Effect of Time of Initiating Dietary Fat Supplementation on Performance and Reproduction of Early Lactation Dairy Cows[a]

J. Son[1], L. L. Larson* and R. J. Grant
Department of Animal Science, University of Nebraska, Lincoln, NE 68583-0908, USA

ABSTRACT : Forty-two Holstein cows (21 multiparous) were assigned by calving date and parity to three dietary sequences to evaluate the effect of time of initiating fat supplementation to diets on lactation and reproductive performance. The dietary sequences were: 1) control, no supplemental fat from 1 to 98 days in milk (DIM) ; 2) control diet from 1 to 28 DIM then 3% supplemental fat (calcium salts of long-chain fatty acids) from 29 to 98 DIM; or 3) 3% supplemental fat from 1 to 98 DIM. Feeding supplemental fat did not enhance mean milk and 4% fat corrected milk (FCM) yields, but efficiency of FCM production was higher for cows fed supplemental fat. Milk fat percentage was unchanged whereas milk protein percentage was depressed with fat supplementation. Feeding supplemental fat reduced DMI and energy balance but there were no differences among treatments on time to resumption of ovarian cyclicity or conception rate to first service. Concentrations of progesterone during the first two ovulatory cycles tended to be greater in the fat-supplemented groups. Feeding supplemental fat starting at either parturition or 29 DIM increased efficiency of FCM production, but did not greatly enhance reproductive performance. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 2 : 182-187*)

Key Words : Fat Supplementation, Lactation, Reproduction, Time of Initiation

INTRODUCTION

High milk production per cow contributes to the profitability of a dairy farm. However, an antagonistic association between milk production and reproduction in lactating dairy cows has been documented (Butter and Smith, 1989; Lean et al., 1989). Negative energy balance (**EB**) often accompanies high levels of milk production in early lactation and has been correlated negatively with reproductive performance. Harrison et al. (1990) reported that high milk production was antagonistic to expression of estrous behavior, but not to reactivation of ovarian activity following parturition. In nulligravid heifers, negative EB reduced luteal secretion of progesterone (**P_4**); (Villa-Godoy et al., 1990) and delayed the onset of diestrus (Villa-Godoy et al., 1990), but did not reduce the concentrations of peak P_4 or duration of estrous behavior.

Fat addition to the diet potentially could be very beneficial to milk production and reproductive performance. The inclusion of prilled fat at 2% of dietary DM in dairy cattle rations beginning at parturition had little effect on rumen fermentation, variable effects on milk yield and composition, and beneficial effects on conception rate (Ferguson et al., 1990). Feeding Ca salts of fatty acids (**CaFA**) from parturition to 120 DIM resulted in higher milk production at the expense of body reserves (Sklan et al., 1991; Sklan et al., 1994). Cows fed CaFA lost more BW and reached a minimum BW later than controls. Palmquist (1990) suggested that fat should be fed minimally or not at all, during the first 5 to 6 wk of lactation based on the reported lack of response in early lactation. If added fat results in reduced DMI during the first several weeks of lactation, then total NE_L intake would be reduced. In fact, Jerred et al. (1990) found that fat supplementation did not enhance lactation performance due to depressed intake during early lactation, and improved persistency of lactation was obtained when fat addition was not started until 35 DIM (Salfer et al., 1995).

Progesterone insufficiency during the early and mid-luteal phase of the estrous cycle is cited frequently as a possible cause of embryo mortality. Greater concentrations of P_4 in the blood during the luteal phase preceding AI were associated with greater conception rates (Britt and Holt, 1988; Folman et al., 1990). Effects of fat supplementation have been variable. Feeding CaFA either increased (Sklan et al., 1991) or had no effect (Sklan et al., 1994) on P_4 concentration in the luteal phase before AI and increased second to fourth AI conception rates (Sklan et al., 1991) or decreased first service conception rate in primiparous cows (Sklan et al., 1994). Carroll et al. (1990) reported that P_4 concentrations during the luteal phase after breeding were higher in cows fed 5%

* Address reprint request to L. L. Larson. Tel: +1-402-472-6420, Fax: +1-402-472-6362, E-mail: llarson2@unl.edu.
[1] Present address: Cell Biology & Human Anatomy Dept., University of California-Davis, School of Medicine, Davis, CA 95616, USA.
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prilled long-chain fatty acids, but that conception rates were not different from controls. Time of addition of partially hydrogenated tallow to diets did not influence reproduction (Salfer et al., 1995).

The objective of this study was to determine the effect of time of initiating supplemental CaFA feeding to increase energy density of the diet on early lactation and reproductive performance. Our goal was to evaluate the effect of feeding CaFA as an energy source starting at different stages of lactation, not to compare different sources of lipid.

MATERIALS AND METHODS

Forty-two Holstein (21 multiparous) cows were blocked by parity and assigned randomly at parturition to one of three diets: 1) control (C), no supplemental fat from 1 to 98 DIM; 2) control diet from 1 to 28 DIM then supplemental fat from 29 to 98 DIM (**C-CaFA**); or 3) supplemental fat from 1 to 98 DIM (**CaFA**). Three C and two C-CaFA cows were removed from the study due to reasons not related to the dietary treatments. The cows were fed individually their assigned total mixed ration once daily for *ad libitum* intake in a tie-stall barn from parturition to 98 DIM. The diets were 48:52 forage to concentrate (DM basis). Supplemental CaFA (Megalac, Church & Dwight Co., Inc., Princeton, NJ) was substituted into the concentrate portion of the control diet at 3% of total ration DM and fed beginning at parturition (**CaFA**) or at 29 DIM (**C-CaFA**). The control and fat-containing diets were formulated to meet or slightly exceed requirements of NRC (1989) and were similar except for energy density. Composition of feed ingredients and total mixed ration were determined at the beginning of the experiment (table 1). Samples of individual feed ingredients were oven-dried (60℃), ground through a Wiley mill (1-mm screen, Arthur H. Thomas Co., Philadelphia, PA), and analyzed for CP (AOAC, 1990), and amylase-modified NDF (Van Soest et al., 1991).

Cows were milked twice daily and production was recorded electronically. A daily composite of milk samples from a.m. and p.m. milkings were taken weekly and analyzed for fat and protein (Milko-Scan Fossomatic, Foss Food Technology Corp., Eden Prairie, MN).

Body weight and body condition score (**BCS**) were determined weekly. Assessment of BCS (1=emaciated, 5=obese) was based on appearance and palpation of the loin and pelvic regions (Wildman et al., 1982).

Table 1. Ingredient and nutrient composition of diets

	Diets	
	Control	CaFA
Ingredients	(% of DM)	
Alfalfa haylage	16.0	16.0
Corn silage	32.0	32.0
Corn, ground shell	24.6	23.2
Soybean meal, 44% CP	16.1	15.8
Corn distillers, dry	5.1	5.0
Blood meal	0.9	0.9
Soybean hulls	1.9	1.9
Mineral-vitamin mix.[1]	3.4	2.2
CaFA[2]	-	3.0
Composition[3]		
DM, %	69.6	69.8
	(% of DM)	
CP	17.8	17.5
RUP[4,5]	6.2	6.1
NDF	30.1	29.8
NE_L[5], Mcal/kg	1.69	1.82

[1] Mineral and vitamin mix contained 15.2% Ca, 7.2% P, 4.1% Mg, 4% Na, 3,000 mg/kg of Zn, 1,750 mg/kg of Mn, 400 mg/kg of Cu, 441,000 IU of vitamin A, 79,000 IU of vitamin D_3, and 1,300 IU of vitamin E.

[2] Calcium salts of long-chain fatty acids, Megalac (Church and Dwight Co., Princeton, NJ). A Ca salt of palm oil; 82.5% lipid and 17.5% Ca. The fatty acid composition of palm oil is 44.0% palmitic, 4.1% stearic, 39.3% oleic, 10.0% linoleic and 2.6% other.

[3] Dietary composition calculated from analyzed composition of individual ingredients.

[4] Rumen-Undegradable Protein.

[5] Calculated from values in NRC (1989), except for NE_L of CaFA for which a value of 2.96 Mcal/kg was used (Andrew et al., 1991).

Two evaluators scored each cow each week and their scores were averaged. Net energy intake (NE_I) was derived from multiplying the weekly DM consumption by the calculated NE_L concentration. Net energy required for body maintenance (NE_m) was calculated using the equation: NE_m=(kg $BW^{0.75}$)×0.08. Net energy for milk was calculated using the equation: NE_{Milk}=Milk yield×(0.312+[0.0962×fat %]). Net energy balance was calculated using the equation net EB=NE_I-NE_m-NE_{Milk} (Lucy et al., 1991). Net EB was used as an indicator of energy status.

Blood samples were collected twice weekly in heparinized vacutainer tubes (Monojet®, St. Louis, MO) from a coccygeal vessel and placed immediately on ice. Blood samples were collected from 2 wk postpartum until 4 wk after first service. The plasma was separated within 2 h of collection, divided into three aliquots, and stored frozen for later determinations of concentrations of P_4. Concentrations of P_4 in blood plasma were used to determine postpartum interval to first ovulation, ovarian cyclicity, and corpus luteum competency.

The breeding program was initiated at 8 wk postpartum. Cows were given 25 mg $PGF_{2\alpha}$ (Lutalyse®, The Upjohn Co., Kalamazoo, MI) on the Monday morning after cows reached this stage of lactation. Cows were bred by standard AI procedures based on observed estrus. The $PGF_{2\alpha}$ treatment was repeated at weekly intervals, for a maximum of three treatments, for cows not previously detected in estrus. Conception rate was defined as the percentage of inseminated cows diagnosed as pregnant. The pregnancy rate was defined as the percentage of total cows in the group diagnosed pregnant. Ovulation was considered to have occurred when concentrations of P_4 were < 1 ng/ml, and then increased to 2 ng/ml for at least two consecutive sampling days. Concentrations of P_4 during luteal phase were determined from samples collected between d 8 to 16 following ovulation.

Concentration of P_4 in plasma samples collected throughout the experiment was analyzed by specific double-antibody radioimmunoassay as described by Roberson et al. (1989). Intra- and interassay CV of variation for P_4 assays were 6.9 and 11.5%, respectively.

Data were analyzed using the general linear models procedure (**GLM**) of SAS (1990). Treatment, parity and treatment by parity interaction were tested for significance as main effects for production as well as reproduction traits. Repeated measures traits included dry matter intake (**DMI**) in kg, body weight (**BW**) in kg, body condition score (**BCS**), milk weight (**MW**) in kg, fat percent, protein percent, fat in kg, 4% fat corrected milk (**FCM**) in kg, net energy intake (**NE_I**) in Mcal, net energy maintenance (**NEm**) in Mcal, net energy milk (**NE_{ml}**) in Mcal, net energy balance (**NEB**) in Mcal, efficiency as FCM/DMI and DMI as % of body weight. Single mean comparisons included days open, days to 1st and 2nd ovulation, luteal progesterone in 1st and 2nd cycle, peak progesterone in 1st and 2nd cycle, days to BW nadir, BW loss to nadir, BW change to 8 wk, days to BCS nadir, BCS loss to nadir, and BCS change to 8 wk. If the treatment by parity interaction was nonsignificant (α =0.05) for any specific trait it was subsequently omitted from the analysis. Data were balanced for all observations across all traits.

Model: $Y_{ijk} = \mu + cow_i + trt_j + par_k + trt*par_{jk} + e_{ijk}$. Where Y_{ijk} as the dependent observation, μ = overall mean, cow_i is the ith cow, receiving treatment j in parity k. $Trt*par_{jk}$ is the treatment by parity interaction and e_{ijk} is residual error. Within treatment comparisons were tested through the contrast of treatments in GLM.

RESULTS

Mean milk yield and 4% FCM during the experimental period, from 1 to 98 DIM, were similar across dietary treatments (table 2). However, efficiency of FCM milk production, kg FCM/kg DMI, was higher ($p<0.01$) in the C-CaFA and CaFA groups compared with the C group. Milk fat percentage was unchanged (table 2), whereas milk protein percentage was depressed by feeding CaFA ($p<0.01$).

Table 2. Effect of time of initiating dietary fat supplementation on lactation performance[1]

	Diets[2]			SEM
	Control	C-CaFA	CaFA	
Number of cows	11	12	14	
Milk yield, kg/d	29.9	29.4	29.2	0.45
4% FCM, kg/d	28.1	27.5	27.4	0.41
FCM/DMI, kg/kg	1.35[a]	1.48[b]	1.57[c]	0.03
Milk composition				
Milk fat, %	3.63	3.61	3.66	0.05
Milk protein, %	3.18[a]	3.08[b]	3.05[b]	0.03

[1] Least square means for the experimental period (1 to 98 DIM).
[2] CaFA=Calcium salts of long-chain fatty acids, Megalac (Church and Dwight Co., Princeton, NJ); C = Control.
[a,b,c] Means within a row with different superscripts differ ($p<0.01$).

Dry matter intake ($p<0.05$) and DMI as a percentage of BW were higher ($p<0.05$) in the C group compared with the C-CaFA and CaFA groups (table 3). Similarly, NEB for the experimental period was higher ($p<0.01$) in the C group compared to the C-CaFA and CaFA groups. Days postpartum to minimum BW and BCS did not differ between treatment groups (table 3). Also, the magnitude of change in BW and BCS to minimum values were similar across dietary treatments.

Peak concentration of P_4 in plasma during the first estrous cycle was greater ($p<0.05$) in the C-CaFA group compared with the C group (table 4). Other comparisons of concentrations of P_4 tended ($p=0.10$ to 0.13) to be enhanced in the CaFA groups compared with the C group (table 4). Plasma concentration of P_4 were similar ($p>0.05$) between the C-CaFA and CaFA groups. The postpartum intervals to first and second ovulation based on P_4 profiles and to first AI were similar ($p>0.05$) among cows fed the three diets

Table 3. Effect of time of initiating dietary fat supplementation on DMI, body measures, and EB[1]

	Diets[2]			SEM
	Control	C-CaFA	CaFA	
Number of cows	11	12	14	
DMI				
Mean, kg/d	21.6[a]	18.8[b]	18.2[b]	0.32
% of BW	3.83[a]	3.40[b]	3.27[b]	0.05
Body weight				
Mean, kg	550	552	554	3.8
Interval to nadir, d	35.1	46.8	33.5	5.3
Change to nadir, kg	-39.8	-46.2	-43.7	6.9
BCS				
Mean	2.97[a]	3.14[b]	3.21[b]	0.05
Interval to nadir, d	45.0	42.0	50.5	4.6
Change to nadir	-0.71	-0.77	-0.82	0.13
Net energy balance				
mean, Mcal/d	6.82[c]	5.29[d]	4.79[d]	0.47

[1] Least square means for the experimental period (1 to 98 DIM).
[2] CaFA = Calcium salts of long-chain fatty acids, Megalac (Church and Dwight Co., Princeton, NJ); C = Control.
[a,b] Means within a row with different superscripts differ ($p<0.05$).
[c,d] Means within a row with different superscripts differ ($p<0.01$).

(table 4). Reproductive performance including percentage of cows ovulating by 98 DIM and first service conception rate were similar ($p>0.05$) among diets. Numerically, more CaFA cows were pregnant by 98 DIM, but the numbers were not adequate for a good statistical test.

DISCUSSION

Overall milk and FCM yields were not enhanced by feeding CaFA starting either immediately after calving or at 28 DIM in contrast to other studies evaluating CaFA feeding from parturition (Sklan et al., 1991; Sklan et al., 1994). But efficiency of 4% FCM production (4% FCM/DMI, kg/kg), was greater in the CaFA cows compared with C cows as they produced a similar quantity of FCM while consuming less DM.

Some studies utilizing partially hydrogenated tallow (Salfer et al., 1995) and poultry fat (Baysingar et al., 1981) have shown that supplemented fat at 2 to 3% of dietary DM had no effect on early lactation milk production, whereas CaFA added at 2.6% (Sklan et al., 1991) and 2.5% (Sklan et al., 1994) from parturition enhanced milk yield and FCM production in high producing cows. Schauff and Clark (1989) summarized several experiments and concluded that

Table 4. Effect of time of initiating dietary fat supplementation on reproductive measures[1]

	Diets[2]			SEM
	Control	C-CaFA	CaFA	
Number of cows	11	12	14	
First ovulation cycle				
Peak progesterone[3], ng/ml	8.88	12.74	10.23	1.05
Luteal phase[4], ng/ml	5.62	8.03	6.51	0.81
Second ovulation cycle				
Peak progesterone, ng/ml	9.52	13.28	11.10	1.17
Luteal phase, ng/ml	5.71	8.80	7.28	1.00
Postpartum intervals to				
first ovulation, d	29.4	40.0	31.4	3.8
Second ovulation, d	50.0	61.4	53.5	3.4
first AI, d	61.6	63.2	62.6	3.2
Conception rate at				
first AI, %	36.4	18.2	35.7	
Performance to 98 DIM	(4/11)[6]	(2/11)	(5/14)	
Ovulated, %	100 (11/11)	100 (12/12)	92.85 (13/14)	
Pregnancy rate, %	36.4 (4/11)	36.4 (4/11)	50.0 (7/14)	

[1] Least square means for the experimental period (1 to 98 DIM).
[2] CaFA = Calcium salts of long-chain fatty acids, Megalac (Church and Dwight Co., Princeton, NJ); C = Control.
[3] Average of two highest concentrations in each cycle.
[4] From samples collected d 8 to 16 after ovulation.
[5] Based on progesterone profiles.
[6] Number of animals.
[a,b] Means within a row with different superscripts differ ($p<0.05$).

supplemented fat of any type is of greatest potential benefit when milk production is greater than 35 kg/d. The average milk production of cows in our study was 29.5 kg/d, similar to that of Salfer et al. (1995) who also observed no milk production response to supplemental fat in early lactation. However, the shape of the lactation curves in the present study were different with daily milk yield being numerically higher from parturition to 35 DIM for the C diet compared with CaFA diet (data not shown). The results are probably due to differences in DMI. Although energy density of the CaFA diet was higher, EB was lower in cows fed CaFA starting at parturition due to depressed DMI. Also, BW loss was most rapid for the CaFA group indicating that DMI was not adequate in early lactation. Palmquist (1990) suggested feed intake might be reduced in early lactation due to high FFA in plasma resulting from adipose mobilization and added dietary fat.

Feeding CaFA did not substantially affect reproductive performance in this study which agrees with previous results utilizing prilled long-chain fatty acids (Carroll et al., 1990) and partially hydrogenated tallow (Salfer et al., 1995). Certain reproductive measures were either enhanced (Sklan et al., 1991) or depressed (Sklan et al., 1994) in other studies with added CaFA.

Postpartum interval to resumption of ovarian cyclicity was not different among treatments in the present study although EB was lower in the CaFA and C-CaFA cows compared with C cows. In contrast, resumption of ovarian cyclicity was delayed in CaFA cows in a study by Sklan et al. (1991) which was attributed to the greater negative energy balance (Butler et al., 1981; Canfield et al., 1990). This relationship was not detected in the present study.

Feeding CaFA did not substantially affect first service conception rates in this study. This lack of affect on conception rate might be a result of the limited affect of the diets on circulating concentrations of P_4. Only peak concentrations of P_4 measured during the first estrous cycle for cows fed the C-CaFA diet were statistically greater than those fed the C diet. In the study of Sklan et al. (1991), feeding CaFA increased plasma concentration of P_4 during the luteal phase before AI and on 9 and 24 d after AI in cows that conceived. The authors suggested that corpora lutea of CaFA-fed cows had a greater potential to secrete P_4 than cows in the control group. However, in a subsequent study (Sklan et al., 1994), plasma P_4 concentrations were similar before estrus but after estrus P_4 concentrations were higher in multiparous and lower in primiparous cows fed CaFA. A relationship between plasma concentrations of P_4 and improved conception rates were not established in this study. In the study of Sklan et al. (1991), conception rates were not different at first service, but were higher for second through fourth services in cows fed fat. Our results tend to support this finding.

Average body condition loss from calving to nadir, -0.77, was similar across treatments and did not affect conception rate at first AI or pregnancy rate to 98 DIM. Changes in BCS of cows during early lactation have been used to indicate how much body tissue is mobilized for milk production. Wildman et al. (1982) proposed a body condition scoring system that is independent of frame size, age, and DMI, which has proved useful for monitoring depletion and repletion of body tissue reserves in dairy cows. Greater than one unit loss of BCS on a five-unit scale after calving resulted in lower fertility (Butler and Smith, 1989), but within the moderate range (one scoring unit), BCS and fertility were not closely related as in our study. However, cows that lose higher amounts of body condition soon after parturition have cumulative pregnancy rates that are similar to those of cows that lose little condition, so the infertility associated with body tissue loss is temporary (Butler and Smith, 1989).

CONCLUSIONS

Efficiency of FCM production was enhanced with supplemental fat, although milk and FCM yields were not increased. Feeding CaFA starting at parturition depressed DMI and EB during the early postpartum period but this effect was not detrimental to resumption of ovarian cyclicity or conception. Plasma P_4 was enhanced by feeding CaFA. Major benefits were not evident from feeding supplemental CaFA starting at either parturition or 28 DIM. Additional studies are needed to determine feeding strategies and methods to increase EB in early lactation cows.

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