PHYSIOLOGY AND MANAGEMENT

Effect of Body Condition Score at Calving on Performance, Some Blood Parameters, and Milk Fatty Acid Composition in Dairy Cows

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ABSTRACT

Effect of body condition score at calving and of change in body condition score on productive and reproductive performance, on lactation curve parameters, and on postpartum disease occurrence was investigated in 213 Italian Holstein-Friesian cows. Plasma FFA, glucose, and insulin concentrations and milk fatty acid composition were analyzed in 15 cows. The cows calving at highest body condition score lost more subcutaneous fat; condition score change did not exceed 1.05 units. Change in body condition score was positively associated with peak and total milk production.

Occurrence of retained placenta was not related to the content of fat stores at calving. Glucose concentrations were relatively constant, FFA concentrations were highest, and insulin concentrations were lower in cows calving at the highest body condition score. Milk fatty acid composition reflected the different utilization of body fat stores.

(**Key words**: body condition score, performance, blood parameters, fatty acids in milk)

Abbreviation key: **BCS** = body condition score, **BCSC** = body condition score change.

INTRODUCTION

Energy reserves in the dairy cow are stored as lipid in adipose tissue and support, during the 1st mo of lactation, about 33% of milk production (2). After parturition, lipogenesis and esterification decrease, and lipolysis and release of FFA increase, because of hormonal influence, including diminished insulin (12). Moreover, adipocytes of cows with high genetic merit are more sensitive to lipolytic signals from the nervous or endocrine systems (20). The percentage of total internal fat increases significantly with lactation capability (22); total internal fat is correlated with subcutaneous fat (27). Increases in body condition score (**BCS**) are associated with increases in tissue DM and ether extract percentage and decreases in crude protein and ash percentages (15). Dairy cows calving in higher body condition have adequate fat reserves to support milk production but often have lower feed intake (4), thus increasing negative energy balance. Negative energy balance delays the onset of ovarian activity (3) because mammary function apparently has metabolic priority over ovarian functions (24) through homeorhesis (2). Excessive body condition at parturition and extensive fat metabolism are generally associated with increased risk of postpartum health problems (5).

The purpose of this study was to examine the relationships between BCS at calving and BCS change (**BCSC**) after calving with productive and reproductive performance. In addition, the effect of BCS at calving on the incidence of retained placenta and the metabolic profile were considered.

MATERIALS AND METHODS

Cows

The study included 213 Italian Holstein-Friesian cows during a 2-yr period in three herds in northern Italy. All cows were housed

Received October 6, 1992.
Accepted May 10, 1993.
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in free stalls, were fed a total mixed ration, and were milked twice a day.

Records

Body condition scoring was carried out by the same person according to the Agricultural Development and Advisory Service method (1) based on palpation of the transverse processes of loin vertebrae, cranial coccygeal vertebrae (tail head), and tuber ischii (pin bones). Scores were assigned using a five-point scale where 0 = very thin to 5 = grossly fat; half scores were included. Cows were scored about 2 wk before calving and subsequently every 10 d until the end of lactation. Only cows that calved with BCS of 3, 3.5, and 4 were considered because only 4 cows calved with BCS of 2.5. Milk production and fat and protein contents were recorded monthly. Milk production was measured as the deviation of 305-d lactation, twice daily milking, mature equivalent milk recorded from the adjusted herdmate average and as actual 305-d milk production. Days from calving to first AI, days open, and number of AI per conception were recorded. Because of incomplete records, only data from 209 cows were considered for lactation performance and from 188 cows for reproductive performance. Data on retained placenta were collected, and cows were classified according to the presence or absence of the disorder.

Milk and Blood Analyses

In one herd, blood and milk samples were drawn from 15 multiparous cows (equally divided in the BCS classes at calving of 3, 3.5, and 4) at 15, 30, 60, 90, and 120 DIM. Milk samples from the p.m. milking were immediately frozen at –20°C until analyses for fatty acid composition by gas chromatography (9). Blood samples were drawn from the jugular vein and immediately centrifuged. Plasma was stored at –20°C until analysis for glucose (glucose-oxidase peroxidase method), FFA (acyl-coenzyme A synthetase-acyl-coenzyme A peroxidase assay), and insulin (23) concentrations.

Statistical Methods

To provide a description of lactation curves, equations developed by Wood (26) were fitted to the monthly observations of 4% FCM for each cow to determine a scaling value estimating production at time zero (a), slope to peak (b), slope from peak (c), peak production [a $(b/c)^b \exp(-b)$], week of peak (b/c), and persistency $(c^{-(b+1)})$. The atypical lactation curves—characterized by negative values of a, b or c—were deleted from the data. One hundred eighty-five cows were considered for the subsequent analyses. The BCSC was calculated from calving to the period at which BCS reached the minimum in each BCS class (7, 10, and 12 wk, respectively, for BCS 3, 3.5, and 4).

A nonsequential least squares means ANOVA and analysis of covariance was carried out on productive and reproductive data. For statistical analyses, the general linear models procedure from SAS (19) was utilized. The general model for productive performance was

$$Y_{ijkl} = \mu + HYS_i + BCS_j + NL_k + \Sigma_{ijkl}$$

where

Y_{ijkl} = mature equivalent, 305-d milk production, lactation curve parameters;
μ = overall mean;
HYS_i = effect of herd-year-season interaction i (i = 1, . . . ,17);
BCS_j = effect of BCS j at calving (j = 1, . . . ,3);
NL_k = effect of lactation number k (k = 1, . . . ,5); and
Σ_{ijkl} = random error term with zero mean and variance.

The general model for reproductive performance was

$$Y_{ijkl} = \mu + HYS_i + BCS_j + NL_k + \Sigma_{ijkl}$$

where

Y_{ijkl} = days open, number of AI per conception, and days from parturition to first AI;
μ = overall mean;
HYS_i = effect of herd-year-season interaction i (i = 1, . . . ,17);
BCS_j = effect of BCS j at calving (j = 1, . . . ,3);

NL_k = effect of lactation number k (k = 1, . . . ,5); and

Σ_{ijkl} = random error term with zero mean and variance.

Both models were also run, replacing BCS with BCSC. Days open was dropped from the first model because it did not significantly affect productive performance. Similarly, mature equivalent and 305-d milk production were dropped from the second model because they did not significantly affect reproductive performance. Further, a summary chi-square statistic with 2 df was used to test the association of retained placenta with BCS at calving.

A multivariate ANOVA for repeated measures was developed on milk fatty acid percentages (transformed to arc sines) and on plasma parameters considering the effect of BCS at calving, calving season, lactation number, and 15 DIM. Season and lactation number did not affect the parameters considered and were not considered further. Pearson correlation coefficients were computed for the relationships among plasma components, milk fatty acid composition, milk production, and BCS at calving.

RESULTS AND DISCUSSION

Productive and Reproductive Performance

Cows belonging to BCS class of 3, 3.5, and 4 at calving had maximal loss of .6, .8, and

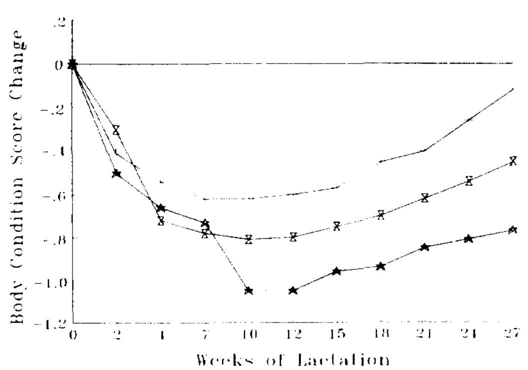

Figure 1. Postpartum body condition score change of cows calving with body condition scores of 3.0 (+), 3.5 (X), or 4.0 (☆).

TABLE 1. Lactation characteristics related to body condition score (BCS) at calving.[1]

BCS at calving	Cows	ME[2]		MP			a		b		c		PW		PP		Pers	
	(n)	$\bar{X}$	SE	$\bar{X}$	SE	n	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
3.0	43	8210	246	7668	228	43	26.1	.87	.16	.02	.028	.003	7.0	.6	29.7	.7	90	12.4
3.5	124	8075	149	7582	138	106	26.7	.56	.15	.01	.027	.002	6.5	.4	29.9	.5	90	7.9
4.0	42	8384	237	7887	219	36	26.6	.92	.16	.02	.030	.003	6.2	.6	29.9	.8	82	12.9

[1]Least squares means and standard errors for productive parameters.

[2]ME = 305-d Lactation mature equivalent, MP = 305-d lactation production, a = production at time zero, b = slope to peak, c = slope from peak, PW = peak week, PP = peak production, and Pers = persistency.

TABLE 2. Reproductive characteristics related to body condition score (BCS) at calving.[1]

BCS at calving	Cows	CFI[2]			IPC		DO	
	(n)	$\overline{X}$	SE	n	$\overline{X}$	SE	$\overline{X}$	SE
3.0	43	80.34	6.27	39	2.09	.25	121	9.3
3.5	117	80.27	3.89	108	1.94	.15	116	5.7
4.0	42	85.76	6.04	41	1.85	.23	107	8.5

[1]Least squares means and standard errors for reproductive parameters.

[2]CFI = Interval from calving to first AI, IPC = number of AI per conception, and DO = days open.

1.05 points (BCSC), respectively (Figure 1). Generally, body condition loss is closely associated with initial fat stores (7, 14). Otto et al. (15) related a live weight change of 56 kg to a 1-unit BCSC. Because a 1-kg BW loss corresponds to –4.92 Mcal of NE_L (13), a loss of 165, 220, and 289 Mcal can be assumed for cows calving with BCS of 3, 3.5, and 4, respectively. Recovery of BCS started at 10 wk for 3 and 3.5 BCS classes but was delayed until 12 wk for BCS class 4.

The BCS at calving did not influence milk production or reproductive performance (Tables 1 and 2). The BCSC was related ($P \leq .05$) to peak production (r = 1.8 kg of milk), to the lactation curve c value (r = –.0071), and to the

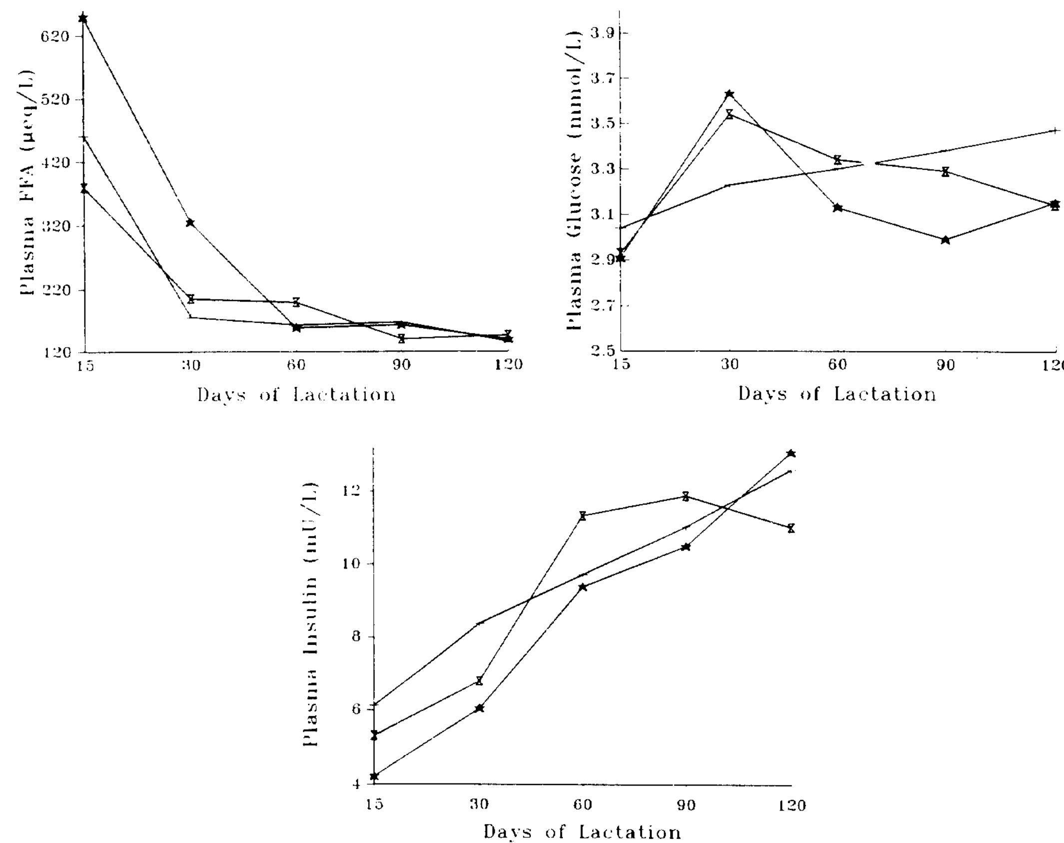

Figure 2. Blood plasma concentrations of FFA, glucose, and insulin during 120 DIM in cows calving with body condition scores of 3.0 (+), 3.5 (⧖), or 4.0 (☆).

TABLE 3. The ANOVA of productive and reproductive performance.

Sources of variance	df	MS ME[1]	MP	df	PP	c	df	CFI	df	IPC	DO
HYS[2]	16	7,447,307***	6,432,651***	16	105.95***	.0004	16	2017.76†	16	4.82***	5554**
Lactation no.[3]	4	2,065,616	8,290,741***	4	362.47***	.0004	4	364.63	4	4.74*	3944
BCSC	1	8,382,299†	5,952,010†	1	82.82*	.0013*	1	6391.13*	1	.64	1020
Residual	208	2,162,606	1,683,482	184	16.22	.0003	201	1250.68	187	1.79	2418

[1]ME = 305-d Lactation mature equivalent, MP = 305-d lactation production, PP = peak production, c = slope from peak, CFI = interval from calving to first AI, IPC = number of AI per conception, DO = days open, and BCSC = body condition score change.

[2]HYS = Herd-year-season interaction.

[3]Lactation number.

†$P \leq .10$.

*$P \leq .05$.

**$P \leq .01$.

***$P \leq .001$.

TABLE 4. The multivariate ANOVA of blood parameters.

Sources of variance	df	MS FFA	Glucose	Insulin
LS[1]	4	61,354***	.1973	8.72
LS × BCS at calving	8	21,852*	.1669	5.66
LS × MP	4	31,266*	.1494	5.08
Error	44	9033	.2904	18.29

[1]LS = Lactation stage, BCS = body condition score, and MP = milk production of 15 DIM.

*$P \leq .05$.

***$P \leq .001$.

interval from calving to first AI (r = 14.5 d) (Table 3). Although not significant, 1 unit of BCSC was associated with 438 kg of mature equivalent production ($P \leq .07$) and with 422 kg of 305-d milk production ($P \leq .06$). Our results confirm that lipid mobilization supports milk synthesis during early lactation.

The BCSC was not related to number of AI per conception or days open. Although our study did not consider ovarian activity, this lack of effect can support the hypothesis that energy balance (reflected by BCSC) only affects days to first ovulation by influencing the movement of follicles into larger size classes (10). After estrous cycles have been initiated, energy balance does not influence follicular growth or number of follicles within size classes (10) and ovarian activity (21).

Retained Placenta

Cows calving at BCS 3 showed the highest incidence of retained placenta. Markusfeld et al. (11) reported that retained placenta is not related to the nutritional status of the cow. Likewise, the incidence of retained placenta did not seem to be influenced by fat reserves at calving in the present study.

Blood and Milk Parameters

The group with 15 cows followed the same trend described for the group with 209 cows. Cows calving at BCS 4 averaged 45.07 kg of milk from 15 to 60 DIM, and cows calving at BCS 3.5 and 3 averaged 39.86 and 37.54 kg, respectively. Cows belonging to BCS classes

TABLE 5. The multivariate ANOVA of milk fatty acid (FA) composition.

Sources of variance	df	MS			
		FA			
		Short-chain	Long-chain	Unsaturated	C_4:$C_{18:1}$
LS[1]	4	18.48**	28.04*	34.30*	.00036
LS × BCS at calving	8	12.38**	24.03*	21.54*	.00073*
LS × MP	4	12.18*	14.07	20.18	.00028
Error	44	4.05	9.63	9.92	.00030

[1]LS = Lactation stage, BCS = body condition score, MP = milk production of 15 DIM.
*$P \le .05$.
**$P \le .01$.

of 3, 3.5, and 4 had maximal losses of .5, .9, and 1.05 points, respectively.

Concentration of FFA was significantly affected by lactation stage, BCS at calving, and initial milk production (Table 4). Concentration of FFA was highest at 15 d postpartum and declined steadily thereafter (Figure 2). The FFA are good indicators of energy balance (10), and their concentration reflects the active lipolysis involved in the first stage of lactation (6, 12). The cows calving at BCS 4 had higher plasma concentrations of FFA and were characterized by greater BCSC and by higher milk production. At 30 DIM, the plasma concentrations of FFA were lower than 300 μeq/L, the value considered to limit DMI (8), for cows calving at BCS 3 and 3.5, but plasma FFA remained elevated for cows calving at BCS 4.

Glucose concentration was not related to BCS at calving; values were lowest at 15 DIM (Figure 2), which can be attributed to the tendency of the cow to maintain a relatively constant glucose concentration in the blood (17).

Although not significant ($P \le .07$ at 15 DIM; $P \le .06$ at 30 DIM), insulin concentration was lower in the cows calving at BCS 4 than in the BCS 3 cows during early lactation (Figure 2). Insulin concentrations were lowest in high producing lactating cows, and these concentrations promote lipid mobilization (18).

Lactation stage and BCS at calving were significantly related to milk fatty acid composition; milk fat from cows calving at BCS 3 was characterized by the highest content of short-chain fatty acids and the lowest content of long-chain and unsaturated fatty acids (Table 5). The C_4:$C_{18:1}$ ratio was significantly higher in milk at 15 and 30 DIM from cows calving at BCS 3 (Figure 3). During early lactation, cows with low adipose reserves use body fat for milk synthesis less than the cows with high lipid stores and derive the milk fat from ingested DM. Short-chain fatty acids are synthesized from ruminal acetate, and long-chain fatty acids are derived from either body fat or, to a lesser degree, ingested lipid (16).

Pearson correlation coefficients for milk and blood parameters and for milk production for 15 DIM are listed in Table 6. Correlations were similar at 30 and 60 DIM. The BCS at calving was correlated with unsaturated fatty acids, C_4:$C_{18:1}$, insulin ($P \le .05$), and short- and long-chain fatty acids ($P \le .01$), but not with glucose and FFA. The BCS at calving was positively correlated with milk fat components derived from adipose tissue (long-chain

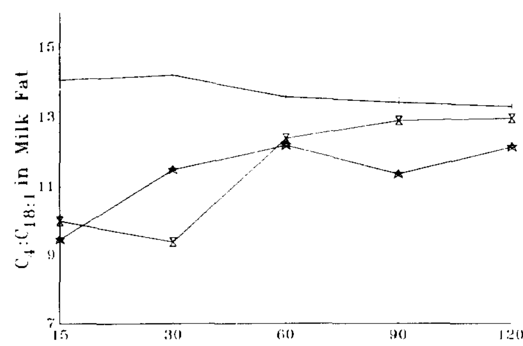

Figure 3. The C_4:$C_{18:1}$ ratio in milk fat during 120 DIM in cows calving with body condition scores of 3.0 (+), 3.5 (⩡), or 4.0 (☆).

TABLE 6. Coefficients of the correlations among blood components, milk fatty acids (FA), milk production, and body condition score (BCS) at calving at 15 DIM from parturition.

	BCS	FFA	Glucose	Insulin	FA			
					Short-chain	Long-chain	Unsaturated	C_4:$C_{18:1}$
BCS								
FFA	.338							
Glucose	-.068	-.290						
Insulin	-.515*	-.507	.271					
Short-chain FA	-.718**	-.380	-.082	.096				
Long-chain FA	.693**	.249	-.095	-.122	-.911***			
Unsaturated FA	.614*	.251	.083	-.073	-.845***	.866***		
C_4:$C_{18:1}$	-.561*	-.121	-.208	-.035	.882***	-.889***	-.825**	
Total milk production	.094	-.493	.009	.045	.009	.009	-.051	-.005

*$P \le .05$.

**$P \le .01$.

***$P \le .001$.

and unsaturated fatty acids) and negatively related to short-chain fatty acids synthetized from acetate. According to Wilson et al. (25), the relative mass of body reserves may be the dominant factor that affects the proportion of milk solids derived from body tissue in early lactation.

CONCLUSIONS

Cows that lost more body fat reserves (more loss in BCS) utilized these reserves for milk production without negative effects on reproductive performance or on the incidence of retained placenta. Plasma glucose concentrations were not related to lactation stage or BCS at calving, but lower insulin concentrations at 15 and 30 DIM reflected more active lipolysis and higher FFA concentrations in early lactation.

The present research confirms that adequate body fat reserves at calving support the energy requirements for milk production.

ACKNOWLEDGMENTS

The work was supported by Italian University, Scientific and Technological Research Ministry (60%). The authors express special thanks to Massimo Pedron for mathematical support.

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