J. Dairy Sci. 84:1201–1209

Body Composition and Estimated Tissue Energy Balance in Jersey and Holstein Cows During Early Lactation[1]

R. R. Rastani,*,[2] S. M. Andrew,* S. A. Zinn,* and C. J. Sniffen†
*Department of Animal Science
University of Connecticut, Storrs 06269
†W. H. Miner Agricultural Research Institute
Chazy, NY 12921

ABSTRACT

The rate and extent of estimated energy mobilization and the relationship between fat depth at the rib and thurl and body condition score (BCS) were investigated in Jersey and Holstein cows in early lactation. Twenty-six cows were paired by breed, parity, and calving date, and were individually fed a total mixed ration ad libitum from parturition through 120 d in milk. Feed intake and milk production were measured daily; body weight (BW), BCS, subcutaneous fat depth, milk composition, and concentration of plasma nonesterified fatty acids were measured every 2 wk. Estimated tissue energy balance (TEB) was calculated using 1989 NRC equations. Net energy intake was greater in early lactation for Holsteins compared with Jerseys, 37.8 and 28.2 Mcal/d, respectively. Milk energy was greater for Holsteins relative to Jerseys, 30.5 versus 21.2 Mcal/d. Fat depth and BCS did not differ between breeds. A positive relationship existed between fat depth and BCS for Jerseys; however, there was no significant relationship for Holsteins. The best-fit regression model for predicting TEB for Holsteins and Jerseys in early lactation included week of lactation, milk composition, and BCS. Jerseys remained in negative TEB for a shorter period of time relative to Holsteins. The TEB nadir was –6.19 and –12.9 Mcal/d, for Jerseys and Holsteins, respectively. Expressed as a proportion of metabolic BW ($BW^{0.75}$), net energy intake did not differ between breeds, yet milk energy and estimated tissue energy loss were greater for Holsteins compared with Jerseys.
(**Key words:** early lactation, energy balance, Holstein, Jersey)

Abbreviation key: FD = fat depth, **MBW** = metabolic BW, **MUN** = milk urea nitrogen, **NEI** = net energy intake, **NE_M** = net energy for maintenance, **TEB** = tissue energy balance.

INTRODUCTION

A vast amount of literature is available describing energy metabolism and changes in the energy status of Holsteins throughout the lactation cycle (Coppock, 1985; Flatt et al., 1965, 1967; Moe, 1981). However, critical information regarding energy metabolism of Jersey cows is lacking.

Body composition changes occur in early lactation due to the mobilization of energy from body tissues. Dairy cows mobilize tissue reserves, primarily in the form of fatty acids, which are then partitioned toward the mammary gland to support lactation. These changes in body composition can be monitored by direct or indirect methods. Two noninvasive methods for measuring changes in subcutaneous fat depots are BCS and ultrasonic measurements of fat depth (**FD**). Measurements of BCS parallel changes in tissue energy balance (**TEB**; Chilliard et al., 1991; Ferguson and Otto, 1989), while measurements of BCS and FD have been positively correlated in previous studies with Holstein cows (Domecq et al., 1995; Neilson et al., 1983; Waltner et al., 1994).

Breed differences have been observed in frame size, body composition, maintenance requirements, milk production, and milk composition for Jersey and Holstein cows (Beaulieu and Palmquist, 1995; Bitman et al., 1996; Enevoldsen and Kristensen, 1997; Solis et al., 1988). However, it is not known whether TEB differs between breeds. Metabolizable energy requirements at maintenance are 21.7% greater for Jerseys compared with Holsteins (Solis et al., 1988). Energy efficiency has been shown to be similar in Jerseys and Holsteins in early lactation, but differs in the second trimester of lactation (Blake et al, 1986). Tyrrell et al. (1990) reported that net energy intake (**NEI**) and utilization of dietary energy in Jersey and Holstein cows were similar

Received July 27, 2000.
Accepted December 12, 2000.
Corresponding author: S. M. Andrew; e-mail: sandrew@canr.uconn.edu.
[1]Manuscript #1963 of the Connecticut Agricultural Research Experiment Station.
[2]Present address: University of Wisconsin, Department of Dairy Science, 1675 Observatory Drive, Madison, WI 53706.

in early lactation when energy variables were adjusted to metabolic BW (**MBW**).

Additional information is needed in this area to improve the nutritional management of Jersey cows in early lactation. Therefore, the objectives of this study were to determine whether breed differences in TEB and tissue mobilization exist, and to examine the relationship between BCS and FD in Jerseys and Holsteins in early lactation. Furthermore, prediction equations were developed to estimate tissue energy changes in Jerseys and Holsteins through 120 DIM.

MATERIALS AND METHODS

Animals

Thirteen Jersey and 13 Holstein dairy cows from the University of Connecticut dairy herd were paired by breed, parity, and calving date. Twelve of the pairs were multiparous, and one pair was primiparous. Cows were assigned to the study in pairs 4 wk before their projected calving date and remained on the study through 120 DIM. The Animal Care and Use Committee of the University of Connecticut approved the use of animals for this study.

Feeding and Management

Cows were housed in a free-stall facility and individually fed using Calan gates (American Calan, Northwood, NH), which were adjusted to the wither height of the animals. Animals were trained to use the Calan gates 4 wk prior to anticipated calving date, and during this time, animals were fed a TMR balanced to meet nutritional requirements (NRC, 1989; Tables 1 and 2). Individual feed intake was not measured during this stage of the experiment when cows were adjusting to their environment.

Cows were moved to maternity pens before anticipated calving date, and remained there until approximately 3 d following parturition, at which time they were moved back to the free-stall facility. Holstein and Jersey cows were individually fed a TMR balanced to meet nutrient requirements for producing approximately 40 kg of milk daily (NRC, 1989; Table 1), ad libitum, once per day at approximately 0930 h. The TMR consisted of all ingredients of the ration except grass hay, which was fed twice daily, 0.7 kg/d at 0900 and 1600 h. Feed offered and orts were weighed daily for each cow. Amount of feed offered was adjusted daily to allow for a 15% feed refusal. The feed offered and orts were sampled daily at 0930 h, and samples were composited weekly for DM analysis. Weekly feed and ort samples were composited monthly and analyzed for CP using Tecator Keltech Auto 1030 analyzer, crude fat by infrared spectroscopy, NDF and ADF by the Ankom A200 filter bag technique and Ca and P by wet chemistry (Dairy One, Ithaca, NY). Soluble CP and RDP was measured with a borate-based buffer (Roe et al., 1990). The net energy value of the ration was calculated according to the discount method of Van Soest and Fox (1992). Corn silage and grass silage were sampled weekly for DM analysis, and ration components were adjusted to account for changes in forage DM.

Table 1. Ingredient and chemical composition of diets fed to dairy cows prepartum and postpartum.

	Diet	
	Prepartum	Postpartum
	(% of DM)	
Ingredient		
Corn silage	37.88	35.30
Grass silage	15.14	12.73
Alfalfa-grass hay	27.55	4.53
Pelleted grain mix[1]	0.00	29.69
Pre-fresh grain mix[2]	19.43	0.00
Soybean-based grain mix[3]	0.00	13.46
Dehydrated beet pulp	0.00	2.51
Megalac[4]	0.00	0.91
Dehydrated molasses	0.00	0.87
Chemical		
CP	13.45	15.94
Crude fat	3.86	5.08
NDF	42.65	40.26
ADF	28.86	24.94
NE_L,[5] Mcal/kg	1.47	1.63
NSC[6]	29.81	32.62
Ca	0.78	0.89
P	0.33	0.57

[1]Pelleted grain mix contained 17.2% CP, 7.5% fat, 1.88 Mcal/kg of NE_L, 1.25% Ca, 0.79% P, 0.98% K, 0.60% Mg, 2.04 IU of vitamin A/g, 0.61 IU of vitamin D/g, and 0.010 IU of vitamin E/g.

[2]Pre fresh grain mix contained 17.7% CP, 4.5% fat, 1.64 Mcal/kg NE_L, 0.72% Ca, 0.58% P, 0.87% K, 0.40% Mg, and 8.2 IU of vitamin A/g.

[3]Soybean-based grain mix contained 45.5% CP, 2.39% fat, 1.88 Mcal/kg NE_L, 1.70% Ca, 0.81% P, 1.63% K, 0.34% Mg, 4.21 IU of vitamin A/g, 1.26 IU of vitamin D/g, and 0.029 IU of vitamin E/g.

[4]Megalac is manufactured by Church and Dwight, Inc. (Princeton, NJ).

[5]Calculated according to Van Soest and Fox, 1992.

[6]Calculated by difference from proximate analysis.

Concentrations of ketones in the urine were monitored for all animals through 21 DIM or when feed intake was depressed (80% of previous days DMI) during 22 to 120 DIM with Ketostix Reagent Strips (Bayer Corporation, Elkhart, IN). Cows with ketone concentrations of 10 mg/dl or greater were treated with 500 ml of intravenous glucose, followed by oral administration of 200 ml of propylene glycol.

Body Composition

Body condition scores were measured independently by the same two individuals every 2 wk using the five-

Table 2. Chemical composition of forages and concentrates (DM basis).

Chemical composition	Corn silage	Grass silage	Pelleted grain mix	Soybean grain mix	Pre fresh grain mix
CP (%)	8.02	17.14	17.16	45.53	17.66
Soluble protein[1] (%)	55.15	56.23	20.75	18.00	19.02
RDP[1] (%)	75.15	74.77	59.15	59.74	NA
NE_L[2] (Mcal/kg)	1.58	1.28	1.89	1.88	1.64
Crude Fat (%)	3.08	4.80	7.47	2.39	4.54
Ash (%)	4.44	10.08	11.46	9.23	5.86
NSC[3] (%)	41.23	16.05	37.66	27.88	39.30
ADF (%)	26.49	37.38	9.64	6.87	NA
NDF (%)	40.92	53.18	27.67	17.55	21.03
Ca (%)	0.26	0.92	1.25	1.70	0.72
P (%)	0.24	0.36	0.79	0.81	0.58
Mg (%)	0.16	0.27	0.61	0.34	0.40
K (%)	1.15	2.89	0.98	1.63	0.87

[1]Given as a percentage of CP.

[2]Calculated according to Van Soest and Fox (1992).

[3]Calculated by difference from proximate analysis.

point visual BCS technique (Wildman et al., 1982). Cows were scored to the nearest quarter point. Body weights were measured every 2 wk at approximately 1030 h.

Subcutaneous FD was measured by ultrasound using an Aloka 500, B-mode instrument (Corometrics Medical Systems, Inc., Wallingford, CT). Measurements of FD were recorded every 2 wk at two body sites: 1) the longissimus dorsi muscle between the 12th and 13th ribs (rib), and 2) 10 cm posterior to the tuber coxae (thurl). These sites correspond to the areas visually considered in assigning a BCS. Both measurements were taken on the left side of the animal as described by Domecq et al. (1995). The measurements were taken on 2 consecutive days or within the same week, and an average of the measurements was recorded. Body condition scores and measures of FD were recorded at different times.

Milk Production and Composition

Cows were milked daily at 0500, 1300, and 2100 h, and milk yields were recorded at each milking. Milk was sampled every 2 wk from three consecutive milkings, and each sample was analyzed for fat, CP, milk urea N (**MUN**), total solids, and SCC (Dairy One, Ithaca, NY). Milk fat and milk CP content were determined by infrared spectroscopy, and MUN and SCC were determined by fossimatic analysis (Foss 4000 and Foss 5000, respectively; Dairy One). Concentrations and yields of fat, CP, and total solids were computed as weighted means for the individual milk yields from the sampling day.

NEFA Analysis

Blood samples from the jugular vein were collected with Vacutainers containing K_3-EDTA (Becton Dickinson, Franklin Lakes, NJ). Blood was centrifuged (1500 $\times g$, 4°C, 30 min), and plasma was decanted and stored at –20°C for subsequent analyses. Plasma NEFA concentrations were determined by colorimetric assay with a commercial kit (WAKO Chemicals, Dallas, TX) with modifications according to McCutcheon and Bauman (1986), and using reduced sample volumes and reduced volumes of reagents (Rastani, 2000). The assay was linear between 62.5 and 2000 μeq/L, and the intraassay CV was 12%.

Energy Calculations

Net energy intake was determined by multiplying the daily DMI by the calculated energy value of the ration (Van Soest and Fox, 1992). Energy required for body maintenance (**NE_M**) was computed using the equation $NE_M = BW^{0.75} \times 0.08$ (NRC, 1989). Net energy required for maintenance was increased 20 and 10% to account for energy needed for growth for cows in their first or second lactation, respectively (NRC, 1989). Milk energy was calculated using the equation $NE_L = MP \times (0.3512 + [0.0962 \times F])$, where MP = milk production and F = fat percentage in the milk (NRC, 1989). Estimated TEB was computed on a weekly basis using the equation $TEB = NEI - (NE_M + NE_L)$.

Net energy intake, milk energy output, and TEB were adjusted by dividing the individual energy values by MBW ($BW^{0.75}$) to account for differences in surface area. Gross efficiencies were calculated as NE_L divided by NEI.

Statistical Analyses

Mixed model procedures of SAS (1997) were used to test fixed effects of breed on measurements repeated within cows over weeks of lactation. Cows were re-

Table 3. Average parity and least square means for DMI, milk production, and milk composition of Jersey and Holstein dairy cows from wk 1 to wk 17 of lactation.

Item	Jersey	Holstein	SEM	*P*
N	9	9		
Parity[1]	2.67	2.44	0.69	
BW, kg	459	670	23	<0.0001
DMI, kg/d[2]	16.5	22.4	0.7	<0.0001
Milk, kg/d	26.6	44.9	1.3	<0.0001
Crude protein, %	3.69	2.99	0.07	<0.0001
Fat, %	4.39	3.71	0.15	0.0048
Total solids, %	13.65	12.21	0.19	<0.0001
MUN,[3] mg/dl	12.1	14.8	0.6	0.0037
SCC, ×1000	327	155	181	0.51

[1]Parity distribution was one first lactation, four second lactation, and four third lactation or greater for each group.

[2]DMI was measured from wk 1 to wk 17 of lactation.

[3]MUN = Milk urea N.

garded as random factors and breed as a fixed factor in the model. Differences between treatments were declared significant at $P < 0.05$, and trends were discussed at $P < 0.10$. Least square means are presented. Using linear regression, equations for prediction of TEB across and within breeds, and the relationship between BCS and FD measurements were evaluated (SAS, 1997).

RESULTS

Nine of the initial 13 pairs completed the experiment. Cows that failed to complete the experimental period had significant health problems, which resulted in a prolonged reduction in feed intake and milk production. One animal was affected with severe laminitis, and the other three pairs were affected with severe metabolic disorders.

Mean parity did not differ across breeds (Table 3). During lactation, DMI (22.4 vs. 16.5 kg/d) was greater for Holsteins relative to Jerseys (Table 3; Figure 1a). However, DMI per unit of BW (kg/kg) did not differ statistically between breeds and was 0.033 for Holsteins and 0.036 for Jerseys. Average daily milk production was greater for Holsteins than for Jerseys, 44.9 and 26.6 kg/d, respectively (Table 3; Figure 1b). Percentages of milk fat and milk CP were greater and concentrations of MUN were lower in milk from Jerseys relative to milk from Holsteins (Table 3).

Body Composition

Initial BW, measured 4 wk prepartum, differed between breeds, with Jerseys weighing 475 ± 24 kg and Holsteins weighing 745 ± 24 kg. Average BW from 4 wk prepartum to wk 17 of lactation was 463 ± 23 kg for Jerseys and 684 ± 23 kg for Holsteins. Based on BW 4 wk prepartum, Holsteins lost 10.6% of BW (79 kg), while Jerseys lost 4.6% of BW (22 kg).

Initial BCS, measured at 4 wk prepartum, did not differ between breeds and was 3.62 and 3.71, for Jerseys and Holsteins, respectively (Figure 2). Over the entire experimental period, a significant breed difference in BCS was observed only at wk 11. Mobilization of body fat, as measured by BCS, occurred until the 11th wk of lactation for Holsteins, and until the 7th wk of lactation for Jerseys.

Subcutaneous FD measurements at the rib and thurl did not differ between breeds. However, there was a breed × week interaction for FD for both body sites measured. Initial FD at both areas was similar between breeds (Figure 3a, b). The subcutaneous changes in FD at the rib area were greater for Holsteins between wk 1 and wk 3 of lactation than for Jerseys. Fat depth at the thurl area was greater for Holsteins at 2 wk prepartum and 1 wk postpartum relative to Jerseys. Changes in FD occurred until the 5th wk of lactation for the rib site and 3rd wk of lactation for the thurl site for both breeds. Fat depth remained constant (approximately 8.38 mm at the rib and 7.90 mm at the thurl) for the remainder of the experimental period and did not differ by breed.

Relationships between BCS and Ultrasound

There was a trend toward a positive relationship between BCS and FD (in mm) at the thurl site for all animals, $BCS = 3.22 + 0.02\ FD_{thurl}$ ($P < 0.07$; SE = 0.28; $r^2 = 0.01$). Body condition score was positively related to FD at the rib and at the thurl in Jersey cows, and the equation relating BCS to FD (in mm) at the rib and thurl in Jerseys was $BCS = 3.00 + 0.01\ FD_{rib} + 0.04\ FD_{thurl}$ ($P = 0.04$; SE = 0.27; $R^2 = 0.05$). In contrast, there was no significant relationship between BCS and FD at the rib or thurl areas for Holsteins.

Energy Balance

Mean NEI and milk energy output were greater for Holsteins relative to that of Jerseys (Table 4). Energy balance was lower for Holsteins from 1 wk postpartum through the 7th wk of lactation (Figure 4). Jerseys remained in negative TEB for a shorter period and to a lesser extent than Holsteins. The TEB nadir was –6.19 Mcal/d for Jerseys and occurred at wk 1 of lactation compared with Holsteins (–12.9 Mcal/d at wk 2). Expressed as a proportion of MBW, NEI did not differ between breeds; however, milk energy output was greater for Holsteins compared with Jerseys when adjusted to MBW (Table 4). Gross efficiency of milk energy

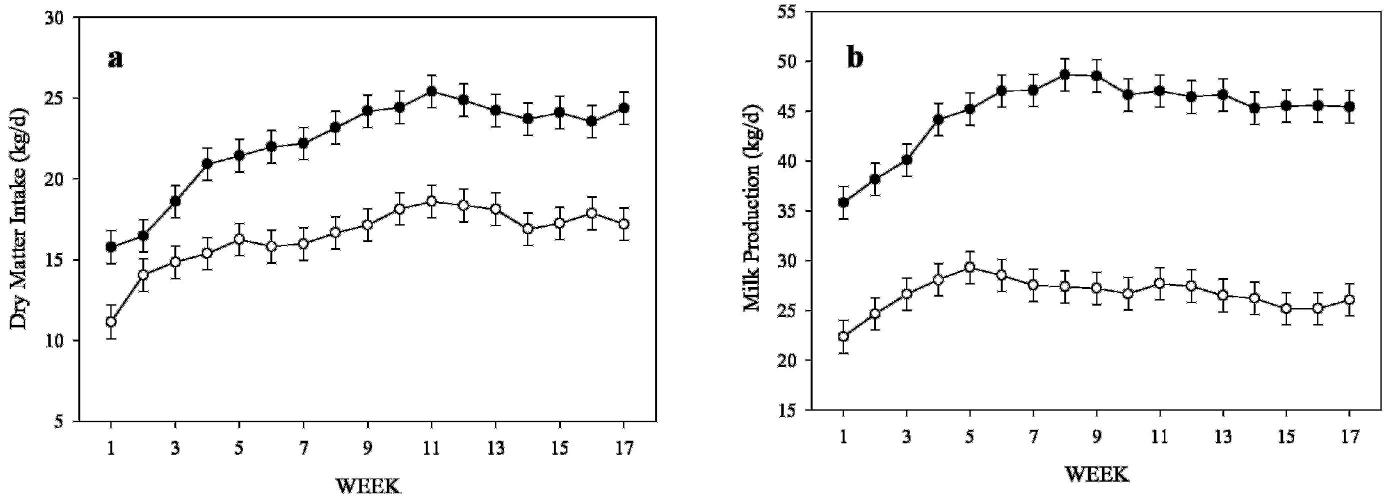

Figure 1. Dry matter intake (a) and milk production (b) for wk 1 to wk 17 of lactation for Jersey cows (○) and Holstein cows (●).

production was greater for Holsteins (Table 4). In contrast, gross efficiency, expressed as a proportion of MBW, was greater for Jerseys (Table 4).

Regression equations were developed to relate TEB to week of lactation, milk yield, milk composition, BCS, and FD. Variables that were significantly correlated were not included in the equations. Week of lactation accounted for 38% of the total variation in TEB for both Holsteins and Jerseys. Milk production accounted for 9% of the total variation in TEB, while the percentage of CP in the milk accounted for 13% of the variation in TEB. However, BW and week in lactation accounted for 46% of the total variation in TEB.

The predictive equation with the best overall fit of the model was TEB = –29.50 + 1.17 wk in lactation + 2.15 BCS – 3.37 fat percentage + 7.57 protein percentage (P = 0.0001; SE = 3.47; R^2 = 0.55). There were no significant correlations between variables. While milk fat output and changes in BCS are important factors in early lactation, neither variable was significantly related to TEB.

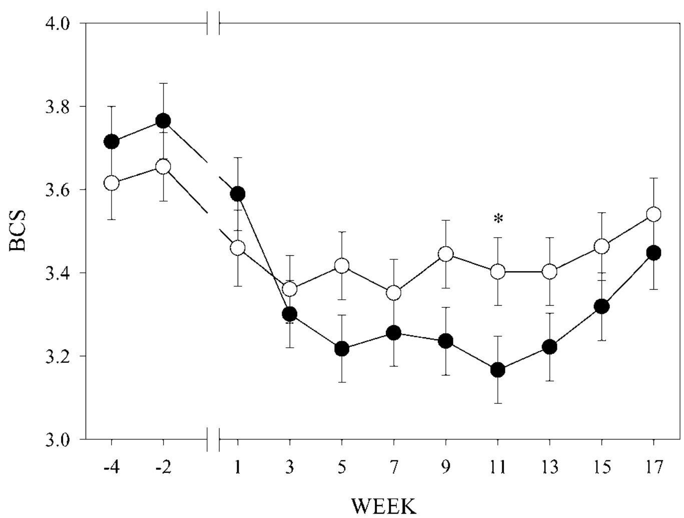

Figure 2. Body condition scores (1 = thin, 5 = obese) of Jersey cows (○) and Holstein cows (●) from wk 4 prepartum to wk 17 of lactation. The break along the x-axis indicates the time of parturition, when no measurements were taken. Asterisks indicate that the BCS differed (P < 0.05) between the two breeds at that time point.

Plasma NEFA Concentrations

One Jersey cow had not eaten before blood collection for the measurement immediately after calving, and the plasma NEFA concentration was much greater than the concentrations of the other animals. As a result, the Jersey and corresponding Holstein in the pair were not included in the statistical analysis of plasma NEFA concentrations (Figure 5).

The mean plasma NEFA concentrations were 185.5 and 128.3 μeq/L, for Holsteins and Jerseys, respectively. Holsteins had a greater NEFA concentration during the 1st wk postpartum (503 vs. 277 μeq/L), and NEFA concentrations tended to be greater for Holsteins relative to Jerseys (P = 0.09).

DISCUSSION

Jerseys had a greater TEB for the first 7 wk of lactation relative to Holsteins, which may be related to milk production. This finding is in agreement with estimates of TEB reported by Erdman and Andrew (1989), demonstrating that lower producing cows remain in a state of negative TEB for a shorter period than higher produc-

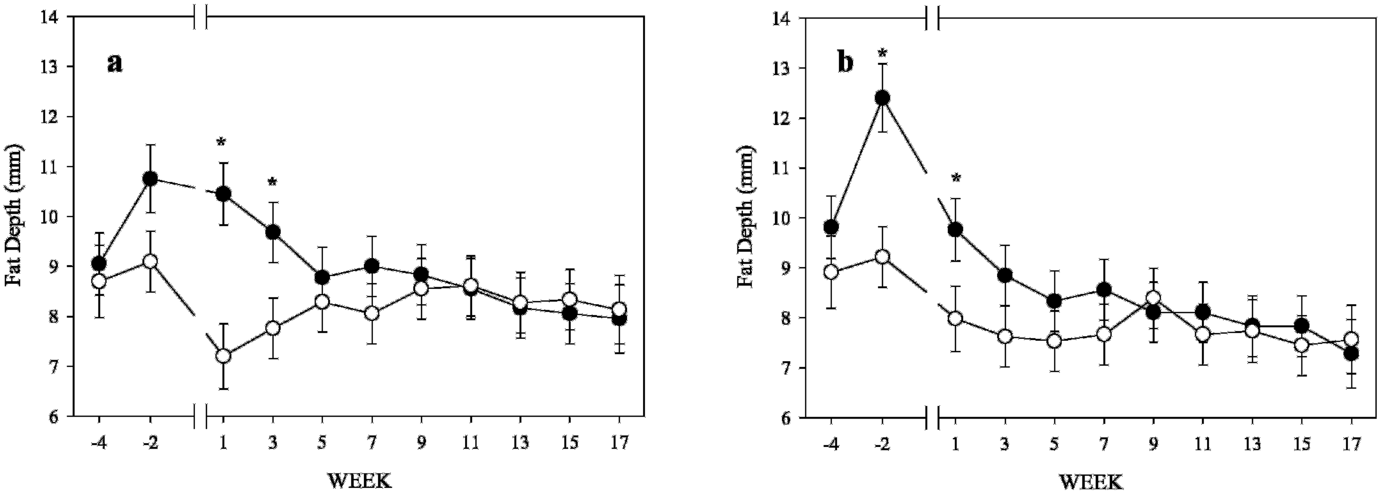

Figure 3. Subcutaneous fat depth of rib area (a) and thurl area (b) in Jersey cows (○) and Holstein cows (●) from wk 4 prepartum to wk 17 of lactation. The break along the x-axis indicates the time of parturition, when no measurements were taken. Asterisks indicate that the fat depth differed ($P < 0.05$) between the two breeds.

ing cows. Tissue energy balance nadir, which occurred within the first 2 wk of lactation, was –6.19 Mcal/d for Jerseys and –12.9 Mcal/d for Holsteins, and by the 11th wk of lactation both breeds were maintaining TEB. Energetic equilibrium was reached between 2 and –2 Mcal/d (Figure 4). This range may reflect errors associated with the equation for estimating TEB. The rate of tissue energy loss at nadir is in agreement with previously reported values (Andrew et al., 1994; Flatt et al., 1967). However, the length of time to TEB nadir was less than previously reported times of 4 to 11 wk into lactation (Andrew et al., 1994; Flatt et al., 1967).

The length of time that tissue mobilization occurred, shown by BCS loss, differed by breed. Chilliard et al. (1984) reported that Holsteins producing 30 kg of 4% FCM mobilized body tissue for the first 8 wk of lactation. The Holsteins used in this experiment produced 42 kg of 4% FCM, and as a result, they mobilized body tissue for a longer time than those reported by Chilliard et al. (1984). In addition, the Jerseys mobilized body tissue for a shorter period as a result of their lower production (28 kg of 4% FCM). The energy loss derived from the estimated TEB was 498.8 and 114.5 Mcal for Holsteins and Jerseys, respectively, in the present study. The

Table 4. Least square means for energy variables of Jersey and Holstein cows from wk 1 to wk 17 of lactation.

Item	Jersey	Holstein	SEM	P
N	9	9		
Energy measurements				
NEI[1] (Mcal/d)	28.2	37.8	1.2	<0.0001
Milk energy[2] (Mcal/d)	20.5	31.8	1.1	<0.0001
TB[3] (Mcal/d)	–0.80	–5.01	0.83	0.0025
Gross efficiency[4]	0.742	0.857	0.022	0.0021
MBW[5]	100	134	3	<0.0001
Energy measurements (Mcal/d)/MBW				
NEI/MBW	0.280	0.282	0.005	0.89
Milk energy/MBW	0.207	0.242	0.005	<0.0001
TEB/MBW	–0.012	–0.040	0.007	0.014
Gross efficiency/MBW	0.0075	0.0066	0.0002	0.013

[1]NEI = Net energy intake.

[2]Calculated using the equation: Milk energy = MP × (0.3512 + [0.0962 × F]), where MP is the milk production and F is the fat percent in the milk.

[3]TEB = Tissue energy balance.

[4]Gross efficiency = Milk energy/NEI.

[5]MBW = $BW^{0.75}$.

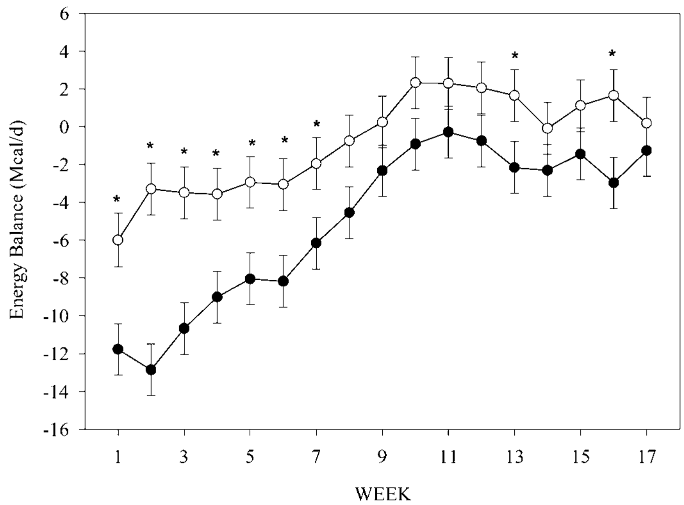

Figure 4. Estimated tissue energy balance of Jersey cows (○) and Holstein cows (●) from wk 1 to wk 17 of lactation. Tissue energy balances calculated according to NRC (1989). Asterisks indicate that the tissue energy balance differed ($P < 0.05$) between the two breeds at that time point.

estimated TEB for the Holsteins is in agreement with the findings of Andrew et al. (1994), in which a loss of 442 Mcal of tissue energy was reported and the cows produced 31 kg of 4% FCM.

Dry matter intake and NEI were similar to those previously reported for Holsteins and Jerseys in early lactation (Beaulieu and Palmquist, 1995; Tyrrell et al., 1990). Based on NRC (1989), on average Jerseys met their energy requirements, but Holsteins averaged a 5 Mcal/d energy intake deficit (Tables 1 and 4). However, breed differences in maintenance requirements (Solis et al., 1988) were not taken into account, and with that difference, Jerseys has a 2 Mcal/d of energy intake deficit. Both breeds met their requirements for CP. In addition, greater milk energy output for Holsteins compared with Jerseys is consistent with results reported by Tyrrell et al. (1990) and Beaulieu and Palmquist (1995).

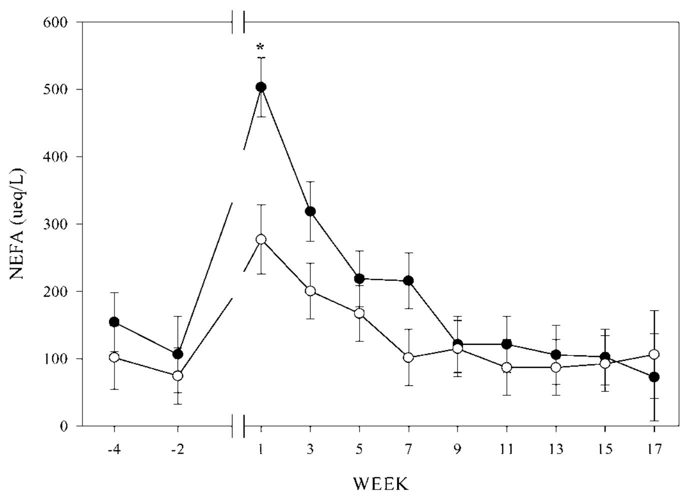

Figure 5. Nonesterified fatty acid concentrations from wk 4 prepartum to wk 17 of lactation for Jersey cows (○) and Holstein cows (●). The break along the x-axis indicates the time of parturition, when no measurements were taken. Asterisks indicate that the NEFA concentrations differed ($P < 0.05$) between the two breeds at that time point.

Holsteins had a significantly lower TEB per unit of MBW relative to Jerseys. This is the result of breed differences in milk energy output per unit of MBW, while there was no difference in NEI per unit of MBW between the two breeds. Furthermore, gross efficiency was greater for Holsteins compared with Jerseys. However, when gross efficiency was adjusted to MBW, Jerseys were more efficient than Holsteins. Similar DM digestibilities between Jerseys and Holsteins have been reported (Blake et al., 1986; Solis et al., 1988), and, therefore, it is assumed that utilization of nutrients was similar for Jerseys and Holsteins. However, Jerseys synthesize more fatty acids in the mammary gland compared with Holsteins, while Holsteins utilize more fatty acids from circulating lipids than Jerseys (Beaulieu and Palmquist, 1995; Bitman et al., 1996). This demonstrates a key difference in metabolism of nutrients between Jerseys and Holsteins. These factors affect nutrient metabolism, either directly or indirectly, and may partially explain the differences in TEB between the breeds.

Concentrations of NEFA in both breeds increased as parturition approached, and then decreased 3 wk into lactation (Figure 5). This is in agreement with previously published results (Kronfeld, 1965; Metz and van den Bergh, 1977; Vazquez-Anon et al., 1994). Holsteins tended to have greater concentrations of NEFA at the initiation of lactation, further indicating that Holsteins were mobilizing more fat than Jerseys. Increased NEFA concentrations have been related to decreased DMI and increased incidence of ketosis (Kronfeld, 1965; Vazquez-Anon et al., 1994). Incidence of ketosis was slightly greater in Holsteins relative to Jerseys (33 vs. 22%), and may be related to the differences in NEFA concentrations between the two breeds.

Changes in BCS followed the same trend as changes in TEB. Loss of BCS, the difference between BCS before parturition and the lowest BCS, was greater for Holsteins relative to Jerseys, 0.59 and 0.29 units, respectively. These values are less than or within the range of 0.4 to 0.7 units of BCS loss reported by Ferguson and Otto (1989) for high producing cows fed complete diets ad libitum. Ferguson and Otto (1989) estimated that the loss of one unit of BCS was equal to 400 Mcal of energy loss. On this basis, Holsteins in the present experiment had an estimated energy loss of 236 Mcal, and Jerseys had an estimated energy loss of 116 Mcal based on BCS loss. In contrast, Chilliard et al. (1991) reported the loss of one unit of BCS was equal to 200 Mcal of energy loss. In the present study, energy loss per unit of BCS was 800 Mcal for Holsteins and 384 Mcal for Jerseys (pooled SEM = 187; $P = 0.15$). The lack of a statistically significant difference may be due to small sample size or individual cow variation.

Butler-Hogg et al. (1985) reported that the total amount of subcutaneous fat, which was measured by physical separation, decreased immediately after parturition and then increased after peak milk production. The results of the present study are not in agreement with those of Butler-Hogg et al. (1985) because FD did not increase after peak milk production, but remained at a constant thickness through 120 DIM. However, Butler-Hogg et al. (1985) also reported that changes in FD at the 12th rib did not correspond to the changes in the total amount of subcutaneous fat.

Breed differences were found in the relationships between BCS and FD, with Jerseys having a positive relationship between BCS and FD, and Holsteins having no significant relationship between BCS and FD. Wright and Russell (1984) found that Holsteins have a greater proportion of fat present in internal depots, and a lower proportion of fat in subcutaneous depots compared with beef breeds with a similar mean BCS. Not much data is available on body composition of Jersey and Holstein cows. Therefore, we hypothesize that Jerseys and Holsteins may deplete different fat depots during tissue mobilization in early lactation, as in the case of Holsteins and beef breeds.

The predictive equations relating TEB to week of lactation, milk yield, milk composition, and body composition accounted for a relatively low percentage of the total variation in TEB (less than 55%). Andrew et al. (1994) reported that DIM accounted for 56% of the variation in empty body energy before 77 DIM and 9% of the variation after 77 DIM. The results from this experiment show that week in lactation accounts for 38% of the variation in TEB prior to 120 DIM. In addition, Andrew et al. (1995) predicted that protein percentage in the milk accounted for 26% of the variation in empty body energy, while the estimate from this experiment is only 13% of the variation of TEB. Therefore, the predictive equations developed from this experiment explained less variation in TEB than those developed by Andrew et al. (1995). This may be an effect of a smaller sample size in the present study. However, the equations developed by Andrew et al. (1995) may have overestimated the actual amount of variation of TEB, since they were based on several groups of animals and not changes in energy status within animals.

Values for MUN in the present study were in the range of 10 to 16 mg/dl, which is the optimal range based on NRC (1989) CP recommendations (Jonker et al., 1998). Jonker et al. (1998) reported that predicted MUN values increased with increasing milk production, which may be why Holsteins have a greater concentration of MUN than do Jerseys. In contrast, Broderick and Clayton (1997) reported a negative relationship between MUN values and milk yield. Another potential reason for the difference in MUN values between Jerseys and Holsteins is a difference in efficiency of N digestion in early lactation. Blake et al. (1986) found that Jerseys digested a greater percent of N in early lactation compared with Holsteins (62.7 vs. 60.3%). Therefore, it is unclear whether the difference in MUN between Holsteins and Jerseys is an effect of production or differences in nutrient metabolism.

CONCLUSION

The rate and extent of energy mobilization differ between Jersey and Holstein dairy cows. Jerseys remain in negative TEB for a shorter period of time and to a lesser extent than Holsteins. This appears to be related to the difference in milk production between the two breeds. Additionally, BCS is positively related to FD at both the rib and the thurl for Jerseys, but there was no relationship for Holsteins. Week of lactation, milk composition, and BCS provided the best estimate of TEB for Holsteins and Jerseys. Differences in milk energy output and NEI between breeds resulted in differences in energy mobilization during early lactation.

ACKNOWLEDGMENTS

We thank David Schreiber, Jr. for his assistance with animal measurements, Arnold Nieminen and the staff at the Kellogg Dairy Center for exceptional care of animals, Mark Tripp for assistance with the interpretation of ultrasound scans, and Thomas Hoagland for his expertise in statistical models. This study was partially funded by the American Jersey Cattle Association (Reynoldsburg, OH).

REFERENCES

Andrew, S. M., R. A. Erdman, and D. R. Waldo. 1995. Prediction of body composition of dairy cows at three physiological stages from deuterium oxide and urea dilution. J. Dairy Sci. 78:1083–1095.

Andrew, S. M., D. R. Waldo, and R. A. Erdman. 1994. Direct analysis of body composition of dairy cows at three physiological stages. J. Dairy Sci. 77:3022–3033.

Beaulieu, A. D., and D. L. Palmquist. 1995. Differential effects of high fat diets on fatty acid composition in milk of Jersey and Holstein cows. J. Dairy Sci. 78:1336–1344.

Bitman, J., D. L. Wood, R. H. Miller, H. F. Tyrrell, C. K. Reynolds, and H. D. Baxter. 1996. Comparison of milk and blood lipids in Jersey and Holstein cows fed total mixed rations with or without whole cottonseed. J. Dairy Sci. 79:1596–1608.

Blake, R. W., A. A. Custodio, and W. H. Howard. 1986. Comparative feed efficiency of Holstein and Jersey cows. J. Dairy Sci. 69:1302–1308.

Broderick, G. A., and M. K. Clayton. 1997. A statistical evaluation of animal and nutritional factors influencing concentrations of milk urea nitrogen. J. Dairy Sci. 80:2964–2971.

Butler-Hogg, B. W., J. D. Wood, and J. A. Bines. 1985. Fat partitioning in British Friesian cows: the influence of physiological state on dissected body composition. J. Agric. Sci. (Camb.) 104:519–528.

Chilliard, Y., M. Cisse, R. Lefaivre, and B. Remond. 1991. Body composition of dairy cows according to lactation stage, somatotropin treatment, and concentrate supplementation. J. Dairy Sci. 74:3103–3116.

Chilliard, Y., J. Robelin, and B. Remond. 1984. In vivo estimation of body lipid mobilization and reconstitution in dairy cattle. Can. J. Anim. Sci. 64(Suppl.):236–237.

Coppock, C. E. 1985. Energy nutrition and metabolism of the lactating dairy cow. J. Dairy Sci. 68:3403–3410.

Domecq, J. J., A. L. Skidmore, J. W. Lloyd, and J. B. Kaneene. 1995. Validation of body condition scores with ultrasound measurements of subcutaneous fat of dairy cows. J. Dairy Sci. 78:2308–2313.

Enevoldsen, C., and T. Kristensen. 1997. Estimation of body weight from body size measurements and body condition scores in dairy cows. J. Dairy Sci. 80:1988–1995.

Erdman, R. A., and S. M. Andrew. 1989. Methods for and estimates of body tissue mobilization in the lactating dairy cow. Pages 19–26 *in* Proc. Monsanto Tech. Symp., Syracuse, NY. Monsanto Co., St. Louis, MO.

Ferguson, J. D., D. T. Galligan, and N. Thomsen. 1994. Principal descriptors of body condition score in Holstein cows. J. Dairy Sci. 77:2695–2703.

Ferguson, J. D., and K. A. Otto. 1989. Managing body condition in dairy cows. Pages 75– 87 **in** Proc. Cornell Nutr. Conf. Feed Manuf., Syracuse, NY. Cornell Univ., Ithaca, NY.

Flatt, W. P., L. A. Moore, N. W. Hooven, and R. D. Plowman. 1965. Energy metabolism studies with a high producing lactating dairy cow. J. Dairy Sci. 48:797–798.

Flatt, W. P., P. W. Moe, A. W. Munson, and T. Cooper. 1967. Energy utilization by high producing dairy cows. II. Summary of energy balance experiments with lactating Holstein cows. Pages 235–251 *inin* Energy Metabolism of Farm Animals, Proc. 4th Symp. Energy Metab. Sept. 1967. Oriel Press, Newcastle upon Tyne, UK.

Jonker, J. S., R. A. Kohn, and R. A. Erdman. 1998. Using milk urea nitrogen to predict nitrogen excretion and utilization efficiency in lactating dairy cows. J. Dairy Sci. 81:2681–2692.

Kronfeld, D. S. 1965. Plasma non-esterified fatty acid concentrations in the dairy cow: Responses to nutritional and hormonal stimuli, and significance in ketosis. Vet. Rec. 77:30–35.

McCutcheon, S. N., and D. E. Bauman. 1986. Effect of chronic growth hormone treatment on responses to epinephrine and thyrotropin-releasing hormone in lactating cows. J. Dairy Sci. 69:44–51.

Metz, S.H.M., and S. G. van den Bergh. 1977. Regulation of fat mobilization in adipose tissue of dairy cows in the period around parturition. Neth. J. Agric. Sci. 25:198–211.

Moe, P. W. 1981. Energy metabolism of dairy cattle. J. Dairy Sci. 64:1120–1139.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

Neilson, D. R., C. T. Wittemore, M. Lewis, J. C. Alliston, D. J. Roberts, L. S. Hodgson-Jones, J. Mills, H. Parkinson, and J.H.D. Prescott. 1983. Production characteristics of high-yielding dairy cows. Anim. Prod. 36:321–334.

Rastani, R. R. 2000. Body Composition and Energy Mobilization in Early Lactation Jersey and Holstein Dairy Cattle. M. S. Thesis, University of Connecticut, Storrs.

Roe, M. B., C. J. Sniffen, and L. E. Chase. 1990. Techniques for measuring protein fractions in feedstuffs. Pages 81–89 *in* Cornell Nutr. Conf., Cornell Univ., Ithaca, NY.

SAS User's Guide: Statistics, Version 7 Edition. 1997. SAS Inst., Inc., Cary, NC.

Solis, J. C., F. M. Byers, G. T. Schelling, C. R. Long, and L. W. Greene. 1988. Maintenance requirements and energetic efficiency of cows of different breed types. J. Anim. Sci. 66:764–773.

Tyrrell, H. F., C. K. Reynolds, and H. D. Baxter. 1990. Energy metabolism of Jersey and Holstein cows fed total mixed diets with or without whole cottonseed. J. Dairy Sci. 73(Suppl. 1):192. (Abstr.)

Van Soest, P. J., and D. G. Fox. 1992. Discounts for net energy and protein. 5th Rev. Pages 40–69 *in* Proc. Cornell Nutr. Conf. Cornell Univ., Ithaca, NY.

Vazquez-Anon, M., S. Bertics, M. Luck, R. R. Grummer, and J. Pinheiro. 1994. Peripartum liver triglyceride and plasma metabolites in dairy cows. J. Dairy Sci. 77:1521–1528.

Waltner, S. S., J. P. McNamara, and J. K. Hillers. 1994. Validation of indirect measures of body fat in lactating cows. J. Dairy Sci. 77:2570–2579.

Wright, I. A., and A. J. F. Russel. 1984. Partition of fat, body composition and body condition score in mature cows. Anim. Prod. 38:23–32.