Controlling Energy Balance in Early Lactation

Mark A. McGuire[1] Mitchell Theurer[2], John L. Vicini[3], and Brian Crooker[4]

[1]Department of Animal and Veterinary Science, University of Idaho, PO Box 442330, Moscow, ID 83844-2330,
Email: mmcguire@uidaho.edu

[2]Standard Nutrition Co., 383 East 300 South, Jerome, ID 83338
[3]Monsanto Co., 800 North Lindbergh Blvd, St. Louis, MO 63167
[4]Department of Animal Science, University of Minnesota, 205 Haecker Hall, 1364 Eckles Ave, St. Paul, MN 55108

Take Home Message

- The determination of energy balance is normally calculated using energy in minus energy out, which includes many estimates that can impact the result.
- Cows can use energy reserves in early lactation to support milk production.
- Cows return to energy balance by 6 to 7 weeks in lactation.
- High producing cows will consume more feed than lower producing cows to meet their energy needs for greater milk production.
- Dry matter intake, not milk yield, is the driving force behind energy balance in early lactation.
- Milk production is not related to body condition score or use of body reserves.

Introduction

Most cows go through some period of negative energy balance during early lactation when feed consumption does not meet demands of milk production. This period of negative energy balance has been associated with immunosuppression, periparturient diseases and increased times to first ovulation and first breeding. A period of negative energy balance should actually be expected for dairy cows. Unlike rodents and humans that rely little on energy reserves in early lactation (Bauman et al., 1985), and seals, bears and baleen whales that consume very little during lactation and rely almost entirely on energy mobilization from tissue stores (Oftedal, 1993), cows increase feed intake rapidly during early lactation to supply most of their nutrient needs. Additional nutrients are derived from tissue mobilization. Several researchers have indicated that as cows are selected for higher production, they partition a greater portion of available energy to milk rather than body tissue accretion (Bines and Hart, 1982; Bauman et al., 1985; Veerkamp and Emmans, 1995). This concept has led to the perception that high producing cows mobilize more tissue and are in greater and more prolonged negative energy balance than lower producing cows. Additionally, personal communications with dairy professionals indicate that there is a large diversity of opinions as to the expectations for the length of time that cows are in negative energy balance. Similarly, many dairy professionals and producers feel that higher production is associated with more prolonged periods of negative energy balance. Greater understanding of the changes in energy balance that occur during early lactation is important for managing herd health, reproductive programs, and POSILAC® use.

■ Methods of Measuring Energy Balance

Energy balance can be determined by either direct or indirect calorimetry; however, these techniques are expensive, involve complicated equipment and are very labor intensive. A more common method to estimate energy balance calculates the difference between energy consumed and energy required for maintenance and milk production. Advantages of this method are that it can be done for long periods, such as for an entire lactation or portions of the lactation; and, no specialized equipment is required. The disadvantage is that the results are estimates and precision of the results is dependent on how accurately energy is calculated for consumed feeds, milk produced and that required for maintenance. The consequence of errors in accurately determining these values is dependent on the purpose of the studies in question. For instance, when comparing results of treatments within a study, errors that occur across all treatments may not be as critical as when comparing results between experiments because different types of experimental error, or bias, may exist.

■ Energy Balance During Early Lactation

In order to investigate the energy balance profile during early lactation with high-producing dairy cows, a study was conducted in Idaho using 29 multiparous cows. These cows were studied for the first 12 weeks of lactation. The cows were fed using Calan gates to measure feed consumption and were

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milked 2X/d. Body weights and body condition scores were obtained weekly. Energy balance was calculated by determining NE_L Consumed (DM intake x NE_L/lb DM) minus NEL Required (NE_L for maintenance + NE_L for milk).

The average milk production during the experimental period was 46.4 kg/d. In spite of the high production of these cows, they were back in positive energy balance by an average of four weeks following calving (Figure 1). This time is similar to a study published recently that was conducted in Israel in which cows were back in positive energy balance by 4 to 5 weeks after calving (Moallem et al., 2000). Just slightly longer estimates were obtained in other studies in which cows returned to positive energy balance between six and eight weeks of lactation (Staples et al., 1990; Block et al., 2001; Heuer et al., 2001).

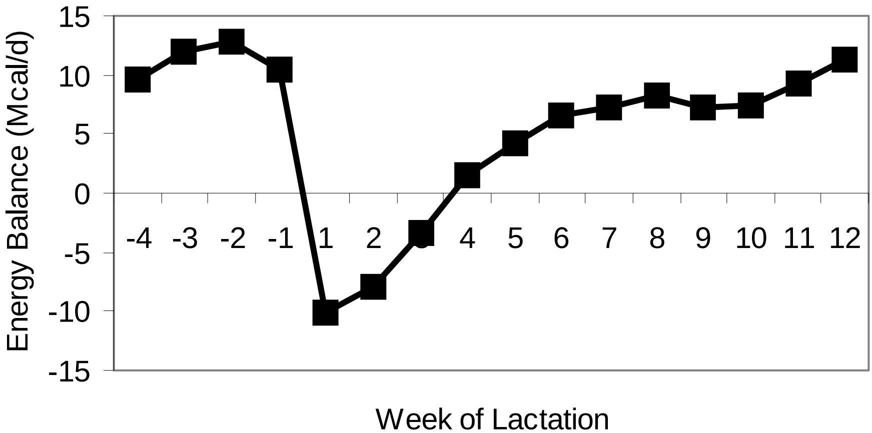

Figure 1. Energy balance of cows (*n* = 29) in early lactation (McGuire, unpublished data).

Dry matter intake for the Idaho study cows averaged 26.3 kg/d. Because energy balance is calculated from energy intake and energy retained in milk, it seems reasonable that both of these would contribute to the time it takes cows to return to positive energy balance. However, for all cows the correlation between DM intake and energy balance was greater than between milk yield and energy balance (Table 1). These data suggest that the high level of feed consumption had a greater effect on energy balance than did the high level of milk production. This should be expected based on the relationship among these variables. During the first 10 weeks of lactation, both DM intake and energy balance are increasing while milk yield has peaked and either plateaued or already begun to decrease. Therefore, it is important to manage cows to maximize feed consumption in early lactation because DM intake accounts for considerably more variation in energy balance than does milk production.

Table 1. Simple Correlations Between Intake, Milk Production, Body Condition Score (BCS) and Energy Balance

	DM Intake	Milk Yield	BCS
Energy Balance	*P < .0001* $r^2 = 0.751$	*P < .037* $r^2 = 0.051$	*P < .017* $r^2 = -0.136$
DM Intake		*P < .0001* $r^2 = 0.511$	*P < .009* $r^2 = -0.148$
Milk Yield			*P < .0001* $r^2 = -0.327$

From McGuire (unpublished data).

Body condition score (BCS) was not well correlated with energy balance. This is not surprising for two reasons. First, a single BCS gives no indication of whether a cow is gaining or losing weight at that time. The second reason is based on the fact that body condition scoring is primarily an assessment of subcutaneous tissue change. When a cow begins to replenish mobilized tissue, abdominal fat and intermuscular fat are replenished before subcutaneous fat. These fat depots are not evaluated (they are not visible) in the body condition scoring procedure. Intermuscular and abdominal fat contribute significantly to the total energy available for mobilization (Butler-Hogg et al., 1985). Thus, although the cow is in positive energy balance and is replenishing body tissue, change in BCS is not apparent until later in lactation.

▪ Effect of Selection for Milk Production

Effects of genetic selection for milk production on energy balance were examined at the University of Minnesota by Weber and Crooker using a population of cows that since 1964 had a stable genetic merit for milk production (Hansen, 2000). These cows (Control) were compared to cows bred to bulls with the highest predicted transmitting ability (Selected). Milk production, DM intake and calculated energy balance were examined for 40 cows fed the same diets ad libitum. As expected, milk production of the Selected cows was greater than that of Control cows (Table 2). Likewise, DM intake was higher for the Selected cows and, as a result, energy balance was essentially unchanged. Both groups were in negative energy balance following parturition and resumed positive energy balance at approximately 7-8 weeks in milk (Figure 2). Similar to the Idaho study, the greater DM intake of the higher producing cows was a critical factor in these cows meeting energy needs for greater amounts of milk produced without a more prolonged period of negative energy balance compared to the cows at lower levels of production.

Table 2. Milk Production and Dry Matter Intake (DMI) of Control and Selected Cows For 10 Weeks of Lactation

Variable	Control	Selected
Cows	19	21
Milk, kg/d	29.9	38.0
DMI, kg/d	13.9	17.6
NE_L balance, Mcal/d	-5.47	-5.26

From Weber and Crooker (see Lucy et al, 1998 and Weber et al., 1998).

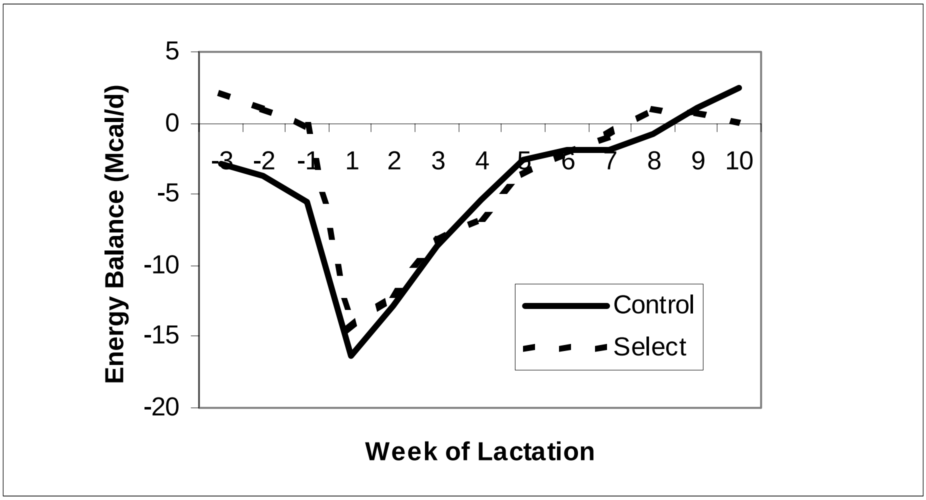

Figure 2. Energy balance of control and selected cows For 10 weeks of lactation (From Weber and Crooker (see Lucy et al, 1998 and Weber et al., 1998).

■ Potential Errors in Calculated Energy Balances

In the Minnesota and Idaho studies, relatively high producing cows returned to positive energy balance by the seventh and fourth weeks of lactation, respectively. These results were dependent on high DM intakes. If there were systematic errors in energy balance calculations, these errors could shift the time that cows attain positive energy balance. However, we think potential errors may have minimal impacts on when these cows resumed positive energy balance.

The most likely error that could affect these data would be an overestimation of consumed feed energy, which is the product of DM intake and the energy content of the feed. Calculation of DM intake is dependent on determining the loss of feed offered and assuming that any losses are actually consumed. Errors in this calculation would most likely result in an overestimation in feed intake. A more probable error would be in estimating the energy content of feeds, especially forages. In these studies, content of energy in feeds was based on composition of the feeds. Systematic errors in determining feed energy would have less of an impact on comparisons between Control and Selected cows in the Minnesota study because each group would have the same bias.

Errors in estimating energy requirements could occur for determining energy required for milk or for maintenance. Milk energy requires accurate measurement of milk production and milk fat composition. Equations for this calculation have been unchanged for several years and are regarded as fairly accurate. Maintenance is a significant portion of the total energy requirement and errors can exist due to inaccuracies in body weight, activity or environmental factors. In these studies, body weights were measured frequently after milking. However, Gibb et al. (1992) have indicated that gut fill increases while DM intake is rising during early lactation. The increase in DM intake that occurs in early lactation would at least partially offset the loss in body weight and thus result in an overestimation of the maintenance energy requirement. Environmental factors were not included in calculations of maintenance requirement for either the Minnesota or Idaho studies. Maintenance is increased when cows are heat stressed or cold stressed and these conditions were not present during these studies.

Even if there were a systematic bias introduced that overestimated energy content of feeds, decreasing energy consumption by 10% would have a minimal effect on when these cows attained positive energy balance. High-producing cows rely on body reserves during early lactation to varying degrees depending on body condition (Garnsworthy, 1988) and then partition energy mostly towards milk at the expense of increased body weight throughout most of lactation (Bines and Hart, 1982; Bauman et al., 1985; Veerkamp and Emmans, 1995). This would partly account for the minimal changes in BCS that occur during the remaining early to mid lactation period when cows are in positive energy balance. But, these authors also indicate that increased animal efficiency is due to not only partitioning of nutrients but also due to greater feed consumption. Data from the Minnesota study suggest that the greater DM intake of high producing cows enables them to avoid more prolonged periods of negative energy balance.

In the Idaho and Minnesota studies, concentrations of non-esterified fatty acids (NEFA) in blood were greatest during the periods of most negative energy balance, as would be expected. Average concentrations of NEFA were back to baseline values at approximately the same time as cows resumed positive energy balance, suggesting that cows were not mobilizing large amounts of body stores at these times. Although estimates of body composition of lactating dairy cows are relatively rare and, when measured, are usually measured at infrequent intervals, available estimates support the notion that lipid mobilization ceases well before 100 days in milk. For example, the slaughter study of Gibb et al. (1992) demonstrated that loss of body fat ceased by the eighth week of lactation. Komaragiri et al. (1998) used the deuterium dilution technique to estimate body composition and demonstrated that body fat loss had ceased by the fifth week of lactation. An earlier evaluation of the effect of dietary protein content (Komaragiri et al., 1997) demonstrated that high protein diets could prolong the duration of body fat loss.

▪ Relationships Between Milk Production and Use of Body Reserves

Theurer et al. (2003) further evaluated the relationship between milk production and use of body reserves in 3 commercial herds in central Washington. Use of body reserves was estimated by maximal decrease in BCS. Cows (n = 252) were scored before calving then monthly until 150 DIM. The minimum BCS was reached by the second month of lactation indicating that further use of body reserves was minimal as the cows were in energy balance (Figure 3). Linear regression analysis did not detect a relationship between peak milk yield and BCS at calving (Figure 4) or change in BCS from calving to minimum BCS postpartum. To further evaluate whether BCS had any effect on milk production, cows were grouped for analysis based upon BCS at calving or maximal postpartum change in BCS (Table 3). Neither peak milk nor total milk production, through 150 DIM (Figure 4), was affected by BCS at calving. Further, change in BCS was not associated with level of milk production (Figure 5). Therefore, cows can use a combination of mechanisms (consume more feed or use body reserves) to meet the energy demand in early lactation for the production of substantial quantities of milk. But, current information indicates that milk production does not seem to limited by extent of change in BCS.

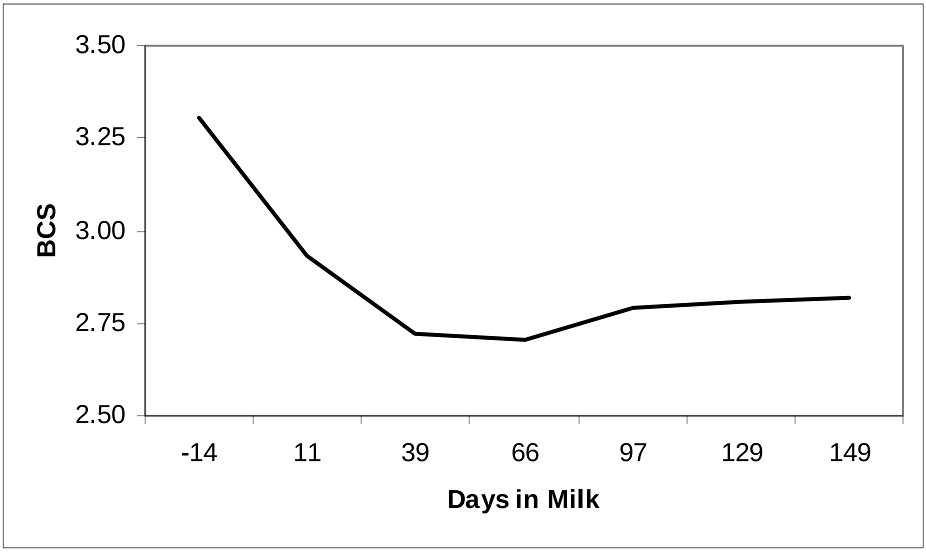

Figure 3. Average body condition score from 14 days prepartum until 149 days in milk. Cows (*n* = 252) were evaluated every 2 weeks from approximately 2 weeks before expected calving until 150 days in milk (Theurer et al., 2003).

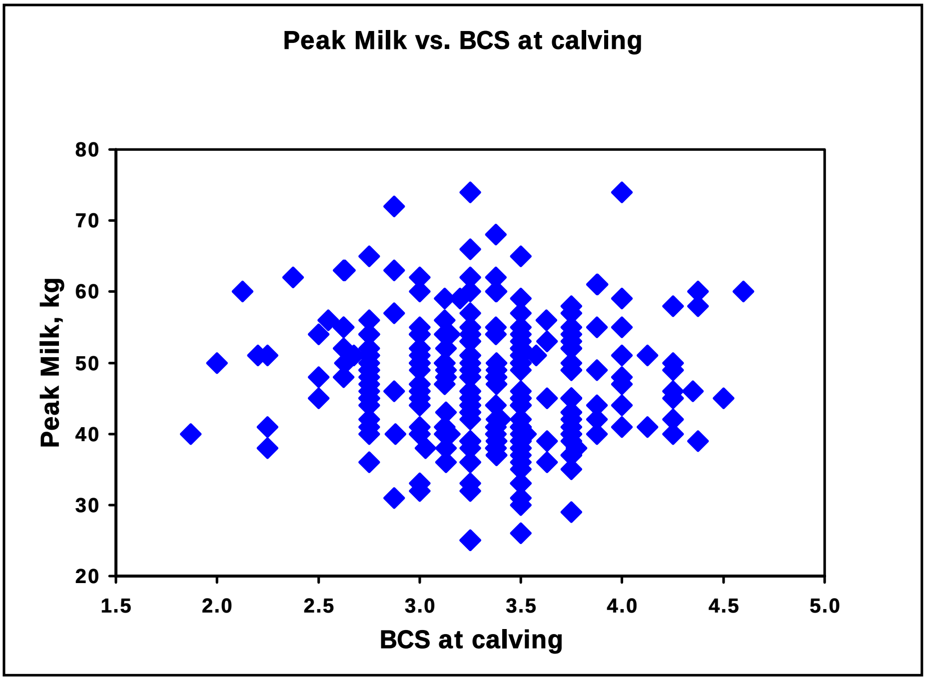

Figure 4. The relationship between BCS at calving and peak milk production. No significant linear regression was detected for peak milk by BCS at calving(r^2 0.0057) (Theurer et al., 2003).

Table 3. Description of body condition score (BCS) groups used in statistical evaluation

BCS Group	BCS at calving	Change in BCS
High	>3.5 (*n* = 65)	>0.75 (*n* = 91)
Mid	3.0 to 3.5 (*n* = 110)	0.5 to 0.75 (*n* = 73)
Low	<3.0 (*n* = 77)	<0.5 (*n* = 88)

Theurer et al. (2003).

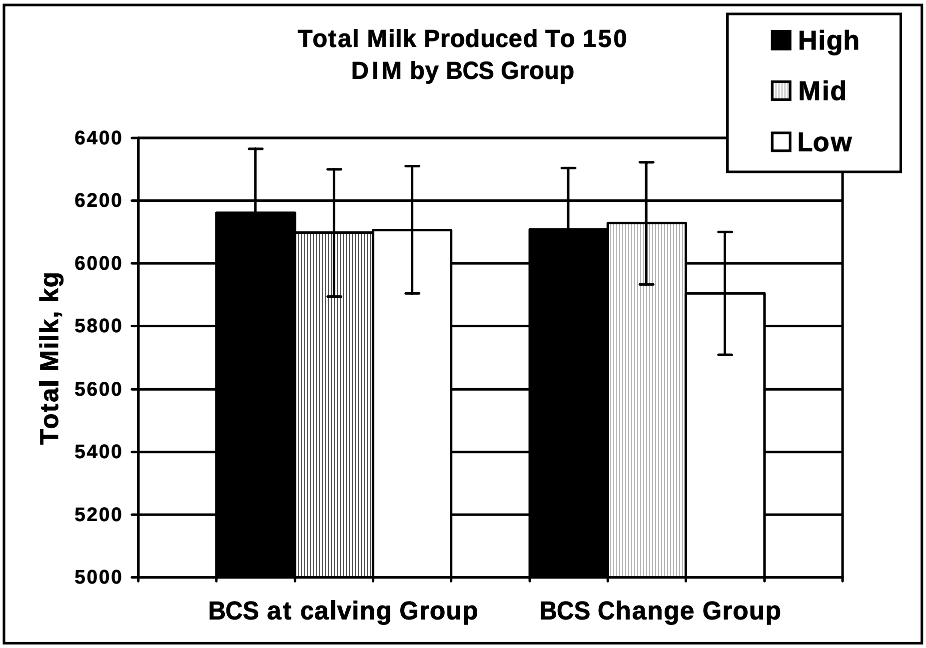

Figure 5. The relationship between BCS at calving or change in BCS from calving to minimum observed postpartum and total milk production through 150 days in milk (From Theurer et al., 2003). The BCS groups are as defined in Table 3. Vertical bars represent the standard errors of the mean for each group.

▪ Summary

Data on extent and duration of negative energy balance in high-producing cows are limited and these data can be equivocal. However, high production itself does not appear to negatively impact energy balance in early lactation. High producing cows partition considerable amounts of energy towards milk production throughout lactation making a determination of energy balance based on BCS impossible. These data indicate that major goals for managing high producing cows should be to manage transition cows to optimize health and maximize feed consumption during early lactation. These practices will minimize the duration of negative energy balance during early lactation.

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