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Energy Balance and Lactation Response in Holstein Cows Supplemented with Cottonseed with or Without Calcium Soap[1,2]

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ABSTRACT

Holstein cows (n = 58, 21 primiparous), fed corn and wilted grass silages (63:37, DM basis) for free choice consumption, were assigned to control concentrate or supplemented concentrate during wk 1 to 16 postpartum with linted whole cottonseed (15% of projected DMI) alone or with Megalac® (.54 kg/d). Our objective was to examine the effects of fatty acids on energy and N balances, total tract digestibility, and milk fatty acids in wk 7 and 16 and to assess total lactation responses. During balance measurements, fatty acids constituted 4.1, 6.8, and 8.6% of DM in control, oilseed, and oilseed plus protected fatty acid diets. Fat additions reduced fiber digestion (attributed to oilseed) and, to some degree, DMI and milk yield, but enhanced fat test without affecting protein percentage. Supplementary fat increased the proportion of $C_{18:0}$ in milk at the expense of short-chain fatty acids. Supplemental oilseed with or without protected fatty acids reduced total heat production by 6% and reduced heat in excess of maintenance by 8%. Best estimates of NE_L in linted whole cottonseed and of fat in Megalac® were 1.81 and 5.69 Mcal/kg of DM. In total lactation, primiparous cows yielded more milk and FCM when fed oilseed plus Megalac® and less of each when fed oilseed alone than controls. In pluriparous cows, milk yield was reduced by 2.7 kg/d relative to other treatments when oilseed plus Megalac® was fed; FCM yield increased about 2 kg/d only when oilseed was supplemented alone. Overall, data suggest that basal ration fat and oilseed supplementation were too high or that supplementation should have been delayed until feed intake was higher.

(**Key words**: calcium soap, cottonseed, tissue balance)

Abbreviation key: ME = metabolizable energy, PF = protected fat (Megalac®), WCS = whole cottonseed.

INTRODUCTION

As daily milk yield at peak lactation increases in modern dairy cows, whether by genetic advance or hormone intervention, a more energy-dense ration must be formulated to support the resulting elevated energy requirement. Palmquist (26) and Chalupa et al. (6) suggested that this may be accomplished by providing about 8% fat in dietary DM so that 15 to 20% of ration metabolizable energy (ME) comes from fat as long-chain fatty acids. There is evidence (1, 21, 35) that ME from long-chain fatty acids is used more efficiently for yield purposes than ME from short-chain fatty acids.

High yielding cows at peak daily milk yield usually are fed high proportions of concentrate

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[2]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the University of New Hampshire and does not imply its approval to the exclusion of other products that also may be suitable.

with forage free choice or TMR. Minimum ADF often is cited as 17 to 22% of dietary DM (5, 25, 26, 32) and minimum NDF as 25 to 28% (25). Substitution of fat for some of the concentrate, if it did not reduce total DMI or fiber digestion rate, under ad libitum consumption would enhance energy intake and help to prevent milk fat depression. Feeding whole cottonseed (WCS) provides a rather even (2), rumination-released mixture of linoleic, palmitic, and oleic acids that is about 70% unsaturated fat (22). This oilseed, in linted form, has the advantage over normal mixed concentrates of containing about 34% ADF, 44% NDF, and 2.23 Mcal of NE_L/kg of DM (25) in addition to 24% CP and 20% ether extract. Ruminally inert Ca soaps of palm oil contain predominately palmitate, oleate, and linoleate and are about 50% unsaturated fat (22). At approximately 80% fatty acids, their NE_L is about 4.46 Mcal/kg of DM; Andrew et al. (1) reported NE_L for Ca salts of fatty acids (Megalac®) of 6.52 Mcal/kg of DM. In their excellent review, Palmquist and Jenkins (27) pointed out that fatty acids, especially polyunsaturates, inhibit growth of ruminal microbes. This can reduce microbial digestion of fiber as fatty acid content in the ration increases, unless these acids are made insoluble by saponification, for example, with Ca. Chalupa et al. (5) and Palmquist (26) suggested that supplementation to raise dietary fat above 5 to 6% be in the form of ruminally inert, long-chain, more saturated fatty acids or that the ration contain about equal parts of fat from natural ingredients, supplemental oilseeds, and ruminally protected fat (5).

Coppock et al. (7) hypothesized that feeding fats to ruminants would decrease their body heat production and thereby reduce the effects of heat stress. They further suggested that, if such were true, fats would be undervalued in NE_L. Positive response in DMI and milk yield to prilled fat supplementation was more pronounced for cows in warm than in cool seasons in one study (30). However, van der Honing (34) reported that animal tallow or soybean oil fed at 5% of concentrate in a ration with about 33% grass hay resulted in lower methane losses but no improvement in conversion of ME to milk; he noted an increase in digestibility of lipid and improved body energy balance with both fats, but depressed fat percentage in milk, when soybean oil was fed.

Our objectives were to examine the effects of substituting WCS (15% of predicted total DMI) with or without protected fat (PF) (.45 kg/d of Megalac®) for concentrate during d 1 to 112 of lactation on energy and N balances and nutrient digestibilities measured wk 7 and 16 postpartum in Holstein cows and on ad libitum feed intake, BW changes, milk yield, and milk composition through complete lactations.

MATERIALS AND METHODS

Fifty-eight Holstein cows (21 primiparous) were assigned randomly at calving to one of three treatment groups. All cows were offered for ad libitum intake (13% orts, SD = .02) a forage mixture consisting of (DM basis) 63% corn silage, with .25% (wet basis) urea added (except 1987) at ensiling, plus 37% wilted grass silage. Cows were fed twice daily at 0600 and 1500 h and were housed in a conventional stanchion barn with individual feed mangers and waterers. All cows were exercised daily for 1 h and milked twice daily at 0430 and 1530 h; milk weights were recorded daily. Two grain mixtures (Table 1), which contained 14 and 38% CP in DM and consisted principally of corn meal and soybean meal, respectively (Table 2), were fed to meet NRC (25) requirements for CP and NE_L of individual cows using our University of New Hampshire Ration Balancer (16); amounts of grain fed were recomputed and adjusted weekly. Until the first milk fat test postpartum, 20% CP grain (blend of 14 and 38% CP grains) was fed at 1 kg/2.5 kg of the previous day's milk. Treatments applied during the first 112 d of lactation were 1) control, 2) WCS (linted) mixed individually with forage and fed at 15% of predicted total daily DMI, and 3) WCS plus .54 kg/d of PF (Megalac®, ruminally inert Ca soaps of palm oil, Church and Dwight Co., Inc., Princeton, NJ) mixed with 10% each of cane molasses and monoammonium phosphate to improve palatability and Ca:P ratio (3:1), respectively. The WCS were substituted for equal weight of 14 and 38% CP grain mixtures, and PF was substituted for equal weight of 14% CP grain. The PF was mixed with silages at feeding time. Each cow received 57 g of sodium bicarbonate twice daily on the silage mixture from calving until after peak of lactation.

Individual feeds and orts weights were recorded daily. Biweekly a.m.-p.m. milk composites were analyzed for fat (Babcock) and SNF (Golding bead test), and alternating composites were analyzed for protein (Orange G dye binding). Forages were sampled weekly for DM (Koster Crop Tester, North Randall, OH) to ensure 63:37 DM ratio of corn and haycrop silages. Feeds were sampled biweekly and composited by 28-d periods for analysis according to standard AOAC procedures. Orts were composited monthly, by treatment, and analyzed as for feeds. Solubility of N in phosphate and bicarbonate buffer was measured in feeds, and haycrop silage samples were examined for ADF N. The PF supplement and a composite of orts from treatment 3 were analyzed for fat by acid hydrolysis (O'Neal Scientific Services, St. Louis, MO). Each cow was weighed biweekly at 1400 h. Health and reproductive traits were monitored.

During wk 7 and 16 postpartum, all cows, except one that was too large (998 kg), were moved to the laboratory to measure ration digestibility and complete energy and N balances using standard large animal calorimetry procedures as described previously (18). One first lactation cow was culled before wk 16 because of foot infection. Composite milk (6-d) was frozen and later analyzed for milk fatty acids (11).

Lactation data first were summarized by 28-d periods postpartum and then combined into complete lactations before least squares ANOVA using SAS (28); the experiment was a completely randomized design with main effects, treatment and lactation (1 vs. 2 or greater), and their interaction in the model. Analysis of calorimetric (balance) data considered weeks (wk 7 and 16) as a split plot in time, and effects examined were treatment, lactation, week, treatment by lactation, week by lactation, treatment by week, and cow lactation within treatment by lactation. Residual was error term for effects involving week, and cow lactation within treatment by lactation was used as error term for other effects. Milk fatty acids were examined as a split plot in time; effects in the model were treatment, cow within treatment (error A), weeks, weeks by treatment, and remainder (error B). No treatment by week interaction was significant. Data for milk fatty acids were missing for some cow weeks because of technical difficulties. Least squares means are presented, necessitated by unequal number of observations in subclasses. Significance was determined at P = .05 throughout unless otherwise noted.

TABLE 1. Composition of concentrate mixtures.

	Concentrates	
	Energy grain	Protein grain
	(% as fed)	
Ingredient		
Corn meal	61.2	0
Soybean meal	0	48.7
Distillers grains with solubles	15.0	20.0
Wheat middlings	13.2	16.8
Wheat feed flour	0	5.0
Cane molasses	6.0	6.0
Calcite flour	.9	1.4
Dicalcium phosphate	2.25	.8
Dynamate® [1]	.30	.25
Salt	1.0	1.0
Vitamin-trace mineral premix[2]	.1	.05
	(DM basis)	
Theoretical analysis		
CP, %	13.2	36.0
CP solubility,[3] % CP	18	18
Fat, %	3.99	2.92
NE_L, Mcal/kg	1.81	1.83
Ca, %	1.11	1.10
P, %	.80	.79

[1]Provides 22% S, 18% K, and 11% Mg (International Minerals and Chemical Corp., Libertyville, IL).

[2]Provides (ppm of mixed feed) 69 Zn, 50 Fe, 12 Mn, 1.6 I, .35 Co, and .12 Se; 6600 IU/kg of mixed feed each of vitamins A and D.

[3]Soluble in phosphate and bicarbonate buffer.

RESULTS AND DISCUSSION

Three cows in the control group were culled from experiment, one first lactation cow for persistent foot infection, another for poor body conformation (nerve damage) and mastitis, and an older cow for teat injury with accompanying acute mastitis. One first lactation cow on the WCS treatment was culled for poor legs, and an older cow suffered displaced abomasum briefly (no data lost). No serious health problems were encountered in cows on the WCS plus PF treatment.

Composition of the two concentrates is described in Table 1. Both were low in CP solubility and similar in Ca and P. Forages (Table 2), in the DM proportions fed, together averaged 11% CP and, as expected, were high in solubility (mean, 60%). Using equations of the Northeast DHIA Forage Testing Laboratory, corn and haycrop silages contained NE_L of 1.63 and 1.17 Mcal/kg of DM, respectively. Measured ether extract contents of energy and protein concentrates were 24 and 41% higher, respectively, than their NRC (25) estimates (Table 1); forage blend averaged 3.34% ether extract. Composition of WCS corresponded closely to NRC (25), but our WCS was higher in ether extract and lower in ADF than that used by Hein et al. (13).

Composition of orts (Table 2), by its content of CP, NDF, and fat, indicated that orts were composed primarily of forage mixture and also some high fat additives in feed refusals of treated cows. Fat composition of orts from WCS plus PF was not different (5.75 vs. 5.73%) for acid hydrolysis or ether extract methods of analysis, suggesting that little of the fat was PF. Initial acceptance of forage containing WCS with or without PF, noted also by Grummer et al. (12), was somewhat tentative, but we determined, by careful separation of orts components of several of the most affected animals, that over 80% of WCS offered were consumed. Orts composition from WCS and WCS plus PF suggests that about 92% of the WCS and 90% of the PF offered were consumed.

Ration characteristics, BW, intake, and milk traits are shown in Table 3. Intake of feed DM,

TABLE 2. Composition of feeds (forages by harvest year) and orts by treatment.

Feeds and orts	n	DM		CP		ADF		NDF		Fat		Soluble[1]	
		— (%) —		(% DM)								— (% N) —	
		$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Corn silage with urea													
1986 to 1987	2	33.6	.8	10.9	.2	27.0	2.0	45.7	1.0	3.02	.02	63	2
1987 to 1988[2]	14	28.2	.8	7.7	.2	26.2	.6	45.8	.8	3.05	.08	59	2
1988 to 1989	12	31.9	.6	9.8	.2	23.7	1.0	43.2	.8	3.00	.06	67	2
	$\bar{X}$	30.2	...	8.8	...	25.2	...	44.7	...	3.03	...	63	...
Haycrop silage[3]													
1987 to 1988	13	34.3	1.2	14.2	.5	38.5	.6	57.1	1.5	3.68	.15	55	2
1988 to 1989	12	34.2	.9	16.0	.5	36.0	1.0	52.4	1.9	4.16	.24	59	2
1989 to 1990	4	35.7	2.6	13.6	1.3	42.7	.8	64.2	2.9	3.64	.31	51	5
	$\bar{X}$	34.5	...	14.9	...	38.0	...	56.1	...	3.87	...	56	...
Energy grain	22	89.7	.3	14.1	.2	6.47	.16	18.0	.3	4.93	.10	20.1	.7
Protein grain	22	90.8	.3	38.0	.2	9.13	.10	21.2	.2	4.13	.06	20.3	.5
WCS	5	93.8	.6	23.7	.4	33.6	1.2	44.4	1.8	20.3	.1	49	1
PF[4]	4	96.5	.6	6.97	.41	...	...	...	...	69.7[5]	.7	96	2
Orts[6]													
Control	27	35.3	.9	11.7	.4	27.3	.9	44.9	1.3	3.13	.08	...	...
WCS	26	38.7	1.7	13.5	.5	27.4	.8	44.3	1.0	4.85	.43	...	...
WCS + PF	26	40.4	1.2	14.3	.5	24.1	1.0	39.6	1.6	5.75	.50	...	...

[1]Soluble in phosphate and bicarbonate buffer.

[2]No urea added to corn silage this harvest year.

[3]Mean ADF N was 9.0 ± .6% N; 5 of 29 samples exceeded 9.7%.

[4]PF = Protected fat (palm oil-Ca containing 10% molasses for palatability and 10% monoammonium phosphate to balance Ca:P).

[5]Acid hydrolysis method (O'Neal Scientific Services, St. Louis, MO).

[6]WCS = Whole cottonseed offered at rate of 15% of weekly estimated DMI and substituted for equal weights of energy and protein grains (approximate isonitrogenous basis) during wk 1 to 16 postpartum; WCS + PF = same as WCS with PF as .45 kg/d Ca soap of palm oil substituted for equal weight of energy grain during wk 1 to 16 postpartum.

in general, was unexpectedly low during these laboratory measurements; ration DMI was not significantly different among treatments or between weeks, as noted also by Hoffman et al. (14), but it was lower for parity 1 than for older cows. Proportion of concentrate in dietary DM was somewhat lower for WCS alone than for controls and was significantly higher for WCS plus PF. Part of this discrepancy can be explained by differences in milk yield and fat test, two important determinants of NE_L requirements used to balance rations weekly, and part by voluntary intake of forages. Nevertheless, daily ration NDF intake averaged 1.0 to 1.1% BW, which was close to that suggested by Mertens (23), and NDF averaged above 30% of DM. Except when PF was fed, forage NDF in ration DM exceeded the minimum, 21%, sometimes used as a guide to avoid milk fat depression. Ether extract content of the control ration (4.07%) was higher than expected because of the factors discussed previously. Supplementation with WCS increased dietary fat by 2.7 percentage units, and inclusion of PF increased this increment by an additional 1.9 units. Thus, the WCS diet exceeded the 5 to 6% unprotected fat recommended by Chalupa et al. (5) and Palmquist (26); however, numerous reports [e.g. (17, 31)] showed satisfactory responses as high as 15% inclusion of WCS in ration DM. Only with WCS plus PF did total dietary fat intake exceed milk fat secretion (1.48 vs. 1.26 kg/d) and exceed by 17% the guidelines suggested by Chalupa et al. (5). Dietary fat averaged a little higher for first lactation cows than for older cows. Ration CP was lower for fat-supplemented than for control diets because WCS was several percentage units lower in CP than the equal weights of 14 and 38% CP grains it replaced, but CP was close, as expected, to recommended amounts (25). Approximate percentages of solubility of CP in rations were 32, 35, and 33%; insoluble protein intake was 2.2, 1.8, and 1.9 kg/d for control, WCS, and WCS plus PF treatments, respectively. The fat-supplemented diet with WCS alone was higher in CP solubility than the 30 to 34% range usually recommended for early lactation cows. Chalupa et al. (5) recommended that, as dietary fat increases from 3 to 8% of DM, undegradable protein should increase from 37 to 49% of intake CP, but Hoffman et al. (14)

TABLE 3. Ration characteristics, BW, intake, milk yield, and milk composition of primiparous and pluriparous Holstein cows receiving supplemental whole cottonseed (WCS) without or with protected fat (PF) during balance trials conducted wk 7 and 16 postpartum.

	Treatment (T)				Lactation (L)		Postpartum		Effect, $P <$		
Trait	Control	WCS	WCS + PF	SE	1	>1	wk 7	wk 16	T	L	Week
n	33	34	40	. . .	37	70	54	53	. . .	. . .	. . .
Ration fat, % DM	4.07	6.76	8.63	.07	6.62	6.35	6.49	6.49	.01	.05	NS[1]
Ration NDF, % DM	32.2	36.3	33.5	.6	34.3	33.8	31.8	36.3	.01	NS	.01
Forage NDF, % DM	23.4	23.8	19.7	1.1	22.8	21.8	19.2	25.4	.05	NS	.01
Ration CP, % DM	18.1	16.8	17.2	.2	17.2	17.5	18.2	16.6	.05	NS	.01
BW, kg	544	530	535	2	497	576	533	539	NS	.01	.05
DMI											
kg/d	17.4	16.6	16.8	.3	15.0	18.8	16.9	16.9	NS	.01	NS
% BW	3.21	3.11	3.13	.05	3.02	3.29	3.16	3.14	NS	.05	NS
g/kg of $BW^{.75}$	154.6	149.3	150.5	2.5	142.4	160.6	151.8	151.2	NS	.01	NS
Concentrate DM, % DM offered	54.3	51.5	59.7	1.5	52.9	57.4	62.2	48.0	.01	NS	.01
Milk yield, kg/d	35.2	29.6	32.5	.5	28.7	36.2	35.1	29.8	.05	.01	[a]
Fat, %	3.32	4.14	3.89	.10	3.82	3.74	3.74	3.83	.01	NS	NS
SNF, %	8.39	8.64	8.39	.04	8.60	8.35	8.53	8.42	.05	.01	.01
Protein, %	2.86	2.88	2.82	.01	2.88	2.83	2.84	2.86	.05	.05	NS
4% FCM, kg/d	31.6	30.3	31.9	.4	27.9	34.8	33.7	29.1	NS	.05	.05

[a]Significant L × week interaction ($P < .01$); wk 7 and 16: lactation 1, 30.2, 27.2 kg/d and lactation >1, 40.0 and 32.5 kg/d of milk.

[1]$P > .05$.

found no interaction of diet fat content and protein undegradability.

During the balance trials (wk 7 and 16 postpartum; Table 3), milk yield was lower for WCS than for controls, confirming the work of Lubis et al. (21), but their fat test (4.14%) was dramatically higher than ours (3.32%). Part of this decline in milk was compensated for by the inclusion of PF, and 4% FCM yields were not significantly different among treatments. These results conflict with findings of Umphrey et al. (33), who used cows in later lactation and perhaps under heat stress, but they agree with results of Andrews et al. (1) in regard to PF effect. As expected, daily milk yield was higher for older than for first lactation cows, and, for older cows, it was significantly higher in wk 7 than in wk 16. Milk SNF content was higher for cows fed WCS alone than for controls or those supplemented also with PF. Combining PF with WCS lowered milk protein by .06 percentage units, as noted also by Casper and Schingoethe (4) and Umphrey et al. (33), and this was reflected in lower SNF percentage. Casper and Schingoethe (4) proposed that supplemental fat inhibits release of somatotropin, thereby reducing mammary uptake of AA. Also, there is some evidence (3) that ruminally protected AA, provided along with added fat, prevent or reduce the adverse effect of supplemental fat on milk protein percentage.

TABLE 4. Partitions of energy and N, water intake, and apparent daily balances of body protein and fat in primiparous and pluriparous Holstein cows during wk 7 and 16 postpartum when fed supplemental whole cottonseed (WCS) without or with protected fat (PF).

	Treatment (T)				Lactation (L)		Postpartum		Effect, $P <$		
Trait	Control	WCS	WCS + PF	SE	1	>1	wk 7	wk 16	T	L	Week
Gross energy (GE) intake, Mcal/d	75.7	74.2	76.4	1.3	67.1	83.7	75.2	75.7	NS[1]	.01	NS
Feces, % of GE	32.6	36.2	35.1	.4	34.6	34.6	33.6	35.6	.01	NS	.01
Urine, % of GE	2.8	2.4	2.4	.1	2.5	2.6	2.5	2.6	NS	NS	NS
Milk, % of GE	29.9	28.8	29.4	.6	29.4	29.3	31.8	26.9	NS	NS	.01
Methane, % of GE	4.1	3.6	3.3	.1	3.6	3.7	3.2	4.1	.01	NS	a
Heat, % of GE	34.8	33.0	32.8	.4	35.3	31.8	33.9	33.1	.05	.01	NS
Balance											
% of GE	–4.2	–3.9	–2.9	1.0	–5.4	–1.9	–5.0	–2.4	NS	.05	.05
Mcal/d	–2.84	–2.33	–1.88	.73	–3.28	–1.43	–3.26	–1.44	NS	NS	.05
N Intake (NI), g/d	506	448	463	9	416	528	493	451	NS	.01	.01
Feces, % of NI	30.2	31.5	30.6	.5	30.8	30.8	29.2	32.4	NS	.01	.01
Urine, % of NI	27.6	26.5	25.6	.7	25.9	27.2	25.9	27.3	NS	NS	NS
Milk, % of NI	31.7	30.4	31.6	.5	31.2	31.2	32.0	30.5	NS	NS	.05
Balance											
% of NI	10.5	11.6	12.1	.8	12.0	10.8	13.0	9.8	NS	NS	b
g/d	54.0	53.7	56.4	4.1	51.4	57.9	64.3	45.1	NS	NS	c
Water intake, kg/d	67.6	57.5	62.9	1.4	55.9	69.4	67.2	58.1	NS	.01	.01
Apparent body balance, g/d											
Protein	337	335	352	26	322	362	402	282	NS	NS	d
Fat	–502	–447	–406	71	–539	–365	–583	–321	NS	NS	.01

[a]Significant T × week interaction ($P < .01$). Week 7 and 16: control 3.4, 4.9; WCS 3.2, 3.9; and WCS plus PF 2.9, 3.6 kcal of CH_4/100 kcal of GE intake.

[b]Significant T × week interaction ($P < .05$). Week 7 and 16: control 11.8, 9.1; WCS 14.7, 8.6; and WCS plus PF 12.4, 11.8 g of tissue N balance/100 g of NI.

[c]Significant T × week interaction ($P < .05$). Week 7 and 16: control 62.9, 45.1; WCS 70.6, 36.7; and WCS plus PF 59.3, 53.4 g/d of N balance.

[d]Significant T × week interaction ($P < .05$). Week 7 and 16: control 393, 282; WCS 441, 230; and WCS plus PF 371, 334 g/d of body protein.

[1]$P > .05$.

Using midlactation cows, Ferguson et al. (10) fed prilled fatty acids at 0, 3, 6, and 9% of DM and found decreased DMI, increased percentage of milk fat, but no effect on percentage of protein in milk. Milk and FCM increased with 3% but decreased with 6 and 9% fat additions.

Energy and N partitions and related data are in Table 4. Daily intake of gross energy was not different among treatments or between wk 7 and 16 postpartum but was higher for cows in second and subsequent lactations than for first lactation cows, as expected. Fecal energy loss was greater in fat-supplemented cows and during wk 16 postpartum and is discussed later. Urine energy loss was not affected by treatments, age, or stage of lactation. Milk energy did not differ significantly among treatments because of the complementary effect of fat test and milk yield (Table 3). As expected, milk energy was lower in wk 16 than in wk 7. As noted also by van der Honing (34) and Andrew et al. (1), methane energy and heat losses declined with fat additions, compensating for 64% of the higher fecal energy loss on WCS and all of the fecal energy elevation on WCS plus PF treatments. Effect on methane energy confirms the reduction of fiber digestion caused by fat additions. Supplementation of the diet with WCS with or without PF reduced the heat produced in excess of maintenance (.080 Mcal/kg of $BW^{.75}$) by 6.7 and 9.7% and total heat loss by 4.9 and 7.0%, respectively. This may have some implications for formulating rations for cows during periods of heat stress as hypothesized by Coppock et al. (7), especially for first lactation cows, as indicated by their higher heat loss (as percentage of gross energy) and more negative energy balance. Added increments of fat in the diet tended to result in less negative body energy and fat balances, but these treatment effects were not significant. Energy and N balances inherently are associated with large variations because they are computed by difference (remainder). Thus, only very large treatment effects on these traits, and ones computed from them, generally are significant.

Nitrogen partition was not affected by treatments and was not different for lactations 1 versus 2 or greater. Effects of stage of lactation are a reflection of declining milk yield and proportion of concentrate in the diet. Cows supplemented with WCS alone had the highest

TABLE 5. Apparent digestibility and energy traits of rations supplemented with whole cottonseed (WCS) without or with protected fat (PF) and fed to first lactation and older Holstein cows during wk 7 and 16 postpartum.

Trait[1]	Treatment (T)				Lactation (L)		Postpartum		Effect, $P <$		
	Control	WCS	WCS + PF	SE	1	>1	wk 7	wk 16	T	L	Week
Apparent digestibility, %											
DE	67.4	63.9	64.9	.4	65.4	65.4	66.4	64.4	.01	NS[2]	.01
DM	68.7	65.0	65.4	.4	66.2	66.5	67.2	65.5	.01	NS	.01
NDF	47.1	41.3	40.5	.8	43.0	42.9	41.5	44.4	.01	NS	.01
ADF	43.2	36.3	35.4	.9	38.3	38.3	35.9	40.6	.01	NS	.01
Ether extract	81.2	86.4	88.8	.4	85.6	85.4	86.4	84.5	.01	NS	.01
CP	69.8	68.5	69.4	.5	69.2	69.2	70.8	67.6	NS	NS	.01
DE, Mcal/kg of DM	2.93	2.87	2.96	.02	2.93	2.91	2.96	2.88	NS	NS	.01
ME, kcal/kg of DM	2.61	2.57	2.67	.02	2.63	2.61	2.68	2.56	NS	NS	.01
% GE	60.0	57.3	58.8	.4	58.7	58.7	60.1	57.2	.05	NS	.01
Daily ME intake, kcal/ kg of $BW^{.75}$	403	384	402	7	375	418	406	387	NS	.01	.05
Daily NE_L intake, kcal/ kg of $BW^{.75}$	171.7	168.5	179.4	6.2	152.6	193.9	179.8	166.6	NS	.01	NS
NE_L,[3] Mcal/kg of DM	1.63	1.66	1.72	. . .	1.63	1.71	1.71	1.63	. . .	. . .	. . .

[1]DE = Digestible energy, ME = metabolizable energy, GE = gross energy.

[2]$P > .05$.

[3]Calculated from [average daily NE_L intake, kilocalories per kilogram of $BW^{.75}$ plus 80 kcal/kg of $BW^{.75}$ (maintenance)]/DMI, grams per kilogram of $BW^{.75}$.

N balance in wk 7 and the lowest N balance in wk 16. This is attributed to their proportionally lower N intake (421 g/d, 16.0% CP in DM) in wk 16 and their lower intake of insoluble protein, as previously noted, relative to the other treatments. Water intake did not differ among treatments, confirming no differences in urinary N excretion of stressful proportion, and it maintained an average 1.93:1 ratio with milk volume. Water intake was more closely correlated with milk yield and N intake (r = .88) than with DMI (r = .79).

Digestibility, energy density, and intake data are in Table 5. Supplementation with WCS reduced digestibility of ADF (probably cellulose) proportionally more (by 4 percentage units) than NDF, and this was reflected in less pronounced, but significant, reductions in digestibility of energy and DM. Correlation between percentage of fat in the diet and percentage of digestibility of either ADF or NDF was –.05. These findings differ from those of Umphrey et al. (33) but confirm those of Coppock et al. (8) and Jenkins and Palmquist (19). As also noted (8, 33), digestibility of CP was not affected by fat supplementation. Digestibility of ether extract was higher with fat supplements, confirming most previous work, including that of Andrew et al. (1), Coppock et al. (8), and van der Honing et al. (34). Incorporating PF into a diet already containing WCS did not influence diet digestibility and, except for fiber digestibility, slightly improved it. As expected, digestibility of fiber was higher, and

TABLE 6. Computation of NE_L in whole cottonseed (WCS) and protected fat (PF) using observed NE_L and DMI from balance trials (before least squares adjustment of means) and computed NE_L of basal diet ingredients.

Item	NE_L[1]	Control	WCS	WCS + PF
	(Mcal/kg)	(Proportion of DM[8])		
Total grain	1.817, 1.814, 1.814	.515	.329	.352
Energy grain	1.809	(.65)	(.75)	(.76)
Protein grain	1.831	(.35)	(.25)	(.24)
Cottonseed	. . .	0	.168	.175
Megalac®	. . .	0	0	.0243
Corn silage	1.628	.304	.316	.282
Haycrop silage	1.169	.180	.186	.167
Observed NE_L,[2] Mcal/kg of DM		1.507	1.525	1.612
Computed NE_L (basal),[3] Mcal/kg of DM		1.643	1.330	. . .
Observed/computed[4]		.91737	. . .	. . .
Adjusted NE_L (basal), Mcal/kg of DM		1.507	1.220	. . .
Observed – adjusted NE_L,[5] Mcal/kg of DM		. . .	.305	. . .
Computed NE_L (basal),[6] Mcal/kg of DM		. . .	1.635	1.610
Observed/adjusted NE_L		. . .	.93284	. . .
Adjusted NE_L (basal), Mcal/kg of DM		. . .	1.525	1.502
Observed – adjusted NE_L, Mcal/kg of DM		. . .	. . .	.1104

[1]For grains, NRC (25); for forages, New York DHI Forage Testing Laboratory.

[2]Daily NE_L intake/$BW^{.75}$ divided by DMI/$BW^{.75}$ before means were adjusted by least squares analysis.

[3]Sum of products of DM proportion and NE_L of basal ration components.

[4]Fraction of computed NE_L that is observed NE_L, used to adjust computed NE_L of basal diet less supplement.

[5]The NE_L attributable to cottonseed; divide this number by proportion of DM from WCS to obtain its NE_L (1.81 Mcal/kg of DM).

[6]Sum of products of DM proportions and NE_L of basal ration components and supplemental cottonseed.

[7]The NE_L attributable to PF; divide this number by proportion of DM from PF to obtain its NE_L (4.543 Mcal/kg of DM). Divide by 80% of fatty acids to compute NE_L of fatty acids in PF (5.69 Mcal/kg of fatty acid DM).

[8]We assumed that 95% of grain was consumed except for treatment with cottonseed plus PF (88.5%), based on orts ADF (24.1 vs. 27.4%). Percentage of WCS consumed was 95% based on orts fat (4.85 vs. 3.13%). Percentage of PF consumed was 92.5% based on orts fat (5.75 vs. 4.85%). Percentage of corn silage DM in forage DM was 62.8 (control); otherwise it was 62.9%. Parentheses indicate subclass of total grain proportion.

digestibility of other nutrient classes was lower, as lactation progressed and the proportion of forage increased in the ration. Energy density, expressed as digestible energy and ME of the ration, was not affected significantly by treatments but improved 3 to 4% as a result of adding PF to the diet already containing WCS.

Daily NE_L intake per unit $BW^{.75}$ (Table 5) was computed from observed ME minus total heat production (which includes maintenance heat). Dividing this value by DMI, expressed on the same basis, yielded observed NE_L in DM of diet (Table 6). When measuring ad libitum DMI, it is impossible to avoid among-treatment variations in proportions of diet components consumed because of the uncertainty of the percentage of each component in orts. In footnote 8 of Table 6, we present estimates of percentage of each offered feedstuff that was consumed along with the rationale for its computation. Observed NE_L was 91.7% of computed NE_L for the control diet, which is not surprising, given the uncertainty of prediction of NE_L of forages and effects of DMI and other factors. It was assumed that this adjustment factor would apply to the non-supplement portion of the diet containing WCS; a separate factor (93.3%) was computed for the WCS diet and applied to that portion of the WCS plus PF diet that was not PF. Using the computations shown in Table 6, we estimated the NE_L in DM of WCS to be 1.81 Mcal/kg, which is only 81% of that of NRC (25). We also estimated the NE_L in DM of fatty acids in PF to be 5.69 Mcal/kg, which is 97% of NRC [5.84; (25)]. The corresponding estimate by Andrew et al. (1) was 6.52 Mcal/kg, or 1.12 times the NRC recommendation (25).

It is common practice in commercial dairies to formulate diets with 17 to 20% CP for cows in early lactation. Our data suggest that diets with about 17% CP substantially overfed CP, as judged by the high apparent body protein balances (402 g/d, wk 7; 282 g/d, wk 16), which should be closer to zero. Nitrogen balances are determined by differences and are subject to overestimation because of possible loss of (failure to recover) orts or excreta; however, precautions were taken to prevent such losses, including collection of urine into acid-containing receptacles (18). Losses of 10% of feed, 30% of feces, 36% of urine, or some combination of these would have been necessary to account for the 45.1 g/d of N balance, for example, in wk 16 postpartum (Table 4). Although we are not willing to concede losses one-tenth of these amounts, doing so would not change our conclusions. The two grain mixtures provided 60 and 47%, respectively, of the N of diets fed during wk 7 and 16. Overfeeding of CP here, using recommendations of NRC (25), probably resulted from the higher digestibility of CP from grain mixtures and the larger contribution of grain CP to total ration CP than would be the case if

TABLE 7. Least squares mean percentages of fatty acids in milk fat of Holstein cows receiving 15% (DM basis) supplemental whole cottonseed (WCS) without or with protected fat (PF) during balance trials conducted wk 7 and 16 postpartum.

					Treatment			
Milk fatty acid	wk 7		wk 16	SE	Control	WCS	WCS + PF	SE
C_4	3.6		3.4	.1	3.6	3.4	3.4	.1
C_6	1.9		1.9	<.1	2.1	1.8	1.7	<.1
C_8	1.0		.9	<.1	1.2[a]	.9[b]	.8[b]	<.1
C_{10}	2.0	†	2.3	.1	2.6[a]	2.0[b]	1.9[b]	.2
C_{12}	2.4		2.4	.1	3.0[a]	2.1[b]	2.1[b]	.2
C_{14}	7.8	**	8.9	.3	10.0	7.7	7.5	.4
C_{16}	24.2	**	26.3	.5	25.1	24.7	25.9	.6
$C_{18:0}$	16.2		16.8	.6	13.3[b]	18.9[a]	17.1[a]	.7
$C_{18:1}$	36.4	**	32.6	.9	35.2	34.4	34.2	1.1
$C_{18:2}$	4.5		4.5	.3	4.0	4.2	5.3	.4

[a,b]Treatment means with different superscripts differ ($P < .05$).

†$P < .10$.

**$P < .01$.

forages were primarily high protein legumes. Each additional gram of positive body protein balance was associated with a decrease of .6 g of body fat; thus, body protein accretion removes calories from the NE_L that are otherwise available to support milk synthesis. Even with fat-enriched diets, apparent body protein balances substantially were positive (335 and 352 g/d; Table 4), indicating that less CP, with appropriate degradability characteristics, probably could have been fed without sacrificing milk yield and, perhaps, could even enhance it. However, such a strategy might, to some degree, adversely impact BW recovery postpartum (15) to the extent that excess dietary CP spares body tissue loss.

Milk fatty acid profile is presented in Table 7. Data represent about half of the cows studied. Milk fat from controls was somewhat lower in C_4 to C_{16} and $C_{18:2}$ and higher in $C_{18:0}$ and $C_{18:1}$ fatty acids than that for controls reported by DePeters et al. (9). This may be related to the relatively high content of distillers grains with solubles in our concentrates (Table 1). Proportions of C_8 to C_{12} were lower, and C_{18} was higher, in milk of cows receiving supplemental fat, confirming the findings of Smith et al. (31) and Hoffman et al. (14). The enhanced proportion of $C_{18:0}$ in milk fat of cows supplemented with fats in the diet is consistent with ruminal hydrogenation of oleic and linoleic acids from WCS and palm

TABLE 8. Complete lactation means for various traits for primiparous and older Holstein cows fed control diet supplemented during wk 1 to 16 postpartum with whole cottonseed (WCS) alone, at 15% of projected DMI, or with protected fat (PF) at .54 kg/d.

	Lactation (L) 1				L >1				Effect, $P <$	
Trait	Control	WCS	WCS + PF	SE	Control	WCS	WCS + PF	SE	T[1]	L
n	6	6	7	. . .	11	13	12	. . .	. . .	. . .
Age, d	808	780	760	214	1942	1749	1613	156	NS[2]	.01
DIM	317	323	342	15	326	290	311	11	NS	NS
BW, kg	553	540	561	27	641	637	625	20	NS	.01
WCS, kg as fed	0	271	278	14	0	354	356	10	.01	.01
PF, kg as fed	0	0	55	<1	0	0	56	<1	.01	.10
Total grain DM, kg	2664	2116	3292	334	2759	2424	2407	242	a	
Forage DM, kg	2741	2753	2671	222	3397	3151	3289	161	NS	.01
Corn silage, %	62.9	62.8	62.9	. . .	62.9	62.9	62.9	. . .	. . .	. . .
DMI, kg	5405	4868	5963	440	6156	5575	5697	319	NS	NS
Orts DM, % DMI	11.2	12.5	13.2	. . .	11.7	11.5	13.8	. . .	. . .	. . .
Milk, kg	8485	7004	9463	716	9704	8502	8376	520	a	
Fat, kg	287	276	344	33	325	334	321	24	NS	NS
SNF, kg	722	605	802	62	800	717	690	45	a	
Protein, kg	279	234	309	25	308	279	268	18	NS	NS
4% FCM, kg	7706	6946	8947	742	8756	8404	8163	538	NS	NS
SCM, kg	7634	6838	8779	733	8515	8168	7842	532	NS	NS
Grain DM, kg/d	8.3	6.3	9.6	1.0	8.5	8.4	7.8	.7	a	
Forage DM, kg/d	8.6	8.6	7.8	.4	10.4	10.8	10.5	.3	NS	.01
DMI, kg/d	16.9	15.0	17.4	.9	18.9	19.2	18.3	.7	NS	.01
% BW	3.04	2.79	3.10	.12	2.95	3.05	2.92	.09	NS	NS
Milk, kg/d	26.6	21.4	28.0	1.8	29.7	29.3	27.0	1.4	b	
Fat, %	3.47	4.03	3.61	.20	3.36	3.92	3.78	.14	.01	NS
SNF, %	8.51	8.64	8.45	.11	8.25	8.43	8.21	.08	.10	.01
Protein, %	3.30	3.36	3.25	.08	3.18	3.28	3.18	.06	NS	NS
FCM, kg/d	24.2	21.3	26.2	1.8	26.9	28.9	26.1	1.3	b	
SCM, kg/d	24.0	21.0	25.7	1.8	26.1	28.1	25.1	1.3	b	
SCM:grain, wt/wt	2.76	3.32	2.43	.24	2.85	3.08	3.12	.18	a	

[a]Significant T × L interaction ($P < .10$).

[b]Significant T × L interaction ($P < .05$).

[1]T = Treatment.

[2]$P > .10$.

oil soaps. However, their high content of palmitate was not reflected by increased proportion of palmitic acid in milk, as noted also by Mohamed et al. (24) and Smith et al. (31). As lactation progressed from wk 7 to 16, the proportion of $C_{18:1}$ decreased, and the proportions of C_{18}, C_{14}, and C_{16} increased, in milk fat. Overall effect of supplementary dietary fat on milk fatty acid profile was to increase the proportion of stearic acid at the expense of mammary-synthesized, short-chain fatty acids, with very little change in proportions of saturated versus unsaturated fatty acids of milk fat.

Means for various traits measured during complete lactations are in Table 8. Two first lactation cows and one older cow did not complete lactation for reasons unrelated to the experiment. Age at calving, DIM, and BW did not differ significantly among treatments; older cows consumed 30% more WCS than primiparous cows because of their higher projected DMI in early lactation. Rations were balanced individually each week based on biweekly measured and forward-projected BW (maintenance), on milk yield and fat test (4% FCM yield), and on growth (parity 1, only when BW < 567 kg), so grain allocation was driven by demonstrated energy needs rather than vice versa. Treatment by lactation interaction for grain consumed was significant (*P* < .10). Parity 1 cows receiving WCS plus PF ate more grain, and those fed WCS alone ate less grain than controls; older cows receiving either fat supplement ate less grain than controls. Treatments did not affect forage or total ration DMI. Yields of milk, FCM, and SCM generally paralleled grain intake, except that pluriparous cows yielded more FCM and SCM on the WCS diet despite their lower grain intake than controls. Higher FCM yield on WCS alone apparently was not at the expense of body tissue, because BW of pluriparous cows was close to that of controls throughout lactation (Figure 1). We found some evidence (Figure 1) that PF supplementation promoted greater recovery of BW or growth, in addition to enhanced milk yield, than WCS alone in primiparous cows during the last two trimesters of lactation. Changes in BW throughout lactation for older cows fed WCS plus PF were parallel to, but lower than, for other treatments perhaps because they were, on average and by chance, somewhat (not significantly) younger (i.e., higher proportion of parity 2).

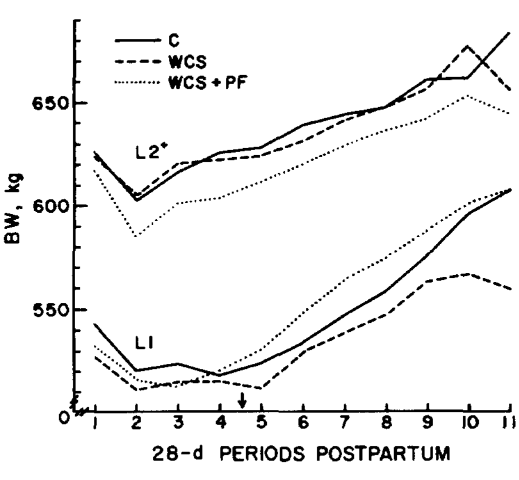

Figure 1. Body weight throughout lactation (L) for Holstein cows fed the control (C) diet supplemented during wk 1 to 16 (↓) postpartum with whole cottonseed (WCS) at 15% of projected DMI or with WCS plus protected fat (PF) at .54 kg/d.

Both WCS and WCS plus PF increased (*P* < .01) milk fat percentage (Table 8) and incresed it somewhat more so when WCS was the only fat supplement fed. Fat test of primiparous cows fed WCS plus PF might have been higher except for the elevated milk yield on that treatment. The SNF content of milk tended to be higher for cows fed WCS alone rather than in combination with PF. Unlike Umphrey et al. (33), we found no effect of WCS or WCS plus PF in the diet on milk protein percentage. Lactation curves for milk yield (Figure 2) showed that yield of primiparous cows fed WCS was lower than controls throughout lactation, but feeding PF with WCS resulted in a milk response above control that commenced during the latter part of the supplementation period and continued throughout the remaining lactation. We computed, for period 7 (wk 25 to 28 postpartum), that NE_L intakes were 107, 97, and 107% of NE_L required for maintenance, milk yield, and growth (.73 Mcal of NE_L/d) of primiparous cows on control, WCS, and WCS plus PF treatments, respectively. This treatment effect of WCS alone was attributed to lower grain allocation and lower total DMI (Figure 3), resulting from

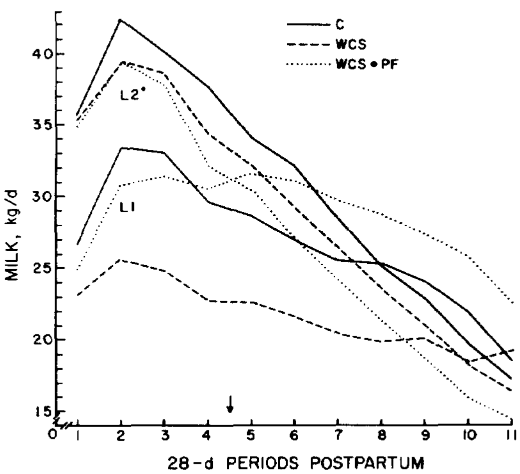

Figure 2. Milk yield throughout lactation (L) for Holstein cows fed the control (C) diet supplemented during wk 1 to 16 (↓) postpartum with whole cottonseed (WCS) at 15% of projected DMI or with WCS plus protected fat (PF) at .54 kg/d.

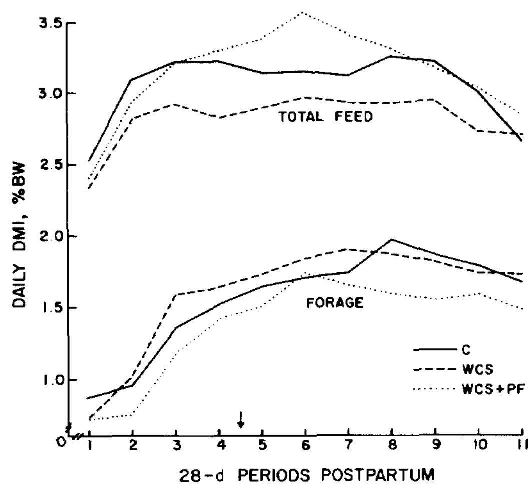

Figure 3. Forage and total feed DMI for primiparous Holstein cows fed the control (C) diet supplemented during wk 1 to 16 postpartum with whole cottonseed (WCS) at 15% of projected DMI or with WCS plus protected fat (PF) at .54 kg/d.

lower prior milk yield and accounts for failure of first lactation cows fed WCS to recover BW and to grow (Figure 1) as the cows on other treatments did. It is not clear why first lactation cows fed diets supplemented with WCS alone peaked lower than controls or those receiving WCS plus PF (Figure 2; treatment by parity interactions, Table 8) because BW and age at calving did not differ significantly among treatments. First lactation cows fed WCS supplement alone consumed somewhat less (but not significantly less) DM (2.3 kg/

TABLE 9. Estimates of NE_L adequacy, oilseed intake, dietary CP, and undegradable CP (UIP) for Holstein cows by lactation category and treatment[1] for selected weeks postpartum.

	Lactation 1			Lactation >1		
	C	WCS	WCS + PF	C	WCS	WCS + PF
Wk 9 to 12						
BW, kg	523	514	513	617	620	601
4% FCM, kg/d	27.4	24.8	28.9	32.4	36.5	34.8
WCS, % of DMI	0	17.2	16.1	0	15.8	16.0
NE_L Adequacy, %	98.2	93.3	101.2	105.1	102.9	108.6
Dietary CP, % of DM	17.87	16.01	16.87	17.66	17.25	17.19
UIP, % of CP	41	38	38	41	39	38
Wk 25 to 28						
BW, kg	547	539	564	644	641	629
4% FCM, kg/d	22.3	20.0	27.0	26.5	26.2	23.0
NE_L Adequacy,[2] %	107.2	97.4	107.0	103.8	102.1	103.4
Dietary CP, % of DM	15.26	14.62	16.86	15.15	14.64	14.44
UIP, % of CP	44	44	43	43	43	44

[1]Cows were fed control (C) diet supplemented, during wk 1 to 16 postpartum, with whole cottonseed (WCS) alone, at 15% of projected DMI, or with protected fat (PF) at .54 kg/d.

[2]Includes .73 Mcal/d for growth during this period of lactation 1.

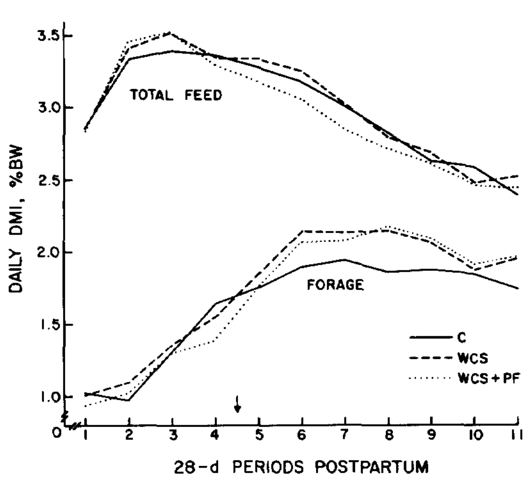

Figure 4. Forage and total feed DMI for pluriparous Holstein cows fed the control (C) diet supplemented during wk 1 to 16 postpartum with whole cottonseed (WCS) at 15% of projected DMI or with WCS plus protected fat (PF) at .54 kg/d.

100 kg of BW) than those fed control and WCS plus PF (2.53 and 2.40 kg/100 kg of BW) during period 1 and throughout lactation (Figure 3 and Table 8). From estimates in Table 9, limitation of yield likely was due, in early lactation, to insufficient NE_L intake and, in later lactation, to inadequate CP content of the ration of primiparous cows. Undegradability of CP was lower in early lactation than suggested by Chalupa et al. (5), but it was not sufficiently different among treatments to permit speculation about its effect on yield; based on work of Hoffman et al. (14), who found no interaction of protein undegradability (33 vs. 36% of CP) and supplemental fat, we expected no response in our experiment.

Intake of WCS exceeded the intended 15% of DMI during wk 9 to 12, probably because ad libitum DMI was 90 and 94% of that projected for primiparous and older cows, respectively. Based on composition of orts, we estimated that WCS constituted 15.0 and 14.2% of actual DMI in parities 1 and 2 or greater, respectively.

Pluriparous cows fed supplements of WCS with or without PF peaked lower in milk yield (Figure 2) than controls but exhibited similar persistency. During wk 5 to 8 (period 2), when adverse effect of WCS supplementation on milk yield was apparent in pluriparous cows, their intakes of forage and total DM were similar to, and slightly above, that of the control (Figure 4). Subsequently, milk yield was lower by about 1.6 kg/d for WCS plus PF than for WCS alone even though ration and forage DMI and rates of recovery of BW (Figure 1) were similar. Because of milk fat response to WCS and WCS plus PF supplements, 4% FCM of pluriparous cows (Figure 5) was higher in the early lactation (supplement) peri-

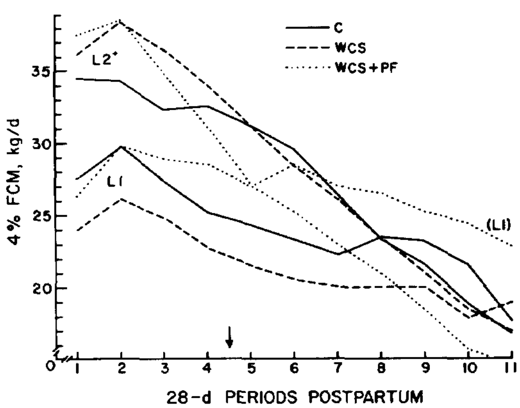

Figure 5. Four percent FCM throughout lactation (L) for Holstein cows fed the control (C) diet supplemented during wk 1 to 16 postpartum with whole cottonseed (WCS) at 15% of projected DMI or with WCS plus protected fat (PF) at .54 kg/d.

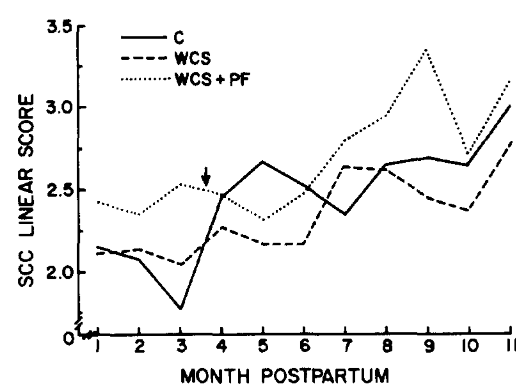

Figure 6. Somatic cell count by month of lactation for Holstein cows fed control ration or supplemented during d 1 to 112 (↓) postpartum with whole cottonseed (WCS) or with WCS plus protected fat (PF).

TABLE 10. Means for reproductive traits of Holstein cows supplemented from d 1 to 112 with whole cottonseed (WCS), at 15% of projected DMI, with or without protected fat (PF) at .54 kg/d.

Reproductive traits	Control	WCS	WCS + PF
n	18	19	19
Not bred, % of cows	5.6	5.3	5.3
Conceived service 1, % bred	35.3	50.0	44.5
Conceived service 2, % bred	35.3	11.1	0
Conceived service 3 to 7, % bred	17.6	22.2	38.9
Bred but no conception, % bred	11.8	16.7	16.7
Services, mean no.	3.0	2.3	4.3
Overall services/conception	1.87	1.87	2.47
Days open (n = 15)	107	96	123

od, but yield of cows receiving PF in addition to WCS started to drop below other treatments in period 4 and continued to be lower throughout remaining lactation; this was associated with somewhat lower ration DMI (Figure 4). Data in Table 8 provide no clue about the cause of the effects of treatment for pluriparous cows.

Linear score for SCC (Figure 6) increased in normal fashion as lactation progressed but generally was low and not affected by dietary treatments. Too few cows were used to evaluate reproductive traits (Table 10), which suggested only that fat supplementation may have influenced more cows to conceive on first service, as noted also by Schneider et al. (29).

CONCLUSIONS

High fat content of the control ration (4.07%), contributed especially by haycrop silage and distillers grains with solubles, and normal additions of oilseed fat (2.7% of ration DM) without or with PF (1.9% of ration DM) in early lactation lowered fiber digestion in early lactation when fat to forage ratio was highest, and this appeared to affect DMI adversely, especially in primiparous cows. Fat supplementation raised fat test without significantly affecting milk protein percentage, but, except for parity 1 cows supplemented with WCS alone, milk yield was reduced in later lactation. It is not known whether delayed fat supplementation would reduce the depression in fiber digestibility observed in wk 7 and 16. We estimated NE_L of WCS and fat in PF to be 1.81 and 5.69 Mcal/kg of DM, respectively.

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