treatment for the entire experiment. Composition of diet is presented in table 3 and analysis of diets in table 4. Weighbacks were recorded daily and cows were weighed within 5 d of parturition and at 120 d in milk. Milk was sampled and production recorded every two weeks for the first 135 days of lactation and then monthly.

Milk fatty acids were determined by gas chromatography of methyl esters on a 15% DEGS column programming from 60 to 180°C. Ruminant fluid and blood were sampled once during the experimental period at 30-60 d in milk. Ruminant volatile fatty acids were determined by gas chromatography on Carbowax 20M (Sklan et al, 1985). Plasma triglycerides, free fatty acids and total cholesterol were determined as previously described (Sklan et al, 1985) and serum lipoproteins were determined by gel permeation chromatography on a Superose 6 column (Pharmacia, Uppsala).

TABLE 4. Composition of Control Diet - Israel Experiment.

Item	% of dry matter
Vetch hay	10
Corn silage	21
Cottonseeds	16
Commercial concentrate ¹	47
Other	4
Vitamins, minerals	2

TABLE 5. Analysis of Diets - Israel Experiment.

Item	% of dry matter
Crude protein	17.1
ADF	18.7
Crude fiber	13.3
Ca	0.73
P	0.55
Mg	
NE ₁ , Mcal/kg	1.72
Ether extract ¹ , %	3.7

¹Excluding cottonseeds.

Data from both experiments was analyzed by method of least squares analysis of variance using general linear model procedures of SAS.

Pennsylvania experiment:

Weighbacks were not recorded in this experiment. Herdsmen reported no problems with intake after cows had adapted to diets. Cows produced 4% more milk and 6% more fat corrected milk with the fat grain compared to the control. Fat production was significantly higher with the CSFA grain and milk fat percent tended to be higher (Table 3).

Response to the fat diet was slightly higher for first calf heifers compared to older cows (Table 4). Mean production for all cows was 25 kg fat corrected milk per day. Examination of cows with mean production greater or less than 25 kg/day indicated a greater response from the lower producing cows.

*

TABLE 6. Production responses to calcium salts of long chain fatty acids - PA experiment.

<u>Item</u>	<u>Control</u>	<u>CSFA</u>	<u>SE¹</u>
Milk, kg	29.3	30.5*	.83
3.5% FCM, kg	27.3	28.8**	.77
Milk fat, %	3.1	3.2	.053
Milk fat, kg	.90	.96**	.028

* P<.05 ** P<.01

¹ Standard error of mean.

Table 7. Production responses to calcium salts of long chain fatty acids for primiparous and multiparous cows - PA experiment.

Item	Primiparous (n=24)			Multiparous (n=49)		
	Control	CSFA	SE ¹	Control	CSFA	SE ¹
Milk, kg	26.2	28.0**	.95	30.6	31.9*	.84
3.5% FCM, kg	24.7	27.0**	.80	28.5	29.6*	.76
Milk fat, %	3.2	3.3	.128	3.1	3.1	.096
Milk fat, kg	.83	.92*	.031	.94	.98	.032

* P<.1 * P<.05 ** P<.01

¹ Standard error of mean.

TABLE 8. Somatotropin and insulin responses to calcium salts of long chain fatty acids - PA experiment.

Item	Control	CaLCFA	SE ¹
Somatotropin, ng/ml	1.66	1.29*	.13
Insulin, uIU/ml	15.63	17.19	1.23

¹ Standard error of mean.

* P<.1

Israel experiment:

Milk, 3.5% fat-corrected milk and percent milk fat were higher with CSFA supplementation (Table 7).

This experiment included cows at varying stages of lactation on the same diet. Thus production responses according to stage of lactation indicated greater response to CSFA supplementation during early and peak lactation (Fig 1) compared to the later stages of lactation.

Supplementation with CSFA was ceased at (on average) 135 d from parturition, and following this, production continued on the higher plane attained previously.

Body weight changes of cows over 120 d were +11.3±18.3 and +30.6±17.5 kg for control and fat fed cows respectively. Mean dry matter intake over the whole period for the control group was 21.0 kg as compared to 20.1 kg for CSFA fed cows. Examination of the responses of cows at different levels of production did not indicate differences between cows producing 30 or more kg milk per day. However, the increment due to the CSFA of cows producing less than 30 kg/d was somewhat less than the higher producing cows.

TABLE 9. Production responses to calcium salts of long chain fatty acids - Israel experiment.

<u>Item</u>	<u>Control</u>	<u>CSFA</u>	<u>SE¹</u>
Milk, kg	34.6	35.8	.78
3.5% FCM, kg	30.6	32.6*	.74
Milk fat, %	2.8	3.0**	.034
Milk fat, kg	.959	1.061**	.026

* P<.05 **P<.01

¹ Standard error of mean.

The composition of the rumen volatile fatty acids was not affected by feeding the CSFA (Table 8) and plasma triglycerides and cholesterol did not change, although a decrease in the levels of free fatty acids was observed (Table 9).

TABLE 10. Production responses to calcium salts of long chain fatty acids for primiparous and multiparous cows - Israel experiment.

<u>Item</u>	Primiparous (32 cows)			Multiparous (86 cows)		
	<u>Control</u>	<u>CSFA</u>	<u>SE¹</u>	<u>Control</u>	<u>CSFA</u>	<u>SE¹</u>
Milk, kg	30.9	31.5	.94	36.0	37.3	1.00
3.5% FCM, kg	27.1	28.1	.81	31.5	34.0*	.94
Milk fat, %	2.7	2.9	.15	2.7	3.0**	.04
Milk fat, kg	.834	.914+	.032	.979	1.103*	.033

+ P<.1 * P<.05 ** P<.01

¹ Standard error of mean.

TABLE 11. Composition of ruminal volatile fatty acids in lactating cows fed CSFA¹ - Israel experiment.

<u>Item</u>	<u>Control</u>	<u>CSFA</u>	<u>SE²</u>
Total VFA, mmol	83.5	83.8	2.31
Acetic, molar %	55.9	55.9	1.13
Propionic, molar %	34.8	35.7	0.92
C2/C3	1.9	1.9	0.05

¹ Data from 20 cows per treatment.

² Standard errors of mean.

TABLE 12. Levels of some plasma parameters in lactating cows fed CSFA¹ - Israel study.

<u>Item</u>	<u>Control</u> - ng/ml -	<u>CSFA</u>	<u>SE²</u>
Plasma cholesterol	2.52	2.66	0.32
Plasma triglycerides	.26	.29	0.041
Plasma free fatty acids	.145	.096*	0.011

¹ Data from 20 cows per treatment.

² Standard error of mean.

* P<.05

Analysis of the reproductive performance of the cows serviced during the CSFA feeding period revealed that 60.5% of CSFA cows conceived at first service as compared to 43.1% in controls. In addition 86.8% of CSFA cows were pregnant at the end of the experiment as compared to 72.3% pregnant controls. The conception/service ratio was 0.55 in CSFA cows and 0.43 in controls.

Discussion

These experiments indicate that feeding CSFA is an efficacious method of enhancing FCM production in early and peak lactation.

The production increases in the experiments in the two countries over the initial period of lactation were 1.5-2.0 kg FCM per day and resulted from increases in the milk and fat production although the latter were on some occasions not significant. These increases in production were maximal during early and peak lactation and decreased to close to controls at 120 days in milk. Examination of the responses of primiparous as compared to multiparous cows did not show a consistent pattern. Responses of primiparous cows were higher in PA but lower in IS. Perplexingly, the lower producing cows in PA appeared to exhibit a somewhat greater response.

The increases in production were not accompanied by greater changes in body weight in the CSFA fed cows, and were achieved while consuming less dry matter daily. No effect of the CSFA was observed on rumen fermentation and plasma cholesterol and triglycerides were unchanged. Plasma free fatty acids were slightly decreased and growth hormone levels were lower, suggesting less fat mobilization. No changes in insulin levels were noted.

The increase in FCM production was obtained with widely different roughage:concentrate ratios (31:69 and at 54:46) and thus the effect of fat does not appear to be dependant on the ration roughage content. The range production levels varying from 8000 to 10500 kg FCM per lactation at which the effect was observed was also considerable.

These facts together indicate that the increase in production in response to CSFA thus appears to be mainly due to optimization of milk production due to direct utilization of dietary fat. Kronfeld (1976) calculated that for optimisation of milk production approximately 16% of digestible energy should originate from fat. Brunby et al (1978) in studies with formaldehyde treated caseinate particles observed maximal utilization of net energy with 15-6% of the digestible energy as fat in weeks 2-13 in milk. In the experiments reported here fat comprised 6.5% in the PA experiment and 9.5% in the IS experiments which is below the optimal. Thus a further increase in the dietary fat levels could possibly provide additional production increases.

From these experiments it was possible using "by difference" calculation to estimate the net energy (lactation) of the CSFA. This procedure yields figures slightly in excess of 5 Mcal/kg. This figure is rather high and may include changes in tissue energy not revealed by body weight determinations. Energy balance experiments are required to determine accurately NE_l values of CSFA.

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CSFA

Lactational response to CaF in a herd with a history of a low milk fat content

Sixteen primiparous and 40 multiparous Holstein cows were paired on the basis of previous fat production, lactation and freshening date. They were randomly assigned to isonitrogenous diets with or without .5 kg/d Ca salts of palm oil (Megalac, Church and Dwight Co., Inc) for the first 150 days post partum. Cows were individually fed Corn silage and haylage (2:1) along with a commercial 24% CP concentrate mix and SBM44 according to production in a tie-stall barn. In this herd with a history of milk fat

Group	<u>Milk (kg/d)</u>		<u>Fat (%)</u>		<u>Fat (kg/d)</u>		<u>FCM (kg/d)</u>		
	Basal	LCFA	Basal	LCFA	Basal	LCFA	Basal	LCFA	
All Cows	36.5a	39.3b	3.1	3.2	1.11a	1.25b	33.7a	37.2b	depression, Ca LCFA
Multiparous	38.1x	40.5y	3.0	3.2	1.13x	1.30y	34.8a	38.1b	did not affect con-
Primiparous	30.5	31.9	3.4	3.4	1.03	1.10	29.8	31.8	centration of milk

fat but improved yields of milk, fat and 3.5% FCM in multiparous cows.

ab P<.05. xy P<.10.

Long-term Lactation Trial of CaF

A 12-month study was conducted on a registered Holstein herd in western Pennsylvania. Cows were paired on the basis of parity and previous 305-day production of FCM. then fed either 0 or 0.45 kg/d of CaF.

Supplemented heifers and multiparous cows produced an extra 2.0 and 3.3 kg FCM per day, respectively. The responses were due mainly to increased milk volume; fat content increased only slightly.

Supplementation had no significant effect on reproductive parameters. These were very good in this herd: pregnancy rate, 0.88; services/pregnancy, 1.75; calving interval, 395 days.

Lactational and Reproductive Responses of Cows to Supplementary Hard Fats [HF, Dairy Fat Prills, BP Nutrition, UK11]

These studies were conducted on 4 Holstein herds, comprized of 40, 55 and 71 cows in 3 herds in southeastern Pennsylvania, and 120 cows in 1 herd in Israel.

Experimental diets of forage and concentrates were fed for 150 days postpartum in PA and 110 days postpartum in Israel. Cows were fed either no HF or 0.45 kg HF [prills]. Heifers were assigned alternately as they calved. Cows were blocked into pairs according to age and to production in the previous lactation.

Reproductive responses to HF were generally favorable, significant and similar in all herds [Table 13].

TABLE 13. Overall reproductive responses.

LCFA	0	0.5
Number of Cows	138	115
Pregnant	119	107
Total Services	272	181
S/C	1.96 A	1.57 B
Days Open	118 A	103 B
Days First Service	80.8	80.3
First Service CR (%)	42.6 A	59.1 C
CR all services (%)	40.7 A	59.3 D
Superscripts on same row: A vs B $p < .05$ A vs C $p < .005$ A vs D $p < .001$		

Supplements with HF increased the "risk" of pregnancy, with odds ratios of 2.21 for the first service, and 2.22 for all services.

Services per conception improved from 1.96 to 1.57, and overall conception rate from 40.7% to 59.3%.

More details are available currently on the HF trial in Israel. In addition to milk production and reproduction, blood and rumen samples were monitored at weekly intervals.

Cows in Israel were fed a ration containing 17% crude protein, at least 13% crude fiber, and 1.75 Mcal/kg. The ration consisted of 14.3% cottonseeds and 33% roughage (either vetch haylage or alfalfa and corn silage), 20% commercial concentrate, and the balance of slightly differing mixtures of soybean meal, barley, corn, tapioca and citrus peel, and a vitamin mix with limestone; these rations met NRC requirements for protein, energy and minerals.

The ration was fed individually from a mixing wagon. Control cows received the basal ration. Treated cows received the basal ration plus 0.5 kg HdF. The HdF comprised 16.2% palmitic acid and 81.6% stearic acid.

Each morning, remaining feed was removed and weighed. Cows remained on this regimen for 105 days.

During this period milk was sampled individually every two weeks, and fat, protein and lactose were assayed with a Foss Milkotester. Milk fatty acids were determined by gas chromatography of methyl esters on a 15% DEGS column, programming from 60-180 C.

Samples of rumen fluid and jugular blood were taken once during the experiment. Rumen volatile fatty acids were determined by gas chromatography on Carbowax 20M. Plasma triglycerides, free fatty acids and total cholesterol were measured.

Cows were weighed at parturition, at nominal 30d intervals, and at the end. Records were made of inseminations and conceptions.

Statistical analysis was by two-way ANOVA.

Ruminal propionate increased at the expense of acetate in cows given HdF [Table 1]. This change usually is associated with a high milk volume production, which was observed [see below], but not with higher milk fat content.

Table 1. Responses of ruminal fatty acids

Measurement	Hardened fat -----% of diet-----		
	0	5	P
Total VFA (mmol)	87.3	86.3	.76
Acetic (mol %)	65.1	60.1	.13
Propionic (mol %)	21.3	25.6	.05
C2/C3	3.0	2.3	.01

Data are from experiments in Saad, and
represent 20 cows in each group.

Plasma variables showed no response to HdF [Table 2].

Table 2. Plasma parameters in cows fed HdF

Measurement	Hardened fat: -----% of diet-----		
	0	5	P
	-----mg/dl-----		
Plasma cholesterol	2.34	2.40	.71
Plasma TG	0.27	0.28	.86
Plasma FFA	0.087	0.091	.79

Data are from groups of 20 cows in Saad.

Milk volume responded favorably to HdF for 60 days but not thereafter [Table 3]. Milk fat content was increased by HdF at 30 days, but protein and lactose were unchanged [Table 4].

Body weight loss was diminished by HdF [Table 3]. This should have a favorable effect on fertility, and this trend was detected but was not statistically significant [Table 5].

Table 3. Responses of lactation and body weight to HdF

Days lactation	Milk kg	Fat fed Fat %	FCM kg	Milk kg	Control Fat %	FCM kg
<u>Hardened fat</u>						
0-30	39.8*	3.3*	38.5*	37.1	3.1	34.8
30-60	43.6*	3.1	40.8*	41.4	3.0	38.0
60-90	41.4	3.1	38.7*	40.5	3.0	37.2
90-120	38.6	3.0	35.5	37.1	3.0	34.1
120-150	35.6	3.0	32.8	36.0	3.0	33.1
Feed consumption (kg)		20.9			22.5	
Feed consumption/kg FCM		0.566			0.634	
Weight changes 30-60d		-24.8			-30.3	
60-90d		-9.5			-16.0	
90-150d		+20.1			+7.3	

Data represent 60 cows per treatment; the experiment was for 110 d; FCM is 3.5%.

Table 4. Composition of milk from cows fed HdF

	Experimental	Control	P
	-----%		
Fat	3.4±0.4	3.1±0.4	.01
Protein	3.1±0.3	3.1±0.3	.75
Lactose	4.8±0.2	4.8±0.3	.88

Table 5. Fertility data from cows fed HdF

	Control	HdF
Cows inseminated	17	23
Cows pregnant	12	20
Service/conception	1.42	1.15
Days open	92	96

Synergism of CaF and BST

Bovine somatotropin [BST] manufactured by bacteria modified by recombinant-DNA biotechnology became available for research during this project. We conducted a pilot project on interactions between BST and CaF supported in part by the USDA, American Cyanamid, and the present project.

Starting 4 weeks postpartum, 16 cows were assigned randomly to receive 0 or 50 mg/d of methionyl-BST [metBST]. Cows also received 0 or 0.77 kg/d of CaF for 5 weeks, then switched for another 5 weeks.

CaF failed to increase milk volume or fat content, contrary to usual responses.

CaF enhanced favorable responses to BST.

Responses of cows to metBST, with or without CaF

metBST, mg/d	0	0	50	50
CaF, kg/d	0	.77	0	.77
Milk, kg/d	36	36	38	41
FCM, kg/d	34	34	37	42
FFA, mEq/L	.19	.21	.25	.33
AAA, mg/dl	.49	.52	.56	1.23

Milk response to the combination was 112% of the sum of the separate responses., and the interaction was significant.

Similarly, responses of plasma free fatty acids [FFA] and acetoacetate [AAA] to the combination were much greater than the sums of the separate responses.

In this study, CaF and metBST acted synergistically.

CaF did not supply sufficient fatty acids to the mammary gland to diminish lipolysis and ketogenesis. Thus CaF would not appear likely to allow BST to be used during the rising phase of lactation.

CaF holds promise, however, of ensuring a more consistent milk response to BST than has been demonstrated in longterm trials.

Discussion

Overall the experiments conducted in this project have demonstrated that both HF and CaF are useful forms of fat for supplementation of dairy rations. CaF appears to be slightly superior in every respect: inertness in rumen, milk production responses, and favorable influence on reproduction.

The milk production response has been consistent in regard to fat-corrected milk. In some instances, only volume increases, in others only fat content increases, and in yet others both increase. The reasons for these inconsistencies remain unknown.

The improvement in reproduction is probably associated with improved lactation efficiency, again in ways not yet determined mechanistically. If milk production increases greatly, it exerts an antagonistic effect on reproduction that may negate the improved lactational efficiency.

Similarly with health, improved lactational efficiency may be expected to improve it, but increased absolute production may be expected to obtund the beneficial effect of improved lactational efficiency.

The use of inert fats in dairy rations is determined on an energy basis in currently available ration formulation programs. The improved efficiency of lactation is not taken into account. When ration formulation programs are developed that include estimates of lactational efficiency, the use of inert fats will become recognized even more as economically beneficial.

COOPERATION

Dr Sklan visited Pennsylvania in June 1988 and met with Dr Kronfeld. Dr Chalupa has been involved in the commercial development of a CaF-product, "Megalac," with Church & Dwight, Inc., Princeton, NJ, and bovine somatotropin with the American Cyanamid Company, Princeton, NJ.

BENEFITS

Inert fats have become established commercially in dairy rations during the 3-year term of this research project. Four products are on the market in the USDA, and one is available in Israel.

Most of the impetus for this commercial development has come from our studies and from those of Dr Donald Palmquist, Ohio State University.

Ohio State obtained a US Patent for uses of CaF in ruminant rations. The rights in the USA have been purchased by Church & Dwight.

The University of Pennsylvania, prompted by Cyanamid which wants the rights, is applying for a patent on the conjoint use of CaF and BST. Drs Chalupa, Kronfeld, Schneider and Sklan are designated as co-inventors.

Our objective initially was to identify some form of fat that would be inert in the rumen, would improve production and health, and would be commercially viable. This objective has been attained, and we believe that the dairy industries of the USA and Israel are currently benefitting greatly from the results of this project.

LIST OF PUBLICATIONS

Arieli & Sklan. 1985. Energy disappearances in the hindgut of sheep. *J Dairy Sci* 68: 2215

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Chalupa & Ferguson. 1988. The role of dietary fat in productivity and health of dairy cows. Dairy Production Medicine Symposium, North Carolina State University.

Ferguson et al. 1987. Reproductive responses in lactating cows supplemented with long chain fatty acids. *J Dairy Sci* 70, 61, 207.

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Kronfeld & Schneider. 1988. Recent advances in nutrition and metabolic disease in dairy cattle: somatotropins, sodium bicarbonate, and protected fat. Proceedings, FORUM, American College of Veterinary Internal Medicine 6: 539-541.

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Schneider et al. 1988. Feeding calcium salts of fatty acids to lactating cows. *J Dairy Sci* 71: 2143-2150.

Sklan et al. 1985. Digestion and absorption of lipids and bile acids in sheep fed stearic acid, oleic acid and tristearin. *J Dairy Sci* 68:1667.

Sklan & Hurwitz. 1985. Movement and absorption of major minerals and water in ovine gastrointestinal tract. *J Dairy Sci* 68: 1659.

Eklan & Halevey. 1985. Digestion and absorption of protein along ovine gastrointestinal tract. J Dairy Sci 68: 1676.

In Preparation

Eklan/Ferguson et al. Responses of ruminal micorganisms and lactating cows to calcium salts of long chain fatty acids.

This paper describes the trials in commercial dairies, 3 in PA and 1 in Israel.

Ferguson et al. Production and reproductive responses in dairy cows fed hard fats.

This papers describes the commercial trials with fat prills.

Schneider/Eklan et al. Synergistic effects of bovine methionyl-somatotropin and calcium salts of long chain fatty acids in lactating cows.

This papers describes the study underlying the paptent application.

Patent Application

University of Pennsylvania. Lactational and metabolic responses of dairy cows to recombinently derived bovine somatotropin and dietary fat.

PAPERS APPENDED

Three copies of 3 papers, 1 abstract, and 1 patent application are appended. The other papers and abstracts have been submitted previously.