Feeding Supplemental Fat and Undegraded Intake Protein to Early Lactation Dairy Cows

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ABSTRACT

Forty-eight Holstein cows (16 primiparous) were fed alfalfa silage-based TMR containing 18% CP with 33 or 36% of the CP as undegraded intake protein and with 0 or 2.8% supplemental fat (DM basis). Expeller soybean meal replaced solvent soybean meal to vary undegraded intake protein, and sodium alginate-treated tallow was used as the fat source. A standard diet containing solvent soybean meal without fat was fed during the first 21 d postpartum for covariate adjustment of milk production. A continuous lactation design with 2 × 2 factorial arrangement of treatments was used with supplemental fat and undegraded intake protein as main effects. Feeding supplemental fat increased actual milk (32.9 vs. 31.7 kg/d) but decreased milk protein concentration. Cows fed supplemental fat also had higher BW, and weight gain was significant with time. Increasing undegraded intake protein did not affect milk yield, composition, or component yield. There were no significant interactions between supplemental fat and undegraded intake protein on milk yield or composition. Milk fatty acid composition was not altered by addition of undegraded intake protein, but C_6 to C_{14} fatty acids were reduced by adding supplemental fat. Results do not support the strategy of increasing levels of undegraded intake protein when supplemental fat is fed. Variation in undegraded intake protein content of feedstuffs appears to be of more importance in ration formulation than interactions between supplemental fat and protein.

(**Key words**: fat, undegraded intake protein, alfalfa)

Abbreviation key: **DIP** = degraded intake protein, **DP** = (degraded protein) control, **DP + F** = control plus fat, **UIP** = undegraded intake protein, **UP** = undegraded protein, **UP + F** = undegraded protein plus fat.

INTRODUCTION

Peak energy intake lags behind peak energy output in early lactation, and, as a consequence, cows are in negative energy balance. Lactating cows are supplemented with high starch grains to increase energy density of the ration in an attempt to meet lactational energy demands. However, the amount of grain that can be fed is limited because milking cows require a minimum amount of forage fiber in the ration for adequate chewing activity and rumen function. Consequently, feeding supplemental fat is utilized as a means of increasing ration energy density. Feeding .45 kg of supplemental fat has increased milk yield an average of 1.5 to 2.0 kg/d per cow (21). Relatively few trials, however, involved a continuous lactation evaluation of the response to supplemental fat in early lactation cows.

In addition to energy, adequate intake of protein is needed to provide the proper amount of total protein to the small intestine for digestion and absorption. Because the amount of protein supplied by microbial synthesis in the rumen is not adequate to meet the needs of high producing cows (19), undegradable intake protein (UIP) often is required. Milk yield responses to increasing the UIP content of

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rations for early lactation cows have been observed, particularly in alfalfa silage-based rations (4). The NRC (12) provided guidelines for UIP requirements and UIP content of common feedstuffs. There have been few attempts in research trials to use these guidelines in formulating rations for high producing cows fed supplemental fat.

Chalupa and Ferguson (5) recommended that an additional 72 g of UIP should be supplemented above NRC (12) guidelines per megacalorie of net energy from fat above 3% of ration DM because fat is not used as an energy source for microbial protein synthesis in the rumen. Ferguson et al. (7) compared 30 and 38% UIP rations (16% CP) containing 0 or .5 kg of calcium salts of palm oil fatty acids from calving to 150 d postpartum. Effects of supplemental fat and UIP on milk yield were additive. This suggests that there may be an additive milk yield response to supplemental fat and UIP.

Objectives of this trial were to evaluate the early lactation responses and interactions of fat supplemented as sodium alginate-treated tallow and UIP supplemented as heat-processed SBM in alfalfa silage diets.

MATERIALS AND METHODS

Thirty-two multiparous and 16 primiparous Holstein cows were assigned to one of four dietary treatments to assess the effect of supplemental fat and UIP on animal performance in early lactation. Animals within parity groups were assigned randomly to treatments, each containing equal numbers of primiparous and multiparous cows. After parturition, animals were fed a standard diet containing oatlage, high moisture ear corn, and solvent soybean meal for a 21-d covariate period and then assigned to their respective treatments, which continued from 22 to 150 d postpartum. Treatments were in a 2 × 2 factorial arrangement and consisted of diets containing either 33.0 or 36.2% of their CP as UIP with or without 2.8% of the ration DM as supplemental fat in the form of ruminally inert (23) sodium alginate-treated tallow (Booster Fat; Balanced Energy Corp., Clinton, IA). Alfalfa silage was the sole forage in the experimental diets; high moisture ear corn was the grain. Solvent and expeller soybean meals (Soyplus; West Central Cooperative, Ralston, IA) were used as protein supplements to vary the level of UIP in the diet. For diet formulation, UIP percentages (12) of 23, 52, and 35 were used for alfalfa silage, high moisture ear corn, and solvent soybean meal, respectively. A UIP value of 64% was used for expeller soybean meal, as previously determined by Broderick (2). The control (degraded protein; DP) diet containing solvent soybean meal was formulated to meet the nutrient requirements of a 600-kg cow milking 40 kg/d at 3.7% fat (12) without considering UIP requirements. Expeller soybean meal replaced solvent soybean meal in the second (undegraded protein; UP) diet to increase dietary concentration of UIP. The DP and UP diets were originally formulated to provide 32 and 38% of the CP as UIP, respectively. Supplemental fat (2.8% of ration DM) then was added to DP and UP diets (DP + F) (UP + F) to formulate the two additional diets.

Diets were group-fed as TMR twice daily at 0800 and 1400 h. Feed refusals were weighed daily at 0600 h and subsampled three times per week and frozen for later analysis. All feed components were sampled weekly throughout the experiment. Samples were analyzed immediately for DM by oven drying for 48 h at 55°C. Samples were ground through a 2-mm Wiley mill (Arthur H. Thomas, Philadelphia, PA) screen for nutrient analysis. Fiber analyses were conducted on samples after regrinding through a 1-mm screen. Orts were prepared as for feed samples; dry, ground samples were composited weekly. Feed and ort samples were analyzed for CP (1) and for ADF, NDF, and ADIN (8). The NDF and ADF were determined nonsequentially, and amylase was used in NDF analyses as described by Robertson and Van Soest (17). Four composites were made from weekly feed and orts samples for ether extract determination (1). The four composites of solvent and expeller soybean meals also were evaluated for UIP by the inhibitor in vitro procedures of Broderick (3). Minerals, Ca, Mg, and K were determined by atomic absorption spectroscopy and P by colorimetric methods. (Coleman Instruments, Inc., Maywood, IL).

Cows were housed in total confinement in groups of 9 and milked twice daily at 0230 and 1430 h. They were weighed on 1 d/wk at 0800 h.

Milk weights were recorded daily, and milk was sampled for component analysis on 1 d/wk. Milk fat and protein were determined on a pooled a.m. to p.m. sample by automated techniques (Milkoscan, Foss Electric, DK). One composite milk sample for each cow for the treatment period was prepared by removing a 2-ml aliquot from each weekly sample. Milk fatty acid composition was determined from these composite milk samples by GLC (9).

Data was analyzed using the general linear models procedure of SAS (18) with the model

$$\gamma_{ijkl} = \mu + \beta\,(\text{cov}) + A_i + F_j + P_k + (FP)_{jk} + (AF)_{ij} + (AP)_{ik} + (AFP)_{ijk} + C_l + W_m + (AW)_{im} + (FW)_{jm} + (PW)_{km} + (AFW)_{ijm} + (APW)_{ikm} + (FPW)_{jkm} + e_{ijklm}$$

where

- γ is the dependent variable (milk yield, milk composition, and BW);
- μ is the overall mean of the population;
- β is the linear regression coefficient for milk production during wk 1 to 3 of lactation for cow l;
- A_i is the average effect of parity i (primiparous or multiparous);
- F_j is the average effect of amount j of fat (0 or 454 g/d per cow);
- P_k is the average effect of level k of percentage UIP;
- C_l is the average effect of cow l;
- W_m is the average effect of week m of lactation; and
- e_{ijklm} is the unexplained residual element assumed to be independent and identically distributed $(N(0,\delta^2)$.

Cow was used as the error term for parity, fat, UIP, and their interactions. Other terms were tested using the residual mean squares. Interactions with $P > .15$ were dropped from the model except $(FP)_{jk}$. Covariate-adjusted means were computed by dropping C_l, W_m, and interactions including W_m from the model.

RESULTS AND DISCUSSION

Chemical composition of forage, grain, and protein supplements is presented in Table 1. Alfalfa silage was of high quality as indicated by CP, ADF, and NDF content and was consistent throughout the study. Dry matter and CP content of the alfalfa silage was similar to that evaluated by Prange et al. (16), which had a UIP content similar to that recommended by the NRC (12) (23%), which was used in formulating experimental rations. The UIP percentages of solvent and expeller soybean meal (39.6 and 54.5), as determined by inhibitor in vitro procedures (3), were not, however, consistent with values used in formulating experi-

TABLE 1. Chemical composition of forage, grain, and protein supplements.[1]

Item	Alfalfa silage	High moisture ear corn	Solvent soybean meal	Expeller soybean meal
	(%)			
DM	51.2	67.6	89.4	87.5
CP	20.3	9.8	45.5	44.1
ADF	32.9	11.8	13.0	14.2
NDF	39.1	21.9	14.3	21.2
Ca	1.24	.07	.50	.44
P	.32	.32	.72	.81
Mg	.35	.22	.41	.46
K	3.42	.73	2.85	2.86
ADIN	1.5	.8	1.6	1.3
Ether extract	3.7	2.7	1.6	4.3
Estimated UIP,[2] % of CP	23.0	52.0	39.6	54.5

[1]Values expressed on a DM basis, except DM is expressed on as-fed basis.

[2]Estimated undegradable intake protein (UIP) expressed as percentage of CP. Values for solvent and expeller soybean meals determined by inhibitor in vitro procedures of Broderick (3). Other values from NRC 1989 values (12).

mental rations. The UIP content of solvent soybean meal was higher than that (35%) reported by the NRC (12), but expeller soybean meal was 9.5% lower than the 64.0% value reported by Broderick (2). It did not appear that the in vitro procedures misrepresented the UIP content of these supplements because a casein standard evaluated within the same in vitro procedure had a UIP content of 19.0%, which was consistent with previous estimates (3).

Ingredient and chemical composition of the experimental diets is presented in Table 2. Diets were isonitrogenous (18.0% CP) and were similar in ADF and NDF content, averaging 21.5 and 29.0% across treatments.

Adding supplemental fat to the DP and UP diets increased ether extract content of the total diet from 3.2 to 5.9%. This increased ration NE_L from 1.65 Mcal/kg for the DP and UP diets to 1.75 Mcal/kg for the DP + F and UP + F diets. Estimated dietary UIP levels were 33.0 and 36.2% of the CP for the DP and UP diets. These values were closer than expected because of the narrower than expected range in UIP content between the solvent and expeller soybean meals.

Milk yield, composition, and BW means are presented in Table 3. Persistency of milk production as indicated by a fat × time interaction ($P < .01$) was improved by the addition of supplemental fat; milk production was increased 1.2 kg/d. The fat × time interaction for milk yield is presented graphically in Figure 1. The milk production response to supplemental fat was not apparent until 5 wk after supplementation. This is consistent with other reports (10, 14, 22). Reasons for the delayed response to supplemental fat are unclear but may be due to an early lactation intake depression (15), which could not be evaluated in the present study because of group feeding procedures.

TABLE 2. Ingredient and chemical composition of experimental diets.

Item	Covariate period	Treatment[1]			
		DP	UP	DP + F	UP + F
	(% of DM)				
Ingredient					
Alfalfa silage	. . .	50.0	50.5	48.5	49.0
Oatlage	52.0	. . .	. . .	. . .	. . .
High moisture ear corn	. . .	39.5	39.0	37.5	36.5
Shelled corn	35.0	. . .	. . .	. . .	. . .
Solvent soybean meal	11.3	8.8	. . .	9.6	. . .
Expeller soybean meal	. . .	. . .	9.1	. . .	9.8
Fat[2]	. . .	. . .	. . .	2.8	2.8
Vitamin-mineral premix	.85	1.45	1.45	1.44	1.43
Calcium carbonate	.63	. . .	. . .	. . .	. . .
Trace-mineralized salt	.27	.21	.21	.21	.21
Chemical composition, analyzed					
CP	16.2	18.1	18.1	18.0	18.0
ADF	22.5	21.7	21.8	21.1	21.3
NDF	35.2	29.0	29.5	28.2	28.8
Ca	.75	.90	.89	.88	.87
P	.51	.54	.55	.53	.54
Mg	.26	.30	.31	.30	.30
K	2.25	2.21	2.21	2.16	2.17
ADIN	1.16	1.17	1.14	1.16	1.14
Ether extract	3.5	3.1	3.3	5.7	6.0
NE_L,[3] Mcal/kg	1.54	1.64	1.65	1.75	1.76
Estimated UIP,[4] %	37.2	32.9	36.1	33.0	36.4

[1]DP = Degradable protein, UP = undegradable protein, and F = supplemental fat.

[2]Sodium alginate-treated tallow.

[3]Calculated using NRC 1989 (12) NE_L values.

[4]Undegraded intake protein expressed as a percentage of CP.

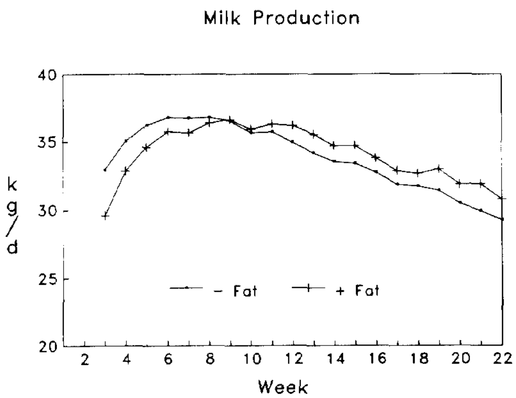

Figure 1. Main effects of feeding supplemental fat from wk 3 through 22 postpartum on lactation persistency (unadjusted means).

Addition of UIP had no effect on milk yield. This is inconsistent with other investigations of UIP supplementation in alfalfa silage-based diets (2, 4). There are several possible reasons for this observed lack of response to UIP. Because UIP content of solvent soybean meal was higher than expected, UIP requirements may have been met by the DP diet. Second, because UIP content of expeller soybean meal was lower than expected coupled with higher than expected UIP content of solvent soybean meal, differences in UIP content between DP and UP diets may not have been sufficient to elicit a response. This underscores the practical difficulty of implementing the UIP and degraded intake protein (DIP) system of ration formulation (12). Third, microbial protein synthesis in these diets may have been enhanced by a rapid rate of degradation of the carbohydrate in high moisture corn (13) and high DIP content of alfalfa silage, thereby reducing the need for additional UIP. Finally, our treatment period did not begin until d 22, and we may have missed the period of lactation during which the greatest response to UIP would be expected.

There was no significant interaction between fat and UIP on milk production or persistency of lactation, which is in contrast with Ferguson et al. (7). Chalupa and Ferguson (5) suggested that for each megacalorie of NE_L from fat above 3% in the diet an additional 72 g of UIP should be fed. However, our results suggest that, although fat and protein interactions may be important (5, 7), practical formulation of diets for UIP without accurate estimates of UIP for each feedstuff is difficult.

Milk fat percentage was not significantly affected by treatment but was slightly higher

TABLE 3. Supplemental fat and undegradable intake protein effects on milk production, composition, component yield, and BW.

	Treatment[1]					Effects (P)[3]			
Measure	DP	UP	DP + F	UP + F	SEM[2]	UP	F	UP × F	Other[4]
Milk yield, kg/d	31.8	31.6	33.1	32.7	.8	. . .	.13	. . .	F × T**
Milk fat, %	3.67	3.63	3.60	3.82	.09	. . .	. . .	. . .	. . .
Milk protein, %	3.14	3.03	3.04	3.00	.04	.07	.03	. . .	F × T**
Milk fat yield, kg/d	1.14	1.15	1.18	1.21	.09	. . .	. . .	. . .	P × T*
Milk protein yield, kg/d	1.00	.96	1.00	.96	.06	. . .	. . .	. . .	P × T†
4% FCM, kg/d	29.9	29.9	30.9	31.2	.9	. . .	.14	. . .	P × T**
BW, kg	611.1	609.7	614.9	622.5	4.6	. . .	.06	. . .	F × T**P × T**
DMI,[5] kg/d	22.7	22.5	22.7	22.7	. . .	. . .	. . .	. . .	. . .

[1]Values listed are least squares means; DP = degradable protein, UP = undegradable protein, and F = supplemental fat.

[2]Pooled standard error.

[3]Only $P < .15$ shown.

[4]Other interactions; T = time, P = parity, UP = undegradable protein.

[5]DMI per cow per day calculated from group intakes.

†$P < .10$.

*$P < .05$.

**$P < .01$.

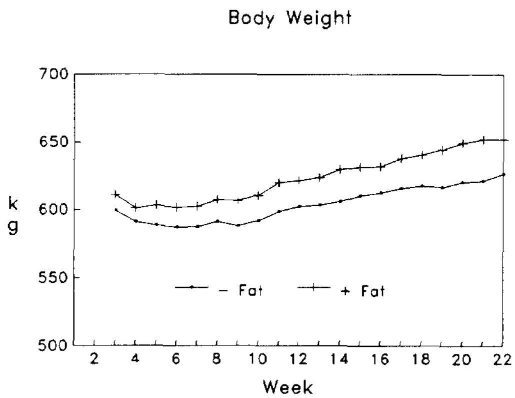

Figure 2. Main effects of feeding supplemental fat from wk 3 through 22 postpartum on BW (unadjusted means).

for the UP + F treatment. Milk protein percentage was reduced .07 percentage units ($P < .03$) by feeding supplemental fat. Milk protein depression resulting from supplemental feeding is well documented (6), but mechanisms are unclear. Milk protein depression due to supplemental fat also varied with time ($P < .01$) and did not occur until wk 8 of lactation, similar to milk response. Depression of milk protein content due to supplemental fat appeared to be correlated negatively with milk response, which may indicate a dilution effect and not a depression in protein synthesis; protein yield was not affected by fat supplementation ($P > .10$). Addition of UIP to the diet did not increase milk protein percentage.

Yield of 4% FCM responded to fat and UIP in a fashion similar to milk yield. The addition of UIP or fat did not affect yield of milk fat or protein, and there were no UIP × fat interactions on component yield. Body weight ($P < .06$) and BW gain ($P < .10$), evaluated by fat × time interaction, were higher for cows fed supplemental fat. Although initial weight loss was not affected by supplemental fat, weight gain during wk 8 through 22 was more rapid on the DP + F and UP + F treatments (Figure 2). Addition of UIP to the diet did not affect weight or weight gain.

Milk fatty acid composition is presented in Table 4. Supplemental fat reduced the proportion of C_{10} ($P < .01$), C_{12} ($P < .03$), and C_6 through C_{14} ($P < .08$) fatty acids. Milk C_{16} to $C_{18:3}$ fatty acids tended to be higher ($P < .11$) for fat-supplemented diets, which is in agreement with other studies (11, 20). Addition of UIP to the diet had no effect on milk fatty acid composition.

TABLE 4. Effect of supplemental fat and undergradable intake protein on milk fatty acid composition.

Fatty acid[1]	Treatment[2]				SEM[3]	Effect (P)[4]		
	DP	UP	DP + F	UP + F		UP	F	UP × F
	(wt %)							
$C_{6:0}$	2.0	2.1	2.6	1.4	.4	. . .	. . .	.13
$C_{8:0}$	1.7	1.8	1.7	1.3	.2	. . .	. . .	. . .
$C_{10:0}$	5.1	5.2	4.1	3.4	.5	. . .	.01	. . .
$C_{12:0}$	5.1	5.3	4.3	3.9	.5	. . .	.03	. . .
$C_{14:0}$	15.0	14.5	14.8	12.6	1.2	. . .	. . .	. . .
$C_{16:0}$	32.0	31.0	29.0	30.5	1.6	. . .	. . .	. . .
$C_{16:1}$	3.2	2.8	2.7	2.9	.2	. . .	. . .	. . .
$C_{18:0}$	8.9	9.7	11.5	11.4	.6	. . .	.01	. . .
$C_{18:1}$	22.3	23.5	24.7	27.5	1.6	. . .	.05	. . .
$C_{18:2}$	2.9	2.5	2.7	3.2	.2	. . .	. . .	.08
$C_{18:3}$	1.8	1.6	1.8	1.7	.4	. . .	. . .	. . .
Total								
C_6–C_{14}	28.9	28.9	27.5	22.6	2.2	. . .	.08	. . .
C_{16}–$C_{18:3}$	71.1	71.1	72.5	77.4	2.2	. . .	.11	. . .

[1]Carbon length:number of double bonds.

[2]DP = Degradable protein, UP = undegradable protein, F = supplemental fat.

[3]Pooled standard error.

[5]Only $P < .15$ is indicated.

CONCLUSIONS

In the present study, we attempted to formulate practical diets using NRC guidelines (12). Increasing dietary UIP concentration did not affect performance of early lactation cows fed alfalfa silage-based diets containing 18% CP. There were no interactions between UIP and supplemental fat on animal performance. Response to supplemental fat was similar to that observed in other studies (10, 19, 22). Lack of production responses to increasing dietary UIP concentration was somewhat unclear but likely was related to higher CP content of the DP diet, narrow range in UIP content of the DP and UP diets, and initiation of treatments during wk 4 of lactation. Normal variation in UIP content in feedstuffs appears to be more of a problem in ration formulation than problems associated with protein status as it relates to supplemental fat. Laboratory methods to measure UIP content of feedstuffs expediently and accurately need to be developed before diets can be formulated for UIP with confidence and before UIP interactions with other nutrients can be elucidated.

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