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Body Composition of Dairy Cows According to Lactation Stage, Somatotropin Treatment, and Concentrate Supplementation

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ABSTRACT

Body weight, condition score, deuteriated water dilution space, estimated body lipids and proteins, and calculated energy and protein balances were determined in 24 multiparous Holstein cows at wk 1, 7, 20, and 39 after parturition. Cows received two levels of energy concentrate (high and low groups) from wk 3. The objective was to estimate changes in body composition as affected by stage of lactation, concentrate level, and bST administration or placebo from wk 9 in a 2 x 2 factorial design.

Cows from high and low energy groups lost 25 and 35 kg of body lipids and 3.3 and .5 kg of body proteins, respectively, during the first 7 wk of lactation. During the end of the winter period (wk 8 to 20), control and bST-injected cows lost 8.5 and 21.1 kg of body lipids, respectively. During the grazing period (wk 20 to 39), bST-injected cows gained more BW (34 kg), water (36 kg), and estimated proteins (5.8 kg) and lost more condition score (–.2 units) and estimated lipids (-11.5 kg) than controls.

Using data from control periods, it was calculated that 1 unit change in body condition score corresponded to changes of 35 to 44 kg in BW (corrected for estimated gut content variation), 21 to 29 kg in body lipids. and 200 to 300 Mcal in body energy. One kilogram of corrected BW change corresponded to a change of 4.3 or 5.5 to 5.9 Mcal in body energy when calculated from cumulative energy balances or body components, respectively.

(Key words: cow, lactation, somatotropin, body composition)

Abbreviation key: BCS = body condition score, CEB = cumulative energy balance, DW = deuteriated water, DWS = deuteriated water space, EB = energy balance.

INTRODUCTION

During a lactation cycle, dairy cows are successively mobilizing and storing body reserves. Tissue mobilization during the first 2 mo of lactation is from 15 to 60 kg of lipids (6, 20) and from 0 to 15 kg of proteins (8) according to milk potential, diet composition, level of feeding, and body condition at calving (14, 18).

Increase in mobilization or decrease in deposition of body fat was observed in bST-treated cows during short trials (8 wk) (5) or when the same diet was given for ad libitum intake to bST and control cows (7, 21, 30).

The aim of the present study was to estimate changes in dairy cow body composition during one lactation cycle according to lactation stage, concentrate supply, and bST treatment.

MATERIALS AND METHODS

Animals and Treatments

Twenty-four multiparous Holstein cows received com silage for ad libitum intake during the dry period and the first part of lactation (winter period). Cows calved from the end of October to the end of December 1986. After wk 24 (± 2) of lactation, they were turned out to pasture.

Concentrate was fed in fixed quantity during wk 1 (4.1 kg/d) and wk 2 (5.7 kg/d)

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TABLE 1. Composition and nutritive value means for diets ingested by each nutritional group during the winter period.[1]

	wk 1 to 8		wk 9 to 18	
	High	Low	High	Low
Ingredient, % DM				
Corn silage[2]	59.1	68.6	68.9	83.9
Protein-rich concentrate[3]	7.6	11.7	4.8	9.5
Energy-rich concentrate[4]	30.9	17.3	23.5	4.5
Urea[5]	1.2	1.2	1.3	1.1
Mineral-rich concentrate[6]	1.2	1.2	1.5	1.5
Nutritive value, per kg DM				
Energy,[7] Mcal NE_L	1.62	1.63	1.60	1.64
CP, g	167	177	156	160
PDI, g	99	103	89	94

[1]Weeks of lactation and level of energy concentrate. CF = Crude fiber, PDI = protein digestible in the intestine, calculated as by Rémond et al. (26).

[2]Dry matter containing 39% grain, 94.5% OM, 18.8% CF, and 9.2% CP.

[3]Formaldehyde-treated soybean (80%) and rapeseed (20%) meals; DM containing 92.5% OM, 8.1% CF, and 47.3% CP.

[4]Ingredients in percentage: wheat, 10; maize, 10; barley, 32; dehydrated alfalfa, 10; dry beet pulps, 25; soybean meal, 5; wheat bran, 5; dicalcium phosphate, 1.5; calcium bicarbonate, 1; salt, .5. DM containing 92.8% OM, 10.4% CF, and 13.7% CP.

[5]Dry matter containing 100% OM and 288% CP.

[6]Commercial supplement containing: Ca, 22.346, P, 8.3%; NaCl, 10%; Mg, 4%; S, 2%; Zn, 4000 ppm; Mn, 3000 ppm; Cu, 800 ppm; I, 60 ppm; Co, 20 ppm; Se, 5 ppm; vitamins (for 100 kg of feed): vitamin A, 25,000,000 IU; vitamin D_3, 8,000,000 IU; vitamin E, 10 g. DM containing 13.2% OM.

[7]Calculated from OM digestibility of corn silage and taking into account the negative effects of percentage of concentrate and level of DMI (26).

postpartum. From wk 3 onward, it was fed according to the expected milk yield calculated from the observed milk yield during the first 2 wk using standard lactation curves recorded in the same herd. At the beginning of wk 3, cows were allotted to two nutritional groups, receiving a high or low level of energy concentrate. During the winter period, cows in the high and low groups received daily 2.5 Mcal NE_L more (approximately 1.3 kg DM of concentrate) and 4.2 Mcal NE_L less (approximately 2.2 kg DM of concentrate), respectively, than the recommended energy supply (730 kcal NE_L/kg 4% FCM) necessary to satisfy the difference between expected milk yield and the yield assumed to be covered (in excess of maintenance requirement) by corn silage intake at wk 5 of lactation: 16 kg of 4% FCM. Cows were adapted to the high or low concentrate level during wk 3 and 4 postpartum. The maximum theoretical supply of concentrate was reached at wk 5 and decreased thereafter. All diet ingredients (Table 1) were fed together once a day and mixed in the manger.

During the grazing period, cows of the low group were fed concentrate (twice a day in the milking parlor) from a milk yield of 12 kg/d higher than the yield from which the high group began to receive concentrate. The milk yield assumed to be satisfied by grass alone declined during the grazing season according to grass availability and quality.

The composition (proportions of grain and cakes) of the concentrates offered to the high and low groups was calculated (Table 1) so that the total protein supply would be the same, assuming that the low group should compensate for half of the difference in concentrate supply by increasing corn silage DMI. Milk recording and calculations of energy and protein balances were as described previously (26).

From wk 9 to 39 postpartum, half of cows of each nutritional group were biweekly injected subcutaneously with either 500 mg of recombinant methionyl bST in a slow release preparation (Sometribove, Monsanto, St. Louis, MO) or placebo.

Measurements and Analyses

Body condition was scored [scale from 0 to 5 (22)], and body water was estimated (28, 31) at wk 1, 7.2 (SD = .5), 20.5 (±1.1), and 38.7 (± 3.1) of lactation. Deuteriated water (DW, 99.8% purity; Commissariat à l'Energie Atomique, Gif sur Yvette, France) was injected (.5 g/kg BW) intravenously between 0800 and 0900 h. Milk was used to determine the decrease in the DW concentration because it gave the same results as blood (10, 20).

Milk was sampled from six consecutive milkings (at 0700 and 1600 h), i.e., at approximately 8, 23, 32, 47, 56, and 71 h after DW injection. Previous work showed that equilibrium of blood DW was reached 6 to 8 h after injection (28). Milk samples were stored at −25°C. Milk water was extracted by deep freezing and vacuum evaporation at room temperature. Concentration of DW in milk water was measured (31) in duplicate by infrared spectrometry at 2512 mn using a double beam apparatus (Perkin-Elmer 180, Norwalk, CT); DW space (DWS) was calculated from the DW concentration at zero time. This concentration was obtained from semilogarithmic plot of DW concentration against time of sampling after the DW injection (28).

Body weight of the cows was registered at 1400 h (i.e., 5 h after a.m. feeding) during 3 consecutive d after DW infusion. Body lipids and proteins were calculated (28) using equations previously calibrated (10) on 20 Holstein multiparous cows (12 dry, 4 at wk 1, and 4 at wk 8 of lactation; 8 fat, 8 lean, and 4 in medium body condition). These cows were fed a corn silage-based diet. Their body composition was measured after slaughter by chemical analysis of the whole body. Equations were

$$\begin{aligned}\text{Lipids (kg)} &= .903 \times \text{BW (kg)} \\ &\quad - 1.135 \times \text{DWS (kg)} \\ \text{Proteins (kg)} &= .088 \times \text{BW (kg)} \\ &\quad + .075 \times \text{DWS (kg)}\end{aligned}$$

Accuracy of the prediction (estimated by the residual SD) was 7.5 kg (8.7%) for lipids and 2.0 kg (2.5%) for proteins (10).

The first three measurements of DWS were during the winter period. Because the fourth measurement was done after 14 wk at pasture, cows were stabled for 18 d just before the last DWS measurement; they had free access to the same mixed diet as at the end of the winter period in order to equalize the digestive contents among DWS determination periods.

Changes in body energy were calculated by two different methods. The first was based on changes in body components (net energy) using values of 9.4 and 5.7 Mcal/kg of lipids and proteins, respectively. The second was from energy balances (EB), calculated as in Rémond et al. (26) aud cumulated during the corresponding periods as EB (Mcal NE_L) during weeks of positive EB and EB/.8 during weeks of negative EB (11). These calculations are based on the assumptions that metabolizable energy is used with the same efficiency for body energy deposition and milk energy secretion and that mobilized body energy is used for milk secretion with an efficiency of 80% (9).

Changes in BW were corrected for expected changes in digestive contents related to variations in DMI [corrected BW (kg) = BW (kg) − 4 x DMI (kg)]. The coefficient of correction was from the absolute variation in ruminal content that was measured with the same diet [+ 3 kg/kg increase in DMI (25)], and an additional increase in intestinal content was assumed to be 1 kg/kg DMI (8).

Data were analyzed using variance-covariance analysis, taking into account effects of bST treatment, energy concentrate supply, and their interaction and using the milk yield of the first 2 wk postpartum as covariate. Probabilities of 10, 5, and 1% were used.

RESULTS

Early Lactation

Mean BW, body water, body lipids, body protein, and body condition score (BCS) at calving were 640, 411, 100, 87 kg, and 3.0, respectively (Figure 1). During the first 2 mo of lactation (Table 2), cows receiving the highest level of energy concentrate lost more BW or corrected BW (16 to 18 kg; nonsignificant) and body proteins (2.5 kg; $P < .05$) and less body lipids (9.0 kg; nonsiguificant) than those receiving the low level, i.e., cows that ingested 1.5 kg/d less concentrate DM. Calculated EB was not different between groups, although calculated protein balance was lower in the high group [−98 g/d, expressed in protein digestible in the intestine; (26)].

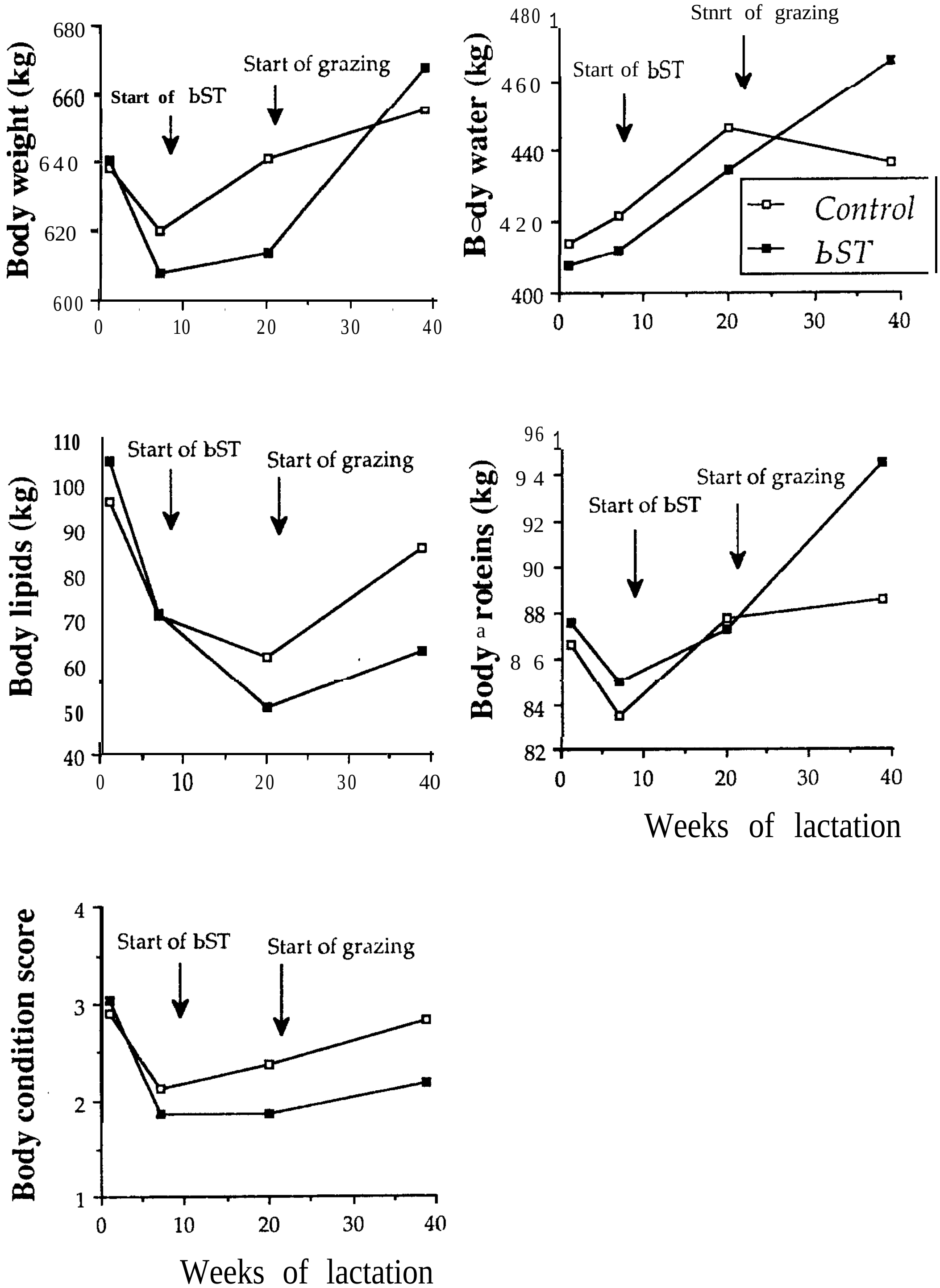

Figure 1. Change in BW, water, lipids, proteins, and condition score (22) in control (n = 11 or 12) and bST-treated cows (n = 11 or 12) throughout lactation.

TABLE 2. Nutritional balances and changes in body components during the first 8 wk of lactation.

	High[1]	Low[1]	Estimated effects[2]		
			Concentrate		Residual SD[3]
	(n = 11)	(11 = 12)			
Nutritional balances[4]					
Milk yield, kg/d	29.6	29.8	.02	NS	2.6[a]
DMI, kg/d	16.1	16.7	–.6	NS	1.1
Concentrate intake, kg/d	6.6	5.1	1.5	**	.4
Energy balance, Mcal NE_L/d	-4.9	–4.5	–.4	NS	2.9[a]
Protein balance, g/d	-150	-55	-98	*	88
Body component changes[5]					
BW, kg	-33.9	-18.7	-15.7	NS	22.6
Corrected BW,[6] kg	-57.5	-39.7	-18.3	NS	22.4”
Condition score	-1.09	–.92	–.14	NS	.73
Water, kg	–4.5	15.4	-20.0	*	17.4
Proteins, kg	-3.3	–.5	-2.9	*	2.6[a]
Lipids, kg	-25.5	-34.7	9.0	NS	25.2
Energy, Mcal					
From body components[7]	-258	-329	68	NS	240
From energy balance[8]	-340	-320	-25	NS	173[a]

[1]Level of concentrate, unadjusted means.

[2]Level of concentrate (high minus low) effect was significant (**$P < .01$, *$P < .05$) or NS ($P >$ J0).

[3]Covariate effect was significant ([a]$P < .01$) or NS ($P > .10$).

[4]Week 1 to 8 of lactation (including wk 1 and 2, i.e., the preexperimental period).

[5]Week 7.2 ± .5 minus wk 1 of lactation (including wk 1 and 2, i.e., the preexperimental period).

[6]BW minus (4 x DMI) (see Materials and Methods).

[7]Calculated from the enagy value of body component changes (see Materials and Methods).

[8]Calculated from cumulative energy balances over the period (see Materials and Methods).

Period of bST Treatment

During the winter period (Table 3), cows from the high groups ingested 2.9 kg DM/d more concentrate than those from the low groups but lowered their com silage intake so that their total DMI was not different. No significant differences in body component variations were observed. Cows injected with bST yielded 3.2 kg/d more milk than controls without increasing total DMI. Although calculated energy and protein balances were significantly decreased by bST, the trends to lower gains in BW or corrected BW (-16 to -19 kg), body proteins (-1.5 kg), and BCS (–.3) and. to higher losses in body lipids (-13.1 kg) than in controls (Figure 1) were not significant.

During the grazing period (Table 4), the slight difference in concentrate level (.9 kg/d) between high and low groups did not affect any measured parameters. Injection with bST significantly increased gains in BW or corrected BW (+32 to 34 kg) and body proteins (+5.8 kg) (Figure 1). It tended to decrease gains in body lipids (-11.5 kg) and BCS (–.2), but not significantly.

During the whole period of bST injection (Table 4), bST significantly increased gains in BW (+24 kg), body water (+38 kg), and body proteins (+5.0 kg), whereas it significantly decreased gains in body lipids (-23 kg) and BCS (–.5).

Relationships Between Different Estimators of Body Components

Computations based on 71 observations (from all cows during control periods only) showed that BCS predicted corrected BW (44 kg/point), body lipids (29 kg/point), and body energy (297 Mcal/point) more closely than body proteins (3.9 kg/point) (Table 5 and Figure 2). When they had the same BCS, bST-injected cows at wk 39 tended to have higher corrected BW and lower body lipids than controls (Figure 2) due to their higher body water (Figure 1).

TABLE 3. Nutritional balances and changes in body components during the winter period of bST treatment.

	High[1]		Low[1]		Estimated effects[2]		
	bST	Control	bST	Control	Concentrate	bST	Residual SD[3]
	(n = 6)	(n = 5)	(n = 6)	(n = 7)			
Nutritional balances[4]							
Milk yield, kg/d	28.5	27.1	29.9	25.7	−.6 NS	3.2 †	4.2’
DMI, kg/d	17.8	18.8	18.0	17.5	.5 NS	−.2 NS	1.6[b]
Concentrate intake, kg/d	5.4	6.0	2.9	2.8	2.7 **	−.2 NS	1.2
Energy balance, Mcal NE_L/d	−.5	1.9	-1.4	1.7	.8 NS	-2.9 **	1.98
Protein balance, g/d	−96	26	-21	70	-58 *	-108 **	54
Body component changes[5]							
BW, kg	11.0	27.8	.7	16.8	10.5 NS	-16.1 NS	24.9
Corrected BW,[6] kg	3.8	28.0	3.8	16.9	5.5 NS	-18.7 †	24.6
Condition score	−.08	.30	.08	.21	.0 NS	−.29 NS	.46[a]
Water, kg	30.3	24.8	15.2	24.3	7.1 NS	-1.3 NS	18.5
Proteins, kg	3.3	4.3	1.2	3.3	1.5 NS	-1.5 NS	3.2
Lipids, kg	-25.2	-3.8	-17.0	-13.1	1.3 NS	-13.1 NS	21.8
Energy, Mcal							
From body components[7]	-218	-11	-153	-104	21 NS	-132 NS	209
From energy balance’	-44	179	-107	140	68 NS	−246 **	187[a]

[1]Level of concentrate, unadjusted means.

[2]Level of concentrate (high minus low) and bST treatment (bST minus control) effects were significant (** $P < .01$, * $P < .05$, † $P < .10$) or NS ($P > .10$).

[3]Covariate effect was significant ([a] $P < .01$, [b] $P < .05$) or NS ($P > .10$).

[4]Week 9 to 18 of lactation.

[5]Week 20.5 ± 1.1 minus wk 7.2 ± .5 of lactation.

[6]Corrected for DMI (see Materials and Methods).

[7]See Materials and Methods.

Correlation coefficients between estimators, and slopes of the regressions, generally were lower when changes between two consecutive measurements during control periods were considered instead of absolute values (Table 5). During the first 2 mo of lactation, the decrease in BCS was more variable than was the decrease in corrected BW (Figure 3A). During declining lactation, there were great changes in corrected BW without corresponding changes in BCS. As a result, the relationship between BCS and corrected BW was not linear (Figure 3A).

Using absolute values, changes in body energy (estimated from DWS) were 297 Mcal/unit of BCS and 5.9 Mcal/kg of corrected BW (Table 5). The corresponding values were calculated to be 207 and 5.5 Mcal when using changes between consecutive periods (Table 5). Cumulative EB (CEB) was 187 and 4.3 Mcal/unit of BCS change and per kg of corrected BW change, respectively, during the same periods (Table 6). Prediction of CEB by changes in BCS or corrected BW, however, was more precise (residual SD = 133 to 150 Mcal; Table 6) than that of change in body energy (residual SD = 204 to 249 Mcal; Table 5). When different periods and treatment groups were separated, the slope of the regression between change in corrected BW and change in body energy tended to be stable although intercepts were changing (Figure 3B). Body energy gain for a given gain of corrected BW tended to be lower in bST-supplemented cows and in control cows during the period from wk 8 to 20.

DISCUSSION

Early Lactation

The loss of 25 to 35 kg of body lipids during the first 2 mo of lactation agrees with

TABLE 4. Milk yield, concentrate intake. and changes in body components during grazing and whole periods of bST treatment.

	High[1]		Low[1]		Estimated effects[2]		
	bST	Control	bST	Control	Concentrate	bST	Residual SD[3]
Grazing period[4]							
Number of cows	5	5	6	7			
Milk yield, kg/d	20.3	19.1	19.3	17.8	.8 NS	1.5 NS	3.3[b]
Concentrate intake, kg/d	1.05	1.26	.23	.27	.89 **	–.13 NS	.44[b]
BW, kg	47.3	10.0	46.9	17.1	-4.8 NS	33.7 **	24.6
Corrected BW,[6] kg	53.9	15.2	48.7	24.3	-3.8 NS	31.9 *	27.4
Condition score	.00	.50	.42	.43	–.22 NS	–.25 NS	.49[b]
Water, kg	26.8	-1.2	28.6	-15.3	4.5 NS	36.2 **	14.7[b]
Proteins, kg	6.2	.8	6.3	.3	-.1 NS	5.8 **	2.7[c]
Lipids, kg	11.5	10.5	9.2	33.2	-9.6 NS	-11.5 NS	23.5
Energy, Mcal							
From body components[7]	144	103	123	314	–90 N S	-76 NS	227
Whole period[5]							
Number of cows	5	5	6	7			
Milk yield, kg/d	22.8	21.2	22.6	20.0	.2 NS	2.2 NS	3.4[a]
BW, kg	71.3	37.7	47.6	33.8	12.5 NS	23.9 †	31.8
Corrected BW,[6] kg	69.0	43.1	52.6	4[illegible] .64	7.8 NS	18.8 NS	33.7
Condition score	–.10	.80	.50	9.0	–.20 NS	–.52 †	.69
Water, kg	64.5	23.6	43.8		15.2 †	38.2 **	17.7[a]
Proteins, kg	11.2	5.1	7.5	3.7	2.3 NS	5.0 **	3.5[c]
Lipids, kg	-10.3	6.7	-7.8	20.1	-6.3 NS	-22.8 †	29.9
Energy, Mcal							
From body components[7]	-33	92	-30	210	-46 NS	-185 NS	290

[1]Level of concentrate, unadjusted means.

[2]Level of concentrate (high minus low) and bST treatment (bST minus control) effects were significant (** $P < .01$, * $P < .05$, † $P < .10$) or NS ($P > .10$).

[3]Covariate effect was significant ([a] $P < .01$, [b] $P < .05$, [c] $P < .10$) or NS ($P > .10$).

[4]Mean (April 27 to August 5) for milk yield and concentrate intake or difference (wk 38.7 ± 3.1 minus wk 20.5 ± 1.1 of lactation) for body components.

[5]Mean (wk 9 to 39 of lactation) for milk yield or difference (wk 38.7 ± 1.1 minus wk 7.2 ± .5 of lactation) for body components.

[6]Corrected for DMI (see Materials and Methods).

[7]See Materials and Methods.

estimations by in vivo methods. Using DWS measurement, a loss of 17 kg from wk 1 to 8 of lactation was observed by Chilliard et al. (11) in multiparous cows of lower milk potential fed for ad libitum mtake than in the present study. From wk 1 to 12, decreases of 24 and 33 kg were found by Vérité and Chilliard (32) in primiparous (yielding 7050 kg of milk) and multiparous (yielding 8370 kg of milk) cows fed for ad libitum intake, respectively. Martin and Ehle (20) observed a 34-kg decrease (including the gravid uterus) between 1 mo before and 1 mo after parturition and a further 15-kg decrease during mo 2 of lactation. Using ^{40}K measurement, Belyea et al. (3) reported a 48-kg decrease in body plus fetal lipids from wk -1 to 2 of lactation in cows fed for ad libitum intake yielding 7368 kg of milk on average and a further 9-kg decrease from wk 2 to 8.

Using changes in subcutaueous adipocyte diameter and equations calibrated on previously slaughtered cows, Gagliostro and Chilhard (17) observed a 28-kg decrease in body lipids in fistulated cows fed for ad libitum intake that lost 58 kg of empty BW (measured

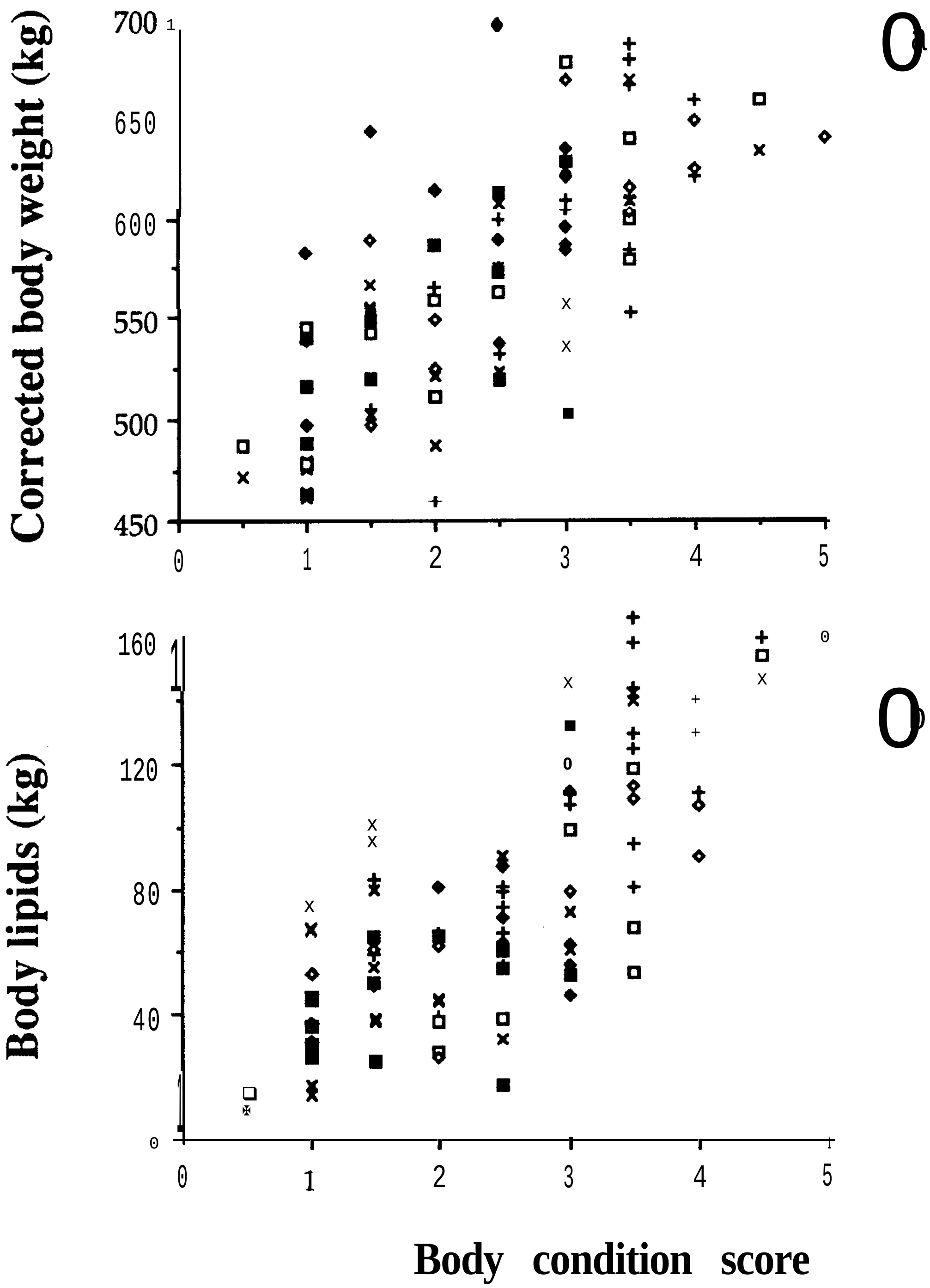

Figure 2. Relationships between body condition score, corrected BW, and body lipids. +, X = wk 1 and 7 in all cows (n = 47); ☐, o = wk 20 and 39 in control cows (n = 24); ■ . ♦ = wk 20 and 39 in bST cows (n = 23).

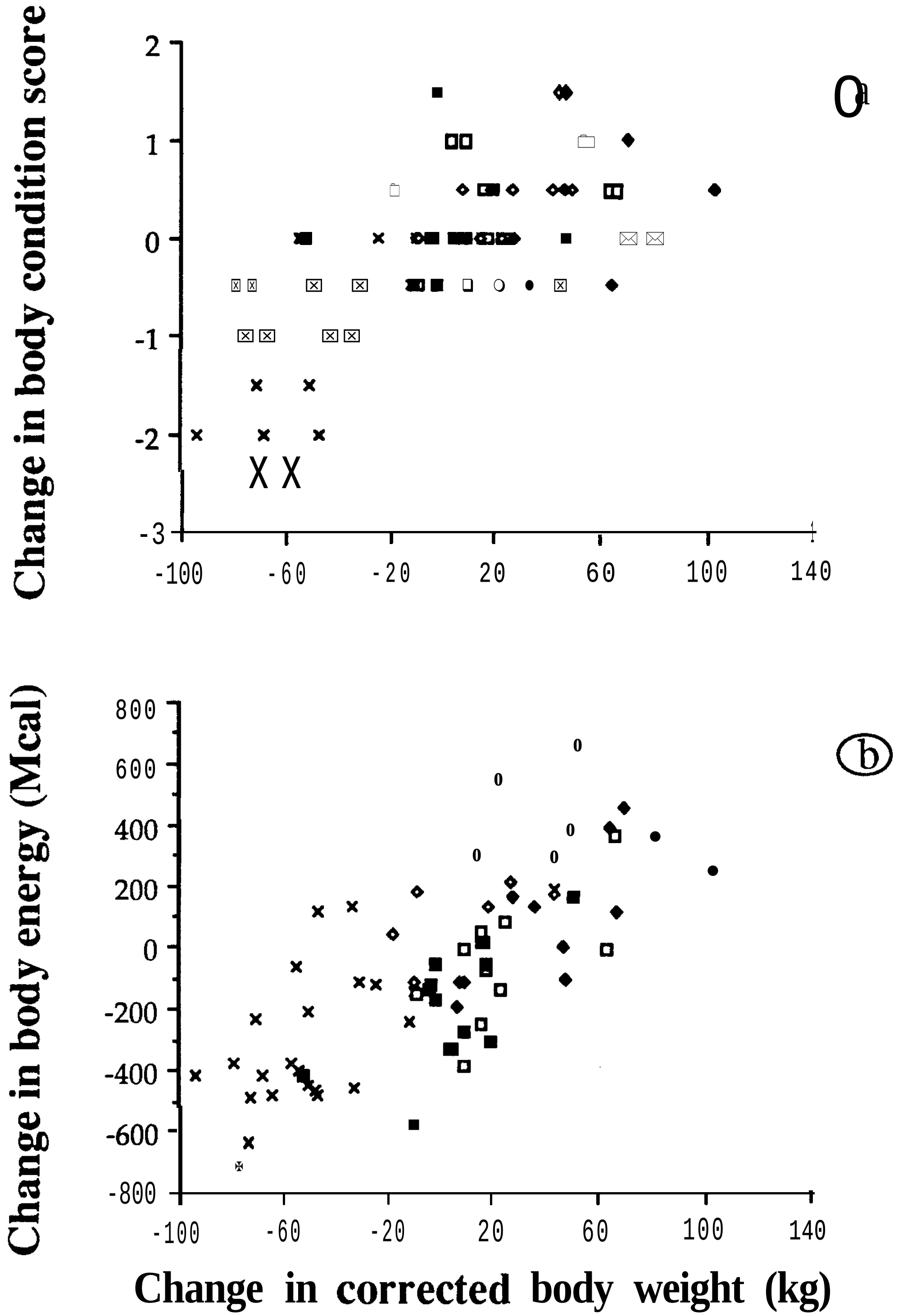

Figure 3. Relationships between change in **corrected** BW, change in body condition score, and change in **body energy** (from body components). X = wk 7 minus wk 1 in **all cows (n** = 23); ❐ = wk 20 minus wk 7 in control **cows** (n = 12); 0 = wk 39 **minus** wk 20 in **control cows** (n = 12); ■ = wk 20 **minus** wk 7 **in bST cows** (n = 12); ♦ = wk 39 minus wk 20 **in bST cows** (n = 11).

TABLE 5. Linear regressions (Y = a + bX) behveen estimators of body components.[1]

Y	X	a	b	r	rSD	a'	b'	r'	rSD'
BW, kg	BCS	533	39.7	.77	37	4	24.9	.71	23
cBW, kg	BCS	459	44.4	.81	36	2	35.2	.76	29
Lipids, kg	BCS	8	29.2	.79	25	-5	20.6	.59	27
Proteins, kg	BCS	78	3.9	.67	4.9	-1	2.3	.57	3.2
Body energy[2]	BCS	519	297	.80	246	39	207	.62	249
Body energy	BW, kg	-2500	5.9	.83	228	79	6.7	.71	224
Body energy	cBW, kg	-2090	5.9	.87	200	32	5.5	.76	204

[1]a, b, r, rSD = Absolute values (n = 71) from all cows at wk 1 and 7 and from control cows at wk 20 and 39; a', b', r', rSD' = gains (n = 47) behveen two consecutive measurements in the same cows; BCS = body condition score; cBW = corrected BW; rSD = residual SD.

[2]Megacalories of body energy calculated from body components (see Materials and Methods).

after rumen emptying) from d 2 to 21 of lactation. Direct comparisons between in vivo estimates and data from the chemical analysis of slaughtered cows are not easy to make because invasive techniques do not allow the body composition of the same cow at the different physiological stages to be taken into account (5, 8).

Integrations from repeated calorimetric measurements suggested that body fat mobilization during the first 2 mo of lactation was between 20 and 60 kg for different groups of cows (9, 14). Comparisons in the same cows between changes in body energy (from body components predicted from DWS) and CEB (taking into account digestibility measurements) showed lower changes when estimated with the DWS technique [(1 1) and Table 2].

The reasons for these discrepancies are not clear. Problems arising from biases due to calibration on animals differing in age or diets (5) or due to short-tenu equilibration between DW and water in different parts of the body (14) do not seem to be involved in our application of the technique (see Materials and Methods). Discrepancies between estimates of changes in body energy from DWS and from CEB were higher in early lactation when energy and protein balances were negative (11) or when protein balance was more negative (high group, Table 2). A higher efficiency in the use of mobilized energy was observed in lactating ewes that were mobilizing more body proteins (19). Such an effect in dairy cows could partly explain the overestimation of body energy changes when calculated from CEB assuming that 80% of the mobilized energy was used as NE_L.

The main effect of the high level of concentrate dming early lactation was to decrease protein balance significantly because this concentrate had a lower protein content (to equal-

TABLE 6. Linear regressions (Y = c + dX) between cumulative energy balance (CEB) and gains in body condition score (BCS), BW, corrected BW (cBW), or plasma NEFA during the winter period.[1]

Y	X	c	d	r	rSD[2]
CEB[3]	BCS	-82	187	.74	150
CEB	cBW, kg	-133	4.9	.71	156
CEB	NEFA, μM[4]	-87	4.3	.80	133
CEB		23	–.41	–.79	137

[1]Data (n = 47) from 24 cows during two periods (wk 1 to 7 and 8 to 20).

[2]Residual SD.

[3]Megacalories of body energy, calculated from cumulative energy balance as described in Materials and Methods.

[4]Values from Cissé et al. (12). The correlation coefficient was slightly improved using log(NEFA) (r = –.82) or $(NEFA)^{1/2}$ (r = –.83) instead of NEFA.

ize the expected protein intakes), and com silage voluntary intake was decreased more than expected (26). This can explain the significant decreases in body water and proteins in this group (Table 2) and, hence, the higher nonsignificant loss of BW. The protein loss (3.3 kg) was lower than that observed previously in underfed cows (6 to 13 kg) but higher than in well-fed cows (1 kg) during the same period (10). The initial values (86 to 88 kg of body pmtein, Figure 1) were well in the range (85 to 90 kg) observed in slaughtered early lactating cows (10, 14, 21).

Declining Lactation

Control Cows. From wk 8 to 20, control cows recovered body proteins lost during early lactation (Figure 1), as observed previously (9). However, they continued to lose some body lipids (4 to 13 kg), contrary to previous results (3, 11, 20) aud despite being in positive calculated EB (Table 1). During the grazing period, there was no further increase in body proteins, whereas body lipids were partially recovered (Figure 1). These results suggest that body lipid changes are not always paralleled by protein changes.

bST-Injected Cows. Body lipids tended to be decreased further by bST injection during the winter period (13 kg below controls) in accordance with the decrease in EB (Table 3) and the increase in blood NEFA of these animals (12). Decreases in EB (7.23). BCS (1, 33), and body lipids (-17 kg) (5) generally were observed during the first 6 to 8 wk of bST treatment, a period in which energy intake was never increased significantly.

The tendency of bST to decrease body lipid deposition during the grazing period (Table 4) can be due to the low concentrate supply combined with the medium quality of available pasture that did not allow bST-injected cows to ingest more energy than the control cows. Other long-term studies also showed lower EB and lipid deposition in bST-treated animals, either when the same total mixed diets were fed for ad libitum intake [-16 to -69 kg of lipids after 36 wk of bST (30); -5 to -35 kg of lipids after 18 wk of bST (21)] or when lirnited concentrates were offered separately from com silage [–42 kg of lipids after 24 wk of bST, Vérité and Chilliard, quoted by Chilliard (7)]. This was in contrast with results in trials in which bST-injected cows received much more concentrate than controls according to individual milk yield and body condition. These cows increased their calculated EB and gained more body condition during the last months of bST treatment, so as to recover ahnost completely the higher BCS loss that was previously observed during the first 6 to 8 wk of bST injection (1, 7, 23).

The bST had no effect on body water and proteins during the winter period although it decreased sharply the calculated protein balance (Table 3). This probably can be related to the N-sparing effect of bST and to the decreased urinary N excretion (29) that was confixmed in these cows by a decreased uremia (12). In contrast, during the grazing period, bST sharply increased body water (36 kg above controls), corrected BW (34 kg), and body proteins (Table 4). The increase in estimated body proteins (6.2 kg in absolute value), however, was surprisingly high for mature cows (32). This could be a bias due to increases in extracellular water compartments, such as gut contents or plasma volume. A 1-kg increase in the water of gut contents, for example, would increase BW by about 1 kg and estimated body proteins by about .088 + .075 = .163 kg (see Materials and Methods). During the last period of DWS measurement (wk 38 and 39 of lactation), DMI of the com silage-based diet was 16.1 kg/d in control cows and 17.1 kg/d in bST-treated cows ($P < .25$). This could lead to an increase in digestive water content by about 4 kg (see Materials and Methods), although any hypothetical residual effect of the previous pasture diet on digestive content cannot be excluded.

Furthermore, there can be an effect of bST per se, because the foregut tissue and content increased by 2 and 10 kg, respectively, in slaughtered bST cows that previously had free access to feed (5). A slower fecal excretion rate of Cr_2O_3 was observed after bST treatment (4). There also were weekly fluctuations in BW (wk 1 vs. 2) after each bST injection (24) that apparently were not related to corresponding fluctuations in feed intake. However, in another slaughter trial, gastrointestinal content (live weight minus empty BW) increased by only 5 kg in bST-treated cows (21). An increase in plasma volume (16) also could contribute slightly to the increase in body water but was not confirmed in a slaughter trial (5). Hypothetical changes in gut contents and blood volume are unlikely to explain completely the 36-kg increase in body water in bST-treated cows compared with controls. Therefore, bST may favor protein (and, hence, water) deposition during late lactation when milk protein secretion is sufficiently low or when hormonal secretions in pregnant animals can act in synergy with bST. Pregnancy stage was 146 (± 41) and 159 (± 39) d in bST-treated and control cows, respectively. This suggests that the gravid uterus (and its water content) was not heavier in treated cows.

Injection with bST decreased BCS only slightly (–.5 under controls). In a previous calibration on 49 slaughtered cows, we found that 1 unit of BCS corresponded to 28 kg of body lipids and 34 kg of BW (27). In contrast, bST treatment (Table 4) decreased body lipids more (23 kg below controls) than predicted (14 kg) from BCS change, and it increased BW (24 kg), although a decrease (-17 kg) was predicted. This can be related to the increases in body water (38 kg) and body protein (5 kg) that masked the predicted decrease in BW (38 + 5 – 17 = +26 kg). Furthermore, the small decrease in BCS may be due to a true increase in muscular mass under the skin compensating for the effect of decreasing subcutaneous fat on BCS. Decrease in BCS without significant change in BW also was observed by West et al. (33) in bST-treated cows.

Estimators of Body Components

In this trial, the relationships between BCS, BW, and body lipids estimated from DWS (using data from control periods only, Table 5 and Figure 2) were close to corresponding relationships calculated by Rémond et al. (27) from 49 slaughtered multiparous Holstein cows:

$$\text{BW (kg)} = 34.2 \times \text{BCS} + 479 \quad (r = .69;\ \text{residual SD} = 47\ \text{kg});$$

$$\text{Bdy lipids (kg)} = 27.5 \times \text{BCS} - 2.5 \quad (r = .84;\ \text{residual SD} = 23\ \text{kg}).$$

This validates both BCS and DWS techniques as useful tools for estimating body stores. Using a literature survey (18), it can be calculated from five trials on multiparous cows that 1 unit of BCS (scale 1 to 4) corresponds on average to 32 kg (± 15) of BW. A value of 56 kg of BW/unit of BCS (scale 1 to 5) was observed in culled dairy cows when using absolute values and of 32 kg of BW/unit of BCS when using changes in early lactating cows (15). There are few data conceming lipids. In nonpregnant, nonlactating Friesian cows, 1 unit of BCS (scale 0 to 5) corresponded surprisingly to 84 kg of lipids and to 110 kg of BW (35).

Changes in body energy (estimated either from body components or from CEB) were 200 to 300 Mcal/unit change in BCS and 4.3 to 5.9 Mcal/kg change in corrected BW (Tables 5 and 6). These values are somewhat lower than estimates from slaughter or feeding trials (250 to 340 Mcal and 4.9 to 7.6 Mcal for BCS and corrected BW, respectively) (8, 34).

In our trial, there was not good agreement between changes in body energy from wk 8 to 20, estimated from either body components or CEB (Table 3), contrary to a previous trial in which both estimations were largely positive from wk 9 to 18 (11). Diet digestibility was not measured in each cow in our trial. However, CEB was closely related to plasma NEFA (r = –.79, Table 6) and to change in corrected BW (r = +.80), although change in body energy (from body components) was less related to these traits (r = –.49, n = 47 with plasma NEFA; r = +.68, n = 47 with corrected BW). An unexpected higher body energy loss (for given change in corrected BW) was apparent for all individual cows from control and bST groups between wk 8 and 20 (Figure 3B). Although differences between consecutive periods represent cumulative variabilities due to DWS measurement or to changes in gastrointestinal water (that is, however, assumed to be rather constant at this lactation stage), it is difficult to explain these systematically lower means (–46 to -244 Mcal, Table 3) of changes in body energy when using the DWS technique compared with CEB. This difference corresponds to about 2 Mcal NE_L/d, i.e., to .1 Mcal NE_L/kg DMI, corresponding to about 7% of the estimated energy value of the diets (Table 1). The same apparent contradiction also was observed by Belyea and Adams (2) in cows that were in positive calculated EB

(+2.65 Mcal/d during mo 3 and 4 of lactation) without gain in body energy as estimated from whole body ^{40}K counting. The cor-relation between body energy and CEB in the present study (r = .55; n = 47), however, was only slightly lower than that (r = .69; n = 20) found in early lactating goats using a two-pool mode1 of tritiated water kinetics to estimate lipid changes (13). A better knowledge of changes in gut water content and improvement of methods to predict them probably would improve in vivo studies on body composition.

CONCLUSIONS

During 30 wk of bST administration, cows gained more BW, water and proteins, and less body lipids than controls. There generally was good agreement among traits such as BW, body water, BCS, CEB, and plasma NEFA that were measured independently. However, the loss of body energy apparently was overestimated during wk 8 to 20 of lactation when predicted from DWS. Results suggest that bST-treated cows need more concentrates than controls in order to achieve the repletion of body fat before the dry period.

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