Effects of Tallow and Escape Protein on Lactational and Reproductive Performance of Dairy Cows[1]

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ABSTRACT

Experiments were performed to determine the effect of energy source and proportion of escape protein on lactational performance, body measurements, and reproductive activity. Sixty-eight lactating Holstein cows were assigned to one of four dietary treatments during wk 2 to 12 postpartum: 1) high fat (3% tallow), high escape protein (5% feather meal:blood meal, 85:15, DM basis); 2) high fat, low escape protein (0% feather meal:blood meal); 3) low fat (0% tallow), high escape protein; and 4) low fat, low escape protein. Diets were similar in energy and CP contents. Overall mean milk yield (32.9 kg/d) was not affected by diet, but efficiency of FCM yield was highest with high fat and high escape protein. Daily DMI and net energy balance were greater for cows fed the diet low in fat and low in escape protein, but days to first ovulation were not different among groups. Total cholesterol in plasma increased as DIM increased, and concentrations were greater for cows fed the high fat diets than for cows fed the low fat diets after 35 DIM. Concentrations of luteal phase progesterone and follicular phase estradiol tended to be greater for cows fed the high fat and low escape protein, but conception rate from first AI was greatest for cows fed the high fat and high escape protein. Supplemental tallow and escape protein did not consistently affect lactational performance but did improve efficiency of FCM yield and conception rate from first AI.

(**Key words**: escape protein, lactation, reproduction, tallow)

Abbreviation key: **BCS** = body condition score, $\mathbf{E_2}$ = 17β-estradiol, **EB** = energy balance, **HE** = high escape protein, **HF** = high fat, **LE** = low escape protein, **LF** = low fat, $\mathbf{P_4}$ = progesterone.

INTRODUCTION

High milk yield and good reproductive performance are important to the profitability of a dairy enterprise. However, the association between milk yield and reproduction is antagonistic (3). High milk yield during early lactation retards development of ovarian follicles, prolonging the postpartum interval to first ovulation; high yield also is antagonistic to the expression of estrus and is associated with reduced conception rates. Nutrient requirements must be satisfied from dietary sources and mobilization of body reserves. During early lactation, the rate of increase in milk yield exceeds that of DMI, resulting in a negative energy balance (**EB**). Thus, EB is closely related to reproductive performance (3, 4). Methods to minimize the extent and duration of negative EB should be beneficial to reproduction.

Supplemental fat can increase caloric density of diets without reducing fiber content, thus increasing energy intake (18, 24) if DMI is not depressed. However, type and dietary concentration of fat may influence lactational response by altering ruminal fiber digestion (18). The inclusion of prilled fat at 2% of DM in rations during early lactation had slight effects on ruminal fermentation, variable effects on milk yield and composition, and beneficial effects on conception rates (8). Reproductive (5, 10, 20, 23) and lactational (14, 20, 21) responses to supplemental fat have been inconsistent. Generally, added fat increased milk yield but depressed milk protein concentration (18). Therefore, addition of dietary RUP potentially could be beneficial to milk protein concentration.

Diets containing 18 to 19% CP are required in early lactation to support high milk yield (16). However, excessive RUP (>63% of total CP) may depress fertility (4). Providing supplemental RUP may enhance reproduction 1) by improving EB by decreasing excessive ruminal ammonia that is energetically costly to excrete or 2) by lowering protein degradability, thereby reducing concentrations of ammonia, urea, or other nitrogenous compounds that are toxic to ova, sperm, or embryos (26).

This experiment evaluated the effect of supplemental tallow in place of corn grain and a proportion of

Received September 5, 1995.
Accepted January 26, 1996.
[1]Published as paper number 11190, Journal Series, Nebraska Agricultural Research Division, University of Nebraska-Lincoln.
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escape protein on milk yield and reproductive performance of early lactation cows.

MATERIALS AND METHODS

Sixty-eight lactating Holstein cows were blocked by parity and assigned randomly to one of four dietary treatments at 2 wk postpartum: 1) **HF** (high fat) + **HE** (high escape protein); 2) HF + **LE** (low escape protein); 3) **LF** (low fat) + HE, and 4) LF + LE. The experimental diets were essentially isocaloric and isonitrogenous (Table 1). The dietary variables were source of energy (0 or 3% tallow in place of corn grain) and percentage of supplemental escape protein (0 or 5%, DM basis). The escape protein supplement was a mixture of hydrolyzed feather meal and blood meal (85:15, DM basis), and the supplemental fat source was tallow (National By-products, Omaha, NE; Table 1). The RUP concentration of the diets was determined in situ using the procedures outlined by Wilkerson et al. (29).

Two separate studies were conducted beginning in March 1992 and September 1993. Experiment 1 was conducted with 28 cows (14 multiparous), and Experiment 2 was conducted with 40 cows (20 multiparous). The experimental diets were fed from wk 2 to 12 postpartum (wk 0 = parturition). Cows were housed in a tie-stall barn and individually fed assigned diets as a total mixed diet for ad libitum intake. Feed samples were collected daily for each diet and composited weekly for analysis. Samples of individual feed ingredients were oven-dried (60°C), ground through a Wiley mill (1-mm screen; Arthur H. Thomas Co., Philadelphia, PA), and analyzed for CP (2), ADF (27), and NDF modified by α-amylase (27). Daily DMI was determined by weighing the amount fed and orts daily.

Net energy intake (NE_I) was derived from multiplying the weekly DM consumption by calculated NE_L concentration of the ration. Net energy required for body maintenance (NE_M) was calculated using the equation NE_M = (kilograms of $BW^{0.75}$) × 0.08. Net energy secreted in milk (NE_Y) was calculated using the equation NE_Y = milk yield (kilograms) × (0.312 + [0.0962 × percentage of milk fat]). Net energy balance was calculated using the equation $NE_B = NE_I - NE_M - NE_Y$ (13).

Cows were milked twice daily, and yield was recorded electronically. A daily composite of milk samples from a.m. and p.m. milkings was taken

TABLE 1. Ingredient and nutrient composition of diets.

Composition	Diet[1]			
	HF + HE	HF + LE	LF + HE	LF + LE
	(% of DM)			
Ingredient				
Alfalfa haylage	40.8	40.8	32.7	32.7
Corn silage	24.5	24.5	16.7	16.7
Corn, shelled	23.5	17.9	41.8	35.0
SBM,[2] 44% CP	2.0	12.4	2.0	13.9
FTH:BM[3]	5.0	. . .	5.0	. . .
Tallow[4]	3.0	3.0	. . .	. . .
Vitamins and minerals[5]	1.2	1.4	1.8	1.7
Composition				
DM, %	56.9	56.1	63.3	64.1
CP	18.3	18.2	18.0	18.4
RUP, % of CP	40.0	30.5	41.0	30.0
ADF	22.7	22.4	18.1	18.1
NDF	35.8	33.4	29.7	27.5
NFC[6]	38.6	36.5	46.0	44.5
NE_L,[7] Mcal/kg	1.76	1.76	1.74	1.76

[1]HF = High fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement).

[2]SBM = Soybean meal.

[3]FTH:BM = Hydrolyzed feather meal:blood meal, 85:15 (DM basis).

[4]Fatty acid content of tallow was 2.7% $C_{14:0}$, 28.5% $C_{16:0}$, 2.8% $C_{16:1}$, 22.6% $C_{18:0}$, 38.8% $C_{18:1}$, 4.3% $C_{18:2}$, and 0.3% $C_{18:3}$. The ratio of unsaturated to saturated fatty acids was 0.86:1.

[5]Supplemented to contain 15.2% Ca, 7.2% P, 4.1% Mg, 4% Na, 3000 ppm of Zn, 1750 ppm of Mn, 400 ppm of Cu, 200,000 IU/kg of vitamin A, 36,000 IU/kg of vitamin D_3, and 585 IU/kg of vitamin E.

[6]Nonfiber carbohydrate calculated according to Van Soest et al. (27).

[7]Calculated using values of the NRC (16).

weekly and analyzed for fat, total protein, and lactose (Milkoscan Fossomatic; Foss Food Technology Corp., Eden Prairie, MN). The BW and body condition score [**BCS**; 1 = emaciated to 5 = obese (28)] were recorded weekly.

Blood samples were collected twice weekly into heparinized vacutainer tubes (Vacutainer®; Becton Dickinson and Co., Rutherford, NJ) from a coccygeal vessel and placed immediately on ice. Plasma was separated within 2 h of collection, divided into three aliquots, and stored frozen for later determinations of concentration of total cholesterol, estradiol ($\mathbf{E_2}$), and progesterone ($\mathbf{P_4}$). Blood samples were collected from 2 wk postpartum until 4 wk after first AI. Cows were observed for estrus twice daily while exercising on a dirt lot. Concentrations of P_4 in blood plasma were used to determine postpartum interval to first ovulation and initiation of estrous cycle.

Time of ovulation was defined as the sample day before concentration of P_4 increased to >2 ng/ml for at least 2 consecutive d of sampling. Cows that did not ovulate were omitted from the analyses. Mean concentrations of P_4 during the luteal phase were calculated from values obtained between d 8 and 16 of the estrous cycle (d 0 = day of behavioral estrus). Mean concentrations of E_2 during the follicular phase of the estrous cycle were calculated using the two greatest concentrations of E_2 between d −4 and d 2 of the estrous cycle.

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 as pregnant.

The breeding program was initiated on the first Monday 7 wk after the day of calving. In Experiment 1, cows were inseminated by standard AI procedures if detected in estrus during wk 7. Cows not observed in estrus by the subsequent Monday were given 25 mg of $PGF_{2\alpha}$ (Lutalyse®; The Upjohn Co., Kalamazoo, MI) and inseminated if estrus was expressed. The $PGF_{2\alpha}$ treatment was repeated each Monday morning (maximum of three times) until cows were observed in estrus and inseminated. Repeat AI were according to standard procedures. In Experiment 2, cows were given 100 μg of GnRH (Cystorelin®; Sanofi Animal Health, Inc., Overland Park, KS) on the first Monday after 7 wk postpartum followed by 25 mg of $PGF_{2\alpha}$ 1 wk later. Cows were inseminated based on observed estrus following $PGF_{2\alpha}$ treatment. Repeated $PGF_{2\alpha}$ treatments were administered to cows that were not in estrus as previously described.

Concentration of P_4 in plasma samples collected throughout the experiment were analyzed by using a specific double-antibody radioimmunoassay (19). Intraassay and interassay coefficients of variation for P_4 assays were 7.1 and 12.4%, respectively.

Concentrations of E_2 in all pooled plasma samples were analyzed by radioimmunoassay, which utilized an antiserum (Lilly Research Lab., Indianapolis, IN), $[^{125}I]E_2$ (IMS.135; E_2-6[O-carboxymethyl]-oximino-$_2$[^{125}]iodohistamine; Amersham Corp., Arlington Heights, IL) as radiolabeled tracer and E_2 (Sigma Chemical Co., St. Louis, MO) as the standard. Assay validation and procedures using this antiserum have been reported (7). The amount of E_2 in each of the unknown samples was determined using a curve-fitting program with four parameters (9). Intraassay and interassay coefficients of variation for E_2 assays were 3.4 and 16.7%, respectively.

Total cholesterol in plasma was determined by enzymatic reactions (1) using a commercially available kit (Sigma Diagnostics®; Sigma Chemical Co.). Absorbance was recorded at 500 nm using a spectrophotometer (DU® Series 600; Beckman Instruments, Inc., Fullerton, CA) with a temperature-controlled cuvet compartment. Intraassay and interassay coefficients of variance were 2.7 and 4.1%, respectively.

Data were analyzed using the general linear models procedure of SAS (21). All data regarding milk yield, composition, FCM, BW, DMI, BCS, total cholesterol, and reproductive measurements were analyzed using a model that included experiment, treatment, cow nested within treatment, and day postpartum. Orthogonal comparisons were performed for HF versus LF, HE versus LE, and the interaction of fat and escape protein.

RESULTS

The effect of treatment on most responses was similar in both experiments, and combined data are presented here. However, an interaction occurred between treatment and experiment ($P < 0.05$) for milk yield; therefore, treatment effects on milk yield are described separately in the text for each experiment, and the overall means are presented in Table 2.

In Experiment 1, milk yield was greater ($P < 0.05$) for cows fed the HF diets (33.6 kg/d) than for cows fed the LF diets (31.0 kg/d) during the experimental period (wk 2 to 12). When all cows were fed the same diet (wk 13 to 16), HF diets resulted in a positive residual effect ($P < 0.05$) compared with LF diets for milk yield (34.3 vs. 31.1 kg/d). In Experiment 2, however, milk yield was higher ($P < 0.05$) from cows fed the LF diets (34.2 kg/d) than from cows fed HF diets (33.4 kg/d). No differences ($P < 0.05$) were detected for any dependent variable (Table 2) using

TABLE 2. Least squares means of the effect of dietary energy source and proportion of escape protein on lactational performance.

Item	Diet[1]				SEM
	HF + HE	HF + LE	LF + HE	LF + LE	
Cows, no.	17	17	17	17	
Milk, kg/d	33.10	32.99	32.95	32.47	0.41
FCM, kg/d[c]	31.66	31.06	30.03	31.40	0.36
FCM/DMI, kg/kg[a,c]	1.39	1.29	1.24	1.25	0.03
Milk composition					
Fat, %[c]	3.71	3.61	3.41	3.78	0.10
Protein, %[c]	2.75	2.87	2.80	2.97	0.05
Lactose,[2] %[b]	5.09	4.95	5.04	4.89	0.03

[a]LF versus HF ($P < 0.05$).

[b]LE versus HE ($P < 0.05$).

[c]Interaction of fat and escape protein ($P < 0.05$).

[1]HF = High fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement).

[2]Only 10 cows were used for determination of the percentage of lactose in each diet.

combined data from the two experiments and analyzed using a contrast statement regarding milk yield from HF versus LF and HE versus LE diets. Efficiency of FCM yield (kilograms of FCM per kilogram of DMI) was highest for cows fed the HF + HE diet. Milk fat percentage of cows fed the LF + HE diet tended ($P < 0.09$) to be depressed, and milk protein percentage of cows fed the HF + HE diet also tended ($P < 0.07$) to be depressed. Milk lactose percentage was not affected by diets ($P > 0.05$).

Daily DMI were 1.2 and 1.1 kg/d greater ($P < 0.02$) for cows fed the LF versus HF and LE versus HE diets, respectively (Table 3; Figure 1). The DMI as a percentage of BW was 7.3% greater for cows fed the LF versus HF diets and for those fed the LE versus HE diets. Similarly, mean net EB from 2 to 12 wk postpartum were also 2.83 and 1.91 Mcal/d greater ($P < 0.01$) for cows fed LF versus HF and LE versus HE diets, respectively. Net EB was the lowest for cows fed the HF + HE diet throughout the experimental period and was highly correlated ($r = 0.96$; $P < 0.01$) with DMI.

Overall BW loss was greater ($P < 0.05$) for cows fed the HF + HE and LF + LE diets (Table 3). Loss of BW was most rapid for cows fed the LF + LE diet and reached a minimum at 35 DIM; cows fed the HF + HE diet continued to lose BW throughout the experimental period (Figure 2).

Mean BCS was lowest for cows fed the LF + LE diet ($P < 0.05$). However, postpartum changes in BCS were similar among groups and were not affected by diet ($P > 0.05$; Figure 2).

Mean concentrations of total cholesterol were greater for cows fed HF diets than for those fed LF diets ($P < 0.01$; Table 4). Plasma total cholesterol increased as DIM increased for cows of all groups; however, concentrations of cholesterol were greater for cows fed the HF diets than for cows fed the LF diets after 35 DIM ($P < 0.05$; Figure 3).

Cows fed the HF diets tended to have greater concentrations of plasma P_4 during the experimental period ($P = 0.08$) and during the luteal phase ($P = 0.10$) after first AI than did cows fed LF diets (Table 4). For the first two estrous cycles after parturition, concentrations of P_4 during the luteal phase and concentrations of E_2 during the follicular phase were greater ($P < 0.05$) for cows fed the HF + LE diet. Only peak P_4 in the second ovulation cycle was correlated ($r = 0.97$) with total plasma cholesterol.

Postpartum intervals to first ovulation, second ovulation, and first AI were similar among cows fed the different diets ($P > 0.05$). Fewer cows fed the LF + HE diet ovulated by 98 DIM than did cows fed the other diets. Conception rate from first AI was greater ($P < 0.05$) for cows fed the HF + HE diet, and pregnancy rate to 98 DIM tended to be greater ($P = 0.10$) for cows fed the HF diets.

DISCUSSION

The effect of supplemental fat on lactational performance might be evaluated by substituting fat for concentrates such that the NE_L content of the test diet is greater than the control diet. In our study, however, all diets were essentially isocaloric in order to test the suitability of energy sources (tallow vs. corn) separately from dietary energy concentration for optimal milk yield. The calculated concentrations

of nonfiber carbohydrate were 20% higher for the LF diets than for the HF diets.

Overall milk yield was similar across dietary treatments when the data for the two experiments were combined. Milk yield was enhanced for cows fed HF diets in Experiment 1, which was conducted during the warm seasons, but not in Experiment 2, which was conducted during the cold seasons; however, efficiency of 4% FCM yield was 10.3% greater for cows fed the HF + HE diet than for cows fed other diets. The observed interaction of treatment by experiment might have been due to environmental conditions. Palmquist (17) noted that the benefit of fat supplementation to cows was greater in hot weather because such a diet resulted in less metabolic heat to be dissipated. Milk and 3.5% FCM yields were not influenced when supplementation of dietary tallow (2%) was initiated prepartum or at parturition (20), but yields and efficiency were enhanced when supplementation was initiated wk 4 postpartum (14). Dietary Ca soaps (23, 24) or Ca soaps plus RUP (25) enhanced milk yield. Dietary feather meal at 3% of dietary DM enhanced milk yield at 14% CP but not at 18% CP. Given the mean milk yield of cows on all diets, the requirement for metabolizable protein was met for cows fed the LE diets (16). Therefore, the lack of milk response between the LE and HE diets in this study was not surprising.

During the first experiment, HF diets had a residual effect on milk yield of cows during wk 13 to 16, which agreed with some continuous feeding studies (22) of residual effects of dietary fat after

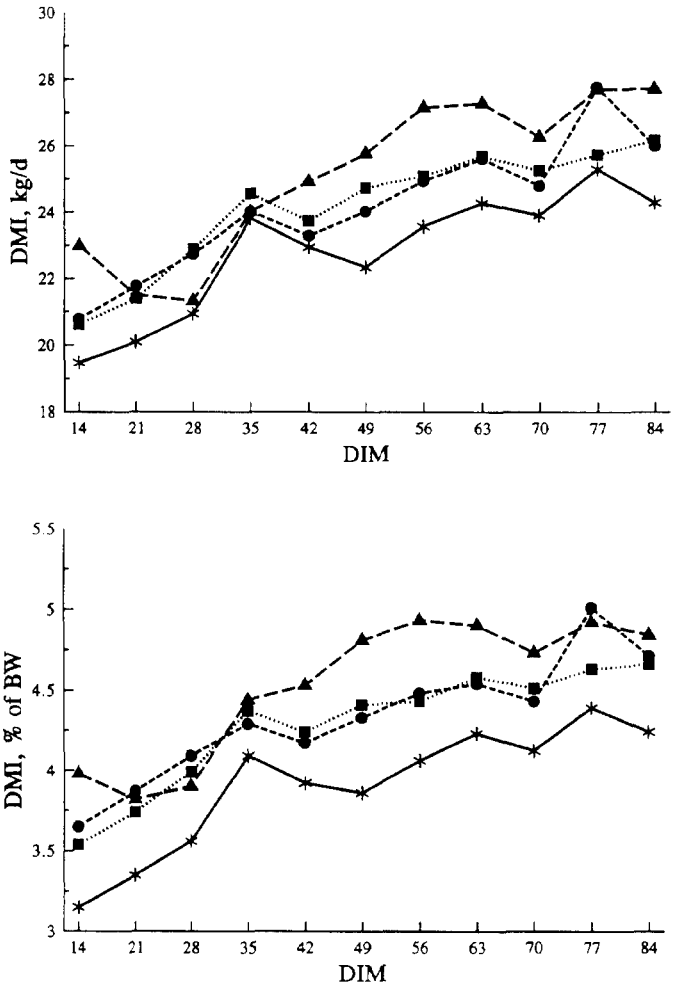

Figure 1. Dry matter intake of cows fed diets differing in energy source and proportion of escape protein. Abbreviations were HF = high fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement). Diets were HF + HE (*), HF + LE (●), LF + HE (■), and LF + LE (▲).

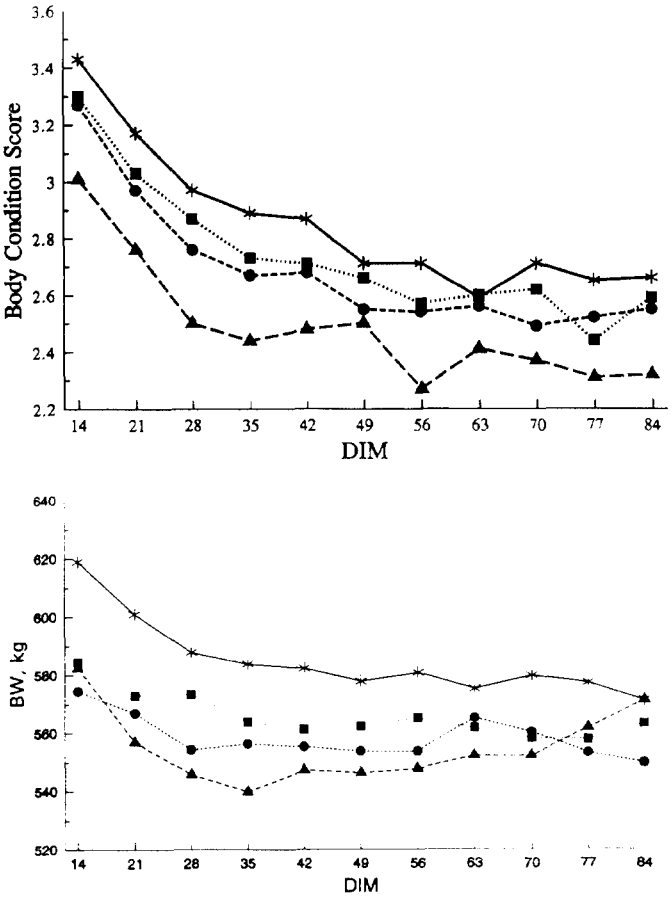

Figure 2. Body weight and body condition score of cows fed diets differing in energy source and proportion of escape protein. Abbreviations were HF = high fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement). Diets were HF + HE (*), HF + LE (●), LF + HE (■), and LF + LE (▲).

supplemental dietary fat was discontinued. Milk fat percentage was not affected by supplemental fat or added escape protein in this study, in contrast to a reported increase (25), but in agreement with another study using 2% tallow (14). Milk protein percentage tended to be reduced with supplemental escape protein or fat. Harris et al. (11) reported that feather meal depressed milk protein percentage. Those researchers suggested that dietary feather meal might need to be linked to escape protein sources with complementary AA profiles, such as blood meal, which contained more lysine and methionine than did feather meal. In our study, the combination of supplemental feather meal and blood meal did not significantly reduce protein percentage, which agreed with results of Moss et al. (15). Several studies (18, 22) found that milk protein percentage was decreased when fat was added to the diet. Significant quantities of dietary energy were unavailable for fermentation and microbial growth when fat was fed (18), potentially decreasing the availability of microbial protein and glucose precursors to the cow. In our study, mean milk protein percentages were somewhat low, but no further reduction was detected with tallow supplementation as previously reported (14).

Inclusion of either 3% tallow or 5% supplemental escape protein (hydrolyzed feather meal:blood meal, 85:15) reduced DMI. The effect appeared to be additive, because DMI, as a percentage of BW, was lowest for the cows fed the HF + HE diet and was highest for those fed the LF + LE diet. This result was in contrast to results of previous studies in which addition of 2% tallow (14, 20) or 3 and 6% hydrolyzed feather meal (11) to diets did not alter DMI. However, DMI was depressed when higher amounts of RUP plus Ca soaps (25) or Ca soaps (23, 24) were fed. Palmquist (17) suggested that high FFA, stimulated by early lactation and overstimulated by additional fat, could slow the increase in feed intake.

TABLE 3. Least squares means of the effect of dietary energy source and proportion of escape protein on energy balance and body measurement.

	Diet[1]				
Item	HF + HE	HF + LE	LF + HE	LF + LE	SEM
Cows, no.	17	17	17	17	
DMI					
kg/d[a,b,c]	22.8	24.1	24.2	25.1	0.5
% of BW[a,b,c]	3.9	4.3	4.3	4.5	0.1
BW Change, kg					
At start (2 wk)[a,b,c]	585.3	558.7	566.0	555.1	3.0
From 2 to 5 wk[c]	−28.0	−15.2	−14.3	−34.8	4.3
From 2 to 12 wk[c]	−37.1	−17.3	−20.3	−30.2	2.2
From 2 wk to first AI[c]	−35.3	−16.2	−18.5	−32.3	2.3
From 2 wk to nadir[c]	−37.1	−17.3	−20.2	−34.8	2.6
Interval to nadir, d[b,c]	84	56	77	35	11
BCS[2]					
At start (2 wk)[a,b,c]	3.43	3.27	3.30	3.01	0.06
At first AI[a,b]	2.71	2.56	2.60	2.31	0.06
At nadir[a]	2.59	2.49	2.44	2.27	0.06
Mean (2 to 12 wk)[a,b,c]	2.85	2.69	2.73	2.49	0.04
BCS Change					
From 2 to 5 wk	−0.42	−0.47	−0.42	−0.44	0.09
From 2 wk to first AI	−0.60	−0.59	−0.56	−0.56	0.06
From 2 wk to nadir	−0.59	−0.62	−0.58	−0.52	0.06
Interval to nadir, d[c]	63	70	77	56	4
Net energy balance, Mcal/d					
From 2 to 5 wk[c]	2.56	6.10	6.46	7.08	1.53
From 2 wk to first AI[c]	4.64	7.77	8.90	10.22	1.18
Mean (2 to 12 wk)[a,c]	5.51	8.80	9.85	10.38	0.69

[a]LF versus HF ($P < 0.05$).

[b]LE versus HE ($P < 0.05$).

[c]Interaction of fat and escape protein ($P < 0.05$).

[1]HF = High fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement).

[2]Body condition score (1 = emaciated to 5 = obese) (28).

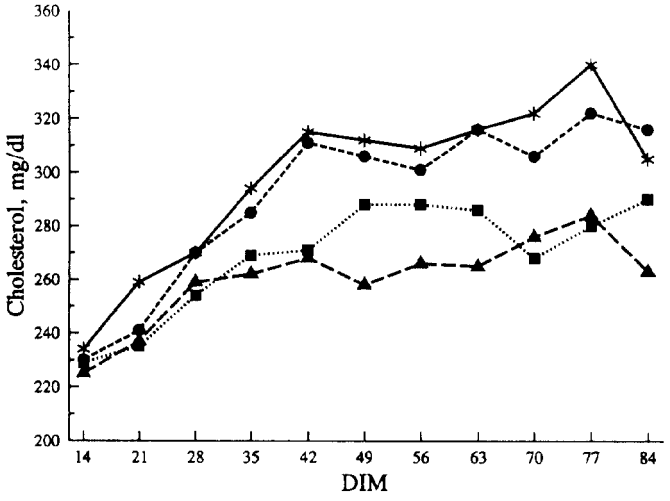

Figure 3. Plasma total cholesterol concentrations of cows fed diets differing in energy source and proportion of escape protein. Abbreviations were HF = high fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement). Diets were HF + HE (*), HF + LE (●), LF + HE (■), and LF + LE (▲).

Dietary treatments did not have major or consistent effects on reproductive performance. Conception rate at first AI was highest for cows fed the HF + HE diet, which was similar to the findings of Sklan and Tinsky (25) with cows fed a combination of bypass fat and protein. In other studies, supplemental fat increased fertility (8, 24) and had no effect (6, 20, 22) or a decreased conception rate at first AI for primiparous cows (23). Excess dietary CP as RDP decreased conception rate from first AI (4), but increased RUP from dietary fish meal did not effect reproductive performance (5).

Resumption of ovarian cyclicity and progesterone production did not vary among diets. Similarly, intervals to first estrus and first AI were not affected by increasing dietary energy density with supplemental fat (6, 20), with increased RUP (5), or with a combination of bypass fat and protein (25). However, Ca soap during early lactation delayed the time of first ovulation (24). In the present study, loss of BW and BCS were similar for the main effects, but BW loss was greatest in cows fed the HF + HE and LF + LE diets. Others (20, 23, 24) have shown that supplemental dietary fat during early lactation did not reduce BW loss. Sklan et al. (24) reported that BW decreased more and ovarian cyclicity commenced later for cows fed Ca soaps, but differences in BW change among diets in our study did not alter the interval to resumption of ovarian cyclicity.

Net EB for the 12-wk experimental period was positive for all cows, even though mean net EB was reduced with supplemental fat and was lowest in cows fed the HF + HE diet. The positive EB during periods of BW and BCS loss that were observed in this study might reflect overestimation of the energy content of the feeds as previously reported (12). However, relative differences in EB among treatments would still be maintained. Mean postpartum interval to first ovulation occurred at 31 ± 4 DIM and did not vary between groups with the lower and higher net EB, in contrast to results of Canfield et al. (4) and Sklan et al. (24). For cows fed the HF + HE diet, EB was lowest, but conception at first AI was highest. Sklan et al. (24) also reported lower EB but higher fertility with fat supplementation, but others (23) found lower conception rates associated with greater negative EB. The overall loss in BCS from parturition to first AI was –0.58, indicating that the use of body reserves was not excessive in the present study. After calving, >1 unit loss of BCS resulted in lower fertility (3), but BCS and fertility were not closely related when the loss was <1 unit, as occurred during our study.

Concentrations of total cholesterol were elevated for cows fed the HF diet; that result was similar to previous observations with 5% prilled long-chain fatty acids (6) but was in contrast to the lack of change when 2.6% Ca soaps of fatty acids were fed (24). A potential mechanism by which supplemental fat may improve reproductive performance involves enhanced utilization of cholesterol for P_4 synthesis (10); however, results have been inconsistent. Supplementation with prilled long-chain fatty acids increased concentrations of both plasma cholesterol and P_4 during the luteal phase but had no effect on reproduction (6). In contrast, Ca soaps of fatty acids had no effect on plasma cholesterol but increased P_4 production and pregnancy rate (24). In the present study, only peak P_4 in the second ovulatory cycle was correlated significantly with concentrations of plasma cholesterol. Therefore, changes in cholesterol and P_4 did not explain the higher conception rates observed in cows fed the HF + HE diet.

CONCLUSIONS

Altering the source of dietary energy and proportion of escape protein did not have major effects on lactational or reproduction performance. The substitution of tallow for corn (which decreased dietary nonfiber carbohydrate content) in combination with

escape protein (which elevated RUP) during early lactation did not consistently enhance milk yield, although efficiency of FCM yield was greatest for cows fed the HF + HE diet. Substitution of tallow for corn did not improve EB, which was lowest for cows fed the HF + HE combination because of depressed DMI. Fat supplementation increased concentrations of cholesterol in plasma after 35 DIM, but concentrations of P_4 in plasma were not significantly increased. The trend of higher E_2 during the follicular phase and P_4 concentrations during the luteal phase for cows fed the HF + LE diet was not associated with an increased conception rate from first AI, which was higher for cows fed the HF + HE diet. Therefore, substitution of tallow for corn as a dietary energy source did not improve EB, but the HF + HE combination did improve efficiency of FCM yield and increased conception rate from first AI.

ACKNOWLEDGMENTS

The authors express appreciation to personnel at the Dairy Research Unit for assistance in completion of these experiments.

TABLE 4. Least squares means of effect of dietary energy source and proportion of escape protein on reproductive measures.

Item	Diet[1]				SEM
	HF + HE	HF + LE	LF + HE	LF+ LE	
Cows, no.	17	17	17	17	
Cholesterol, mg/dl[a,c]	302.3	301.6	278.9	269.6	4.0
P_4 Concentration,[2] ng/ml					
Overall P_4[c]	5.37	4.14	4.43	3.89	0.31
First estrous cycle					
Peak P_4[3,c]	10.07	9.08	10.06	9.14	0.47
Luteal phase[4,c]	6.41	7.19	6.97	6.52	0.53
Second estrous cycle					
Peak P_4[3,a,c]	10.66	10.82	8.62	6.37	0.82
Luteal phase[4,c]	6.37	8.86	8.02	6.60	0.89
After first AI					
Luteal phase	7.93	8.97	6.51	7.31	1.10
E_2 Concentration,[5] pg/ml					
Overall E_2[c]	7.58	9.18	8.96	8.59	0.49
First estrous cycle follicular phase[6]	18.54	21.77	14.94	17.37	2.69
Second estrous cycle follicular phase[6,c]	17.77	21.77	13.09	17.73	2.46
Postpartum intervals to					
First ovulation, d[7]	30.6	31.2	30.8	33.0	3.87
Second ovulation, d[7]	51.5	54.2	52.4	59.9	4.26
First AI, d	67.3	62.4	65.3	76.7	5.54
Conception rate at first AI, %[c]	66.7	23.5	26.7	40.0	11.90
no./no.	10/15[8]	4/17	4/15	6/15	
Performance to 98 d pregnancy rate, %	64.7	58.8	47.1	41.2	12.30
no./no.	11/17	10/17	8/17	7/17	
Ovulated, %[c]	82.4	88.2	76.5	100	8.19
no./no.	14/17	15/17	13/17	17/17	

[a]LF versus HF ($P < 0.05$).

[b]LE versus HE ($P < 0.05$).

[c]Interaction of fat and escape protein ($P < 0.05$).

[1]HF = High fat (3% tallow), HE = high escape protein (5% escape protein supplement), LF = low fat (0% tallow), and LE = low escape protein (0% escape protein supplement).

[2]P_4 = Progesterone.

[3]Mean of two highest concentrations in each estrous cycle.

[4]From samples collected d 8 to 16 after ovulation.

[5]E_2 = 17β-estradiol; only 10 cows from each diet group were used for determination of E_2 concentration.

[6]From samples collected between d −4 and 2 of the estrous cycle.

[7]Based on progesterone profiles.

[8]Number of cows that conceived of number inseminated.

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