Dairy Split Session

Moderator - Rick Allison, Hank Spencer, Robert Corbett

Enhancing Reproductive Efficiency by Optimizing Energy Balance and Dry Matter Intake

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Introduction

Meeting the energy needs of high-producing dairy cows is a top priority for optimizing milk production, reproduction, and health. Not providing an excess of dietary energy is also important. In short, dairymen and their advisors should avoid getting dairy animals too fat or too thin.

Energy balance (**EB**) is an important idea in dairy cattle feeding and management. It is the difference between energy intake and energy output. When an animal's energy intake is less than energy output, the resulting difference is a negative number and the animal is in negative energy balance (**NEB**). An animal in NEB will mobilize energy from fat reservoirs and lose weight. Dairy cattle are commonly in NEB during the first 30 days in milk (**DIM**).[4,20,21] This occurs because the rate of increase of milk production (**MP**) exceeds that of feed intake.

Conversely, when an animal's energy intake is greater than energy output, the difference is a positive number. This is positive energy balance (**PEB**). An animal in PEB will store energy as fat and gain weight. Cattle are generally in PEB after 100 DIM.

Body tissues are dynamic and serve two important roles. During times of PEB, they serve as stores for energy deposition; during times of NEB, they are reservoirs for energy mobilization.

Body condition scoring (**BCS**) is a means of assessing the changes body tissues undergo. It is a method of visually appraising energy changes in the animal. Such evaluation allows one to adjust feeding and management to prevent cattle from becoming fat or exceedingly thin.

The purpose of this paper is to examine EB and dry matter intake (**DMI**) and their effects on reproduction and production in the high-producing dairy cow. Proper energy management is a key priority for optimizing milk production and reproduction. The overall objective is to offer feeding and management principles that will promote greater reproductive efficiency. Discussion will focus on the following points:

- Cows in the most NEB will have poor DMI.
- Negative energy balance adversely affects reproduction at several stages of the reproduction-lactation cycle of the dairy cow.
- Early return to estrus is important about early conception.
- Progesterone level during the luteal phase positively influences conception at first service.
- Energy balance fosters the healthy development of follicles and corpora lutea (**CL**).

Energy Balance

Severity of Negative Energy Balance: Dry Matter Intake Versus Milk Production

Energy is the first limiting dietary nutrient for cows in early lactation.[21] Early-lactation dairy cows are generally in NEB. The degree and duration of NEB are critical factors. Staples[19] measured energy deficits of three groups of cows. He identified these groups according to how quickly they resumed ovarian activity: early, late, and non responders. Table 1 is a summary. The early-responding cows returned to estrus within 40 days after calving. However, these cows still experienced NEB for about six weeks. At week one after calving, the EB was -10 Mcal/day (e.g., energy intake and energy output were 20 and 30 Mcal/day, respectively). Mobilization of energy stores was necessary to make up this 10-Mcal deficit. This produced an average loss of body weight (**BW**) of 40 lb. that week. The deficit progressively declined and reached zero about the sixth week.

Note in Table 1 that the nonresponder cows had a DMI of 33 lb./day, lost 2.7 lb. BW/day, required 2.8 services per conception, and were open 200 days. Thus, the length of time in NEB depends mainly on an animal's ability to accelerate feed intake.[20,21] Stated differently, cows in the most NEB will have poor dry-matter intakes (**DMI**).

Energy balance is more sensitive to DMI than it is milk production (**MP**). Staples[19] and Villa-Godoy[23] proved these relationships:

- .68 vs. -.11 (Staples)
- .73 vs. -.25 (Villa-Godoy)

Table 1. Reproductive Performance of Dairy Cows Differing in Ovarian Activity the First 9 Weeks Postpartum*

Item	Early Responder (n = 25)	Late Responder (n = 14)	Non Responder (n = 15)
4% FCM, lb./day	74	70	63
DMI, lb./day	41	39	33
BW change, lb./day	-1.8	-1.8	-2.7
Days to first obulation	22	43	—
Days to first heat	47	73	110
Services per conception	2.4	1.8	2.8
Days open	133	88	200

* Source: Staples, *et al.*[19]

Lucy[14] also showed the importance of DMI. On average, cows showing 1st ovulation on day 23 postpartum and averaging 67 days open ate more DM and produced more milk than cows showing 1st ovulation on day 65 with 90 days open (**DO**).

Some cows rapidly increase DMI to 3.5% of body weight (**BW**) during the first few weeks of lactation.[19] These cows benefit by spending less time in NEB, by achieving an earlier time to first ovulation, and by producing more milk. In brief, differences among cows in the severity of NEB depend more on how much they eat than with how much they milk.

Stages Where Energy Balance Affects Reproduction

Energy balance influences reproduction at several points during the lactation-reproduction cycle of the cow. Britt[1] cites three stages at which EB affects reproduction in cattle:

(1) Duration of postpartum anestrus
(2) Size of progesterone profiles
(3) Fertility at insemination

Duration of Postpartum Anestrus. Early return to estrus is important concerning early conception. Fertility improves as the number of estrous cycles that occur between resumption of ovarian activity and first insemination. This relationship holds true for cows and heifers. Cows that experienced two or three heats before insemination had nonreturn rates of 44% to 47% compared with 34% for cows that had not shown estrus before 60 days.[22] **The crucial point is that when inseminated at the same time, cows or heifers that have cycled two or three times are more fertile than those inseminated at the first or second cycles.**

Butler[2,3] and his coworkers proposed that commencement of postpartum estrous cycles depend on the occurrence of the postpartum nadir in NEB. By definition, nadir is the point where EB reaches its most negative state (i.e., when EB bottoms). When EB reaches its nadir sooner and then begins to return toward a PEB, it has a positive affect on reproduction. Cows resume estrous cycles sooner and breed back quicker. Approximately 10 days after maximum NEB, first ovulation occurs.[2,3]

Size of Progesterone Profiles. Folman[8] found that early postpartum feeding affects progesterone secretion during the breeding period in high-producing dairy cows. He proved the following:

- Cows that conceived at 1st service had higher levels of progesterone during the luteal phase before the 1st breeding than cows that failed to conceive.
- Cows fed a high energy diet had greater luteal phase progesterone concentrations than cows fed the lower energy diet.
- Cows fed the higher energy diets, required fewer services per conception.
- Cows that gained weight had higher levels of progesterone during the luteal phase before the 1st service than cows that lost weight.

Fonseca[9] also examined the relationship between blood progesterone during the 12 days before 1st service and first service conception rates. This study included Holstein and Jersey cattle. He showed a positive relationship to progesterone level before first breeding.

- In Holsteins 1 ng/mL increase or decrease in average progesterone gave a 12.4% difference in conception rate.
- In Jerseys 1 ng/mL gave a 7.4% difference in conception rate.

Villa-Godoy[23] found that EB during the first two weeks immediately postpartum, exerted a profound latent effect on progesterone secretion. He found that cows that experienced the greatest decline in EB during the nine days following calving also had the lowest progesterone levels during the second and third postpartum estrous cycles occurring 40 to 70 days after parturition.

Fertility at Insemination. Follicular growth takes 80 to 100 days.[15] Negative energy balance influences the normal process of follicle maturation in the dairy cow. In 1991 and 1992, Britt[1] proposed a theoretical model to explain how NEB could adversely affect fertility weeks later. The key elements of his theory are as follows:

- Preantral follicles exposed to adverse environmental conditions would have altered gene expression leading to impaired or altered development.
- Impaired developing follicles would result in the formation of dysfunctional mature follicles, poorer oocytes, weakened corpora lutea (**CL**), and reduced progesterone.
- First and second CL would differ little in progesterone secretion between cows. Despite energy balance postcalving, early follicular development for the first and second CL begins at a time when energy balance is more favorable.
- Third, fourth, and fifth CL would differ because cows that lose more BC (i.e., more severe NEB) should have dysfunctional ovulatory follicles and impoverished CL.

Fonseca[9] cited experimental evidence to support this model. Field experience bears strong evidence for the validity of this model.

Body Condition Scoring

Scoring Systems

Body tissues are dynamic and serve two important roles. During times of PEB, they serve as stores for energy deposition; during times of NEB, they are reservoirs for energy mobilization.

Evaluating EB during the reproduction-lactation cycle of the dairy cow is frequently crucial. Body condition scoring (**BCS**) is a means of assessing changes body tissues undergo. It is a method of visually appraising energy changes in the animal. Such evaluation allows one to adjust feeding and management to prevent cattle from becoming fat or exceedingly thin.

Body condition is a subjective measure of body fat reservoirs. As originally proposed by Virginia Tech workers,[24] it is a 5-point system (Table 2). It is a noninvasive way of estimating fat stores in cattle that is independent of frame size and BW.

Table 2. Five-point Body Condition Scoring System*

SCORE	INTERPRETATION
1	Emaciated
2	Thin
3	Medium
4	Fleshy
5	Fat

*Source: Wildman, *et al.*[24]

Edmonson[10] and Ferguson[5,7] developed refined versions that divide each score into 0.10 and 0.25-point increments, respectively. This permits more specific scoring. One unit of body condition change is equivalent to 123 lb. of live tissue weight. Composition is approximately 70% lipid, 24% water, 6% protein, and 1% ash.[17] Fatter cows and larger cows will lose more tissue per condition score than thinner cows and smaller cows.[7]

Body condition is a field method. It does, however, have advantages over body weight in assessing fresh cow EB. Live weight is a poor estimate of tissue changes in the early postpartum period. Complicating factors include the increase in feed intake, increase in gut fill, increase in mammary gland tissue and yield, involution of the uterus. If anything, live weight loss under predicts energy loss of the animal.

Body Condition and Reproduction

Cows that had BC scores of ≥4.00 at drying off had more problems than cows with lesser scores. These over conditioned cows were 2.5x more likely to experience reproductive diseases, such as dystocia, retained fetal membranes, pyometra, cystic ovarian disease and abortion.[13]

Cows losing extensive BC within a short period are also candidates for reproductive inefficiencies. Butler and Smith[3] showed the following associations:

- Cows that had extreme loss of BC after calving experienced reduced fertility.
- Cows that lost >1.00 BCS during the first five weeks had 17% first service conception rates (**FCR**) compared with 59% for cows that lost <1.00 BCS (Table 3).
- Cows that had moderate loss of BC (i.e., 0.50 to 1.0) had normal fertility.
- The cumulative pregnancy rates were similar for all groups of cows; therefore, the infertility associated with body condition loss was temporary.

Table 3. Relationship Between Body Condition Loss During First 5 Weeks Postpartum and Reproductive Performance*

	BODY CONDITION LOSS		
ITEM	<.50	.50 TO 1.0	>1.0
Number of cows	17	64	12
Days to first ovulation	27	31	42
Days to first heat	48	41	62
Days to first service	68	67	79
First service conception rates, %	65	53	17
Services per conception	1.8	2.3	2.3
Pregnancy rates, %	94	95	100

*Source: Butler and Smith[3]

In another study, cows that lost an average of .60 BCS units suffered reproductively versus cows that gained an average of .10 BCS units. **First service conception rates was 25% for cows losing weight compared with 62% for cows gaining weight (Table 4).**[1]

Ferguson[7] concluded that a half unit of BC between calving and first breeding does not impair fertility.

Greater BC losses (e.g., >two-third points) are very detrimental (Table 5).

Table 4. Interval to First Insemination and Conception Rates in Postpartum Cows Grouped According to Change in Body Condition Score from Week One to Five[a]

Trait	Maintained Condition	Lost Condition
Days to first AI	84.9	82.9
First service conception rates, %	62[b]	25[c]
Conception rate all services, %	61[b]	42[c]
Third ovulation conception rate, %	63	27
Second ovulation conception rate, %	67	50
Fifth ovulation conception rate, %	53	44

[a] Source: Britt[1]

[b,c] Values in rows with different subscripts differ (P<0.05).

Table 5. Relationship of Fertility and Body Condition Change Between Calving and First Insemination[a,b]

Body Condition Change	Conception Rate
+1.0	61.7
+0.5	55.9
0	50.0
0.5	44.1
1.0	38.3

[a] N=516 cows

[b] Source: Ferguson[7]

Managing Body Condition Score

Body condition scoring is an excellent indicator of the combined effects of diet formulation, feeding management, and animal husbandry.[4,18] Consequently, it helps identify divergent feeding practices that can lead to health and reproductive problems.

Excessive mobilization of body stores is usually the result of inadequate DMI. Why do some fresh cows have poor feed intakes? It is primarily over conditioned cows (i.e., >=4.0). Jones and Garnsworth[12] showed that over conditioned cows experienced peak DMI 10 weeks later. They reached PEB 2 weeks later than cows in good body condition. In this study over conditioned cows lost 1 BCS unit; control cows had a slight gain.

Proper BC is necessary throughout the life of the dairy cow (Table 7). The following points are important for successful management of BCS and reproduction:

- Body condition loss should not exceed .50 units during the early postpartum period.
- Excessive BC losses result in extended time before return to estrus and reduced fertility.
- Restore BC during the lactation.
- If necessary, use the dry period to increase BC.

Table 6 shows the tissue energy associated with different BC scores. Note that the energy reserve from a BCS of 2.5 to a 3.5 is 436 Mcal. Based on the following efficiency relationships published in the NRC,[16] calculating the days for a BCS to change is possible:

- Conversion of ME to milk production (NEL) = .64
- Conversion of ME to energy reserves gain = .75
- Conversion of energy reserves to milk production (NEL) = .82

Table 6. Energy Reserves at Different Body Condition Scores[a]

	Condition Score			
	2.5	3.0	3.5	4.0
Body Weight (LB.)	MCAL/Body Condition Score			
1200	187	200	201	203
1300	203	217	219	220
1400	218	234	236	237

[a] Source: Adapted from Fox, *et al.*[11]

1. *If NEL Is Below Requirements by 2.00 Mcal / Day.* 436 Mcal x .82/2.00 = 179 days to drop from a condition score to restore 3.5 to 2.5.
2. *If NEL Is Above Requirements by 2.00 Mcal / Day.* 436 Mcal/ ((2/.64) X .75) = 186 days to increase from a condition score 2.5 to 3.5.

From a practical standpoint, deciding at pregnancy diagnosis how much gain a cow needs by completion of the lactation is desirable. If pregnancy diagnosis is at 45 days, then this leaves 180 days until dry off. A cow scoring 2.5 would need an additional 3 Mcal/day of NEL above requirements to score 3.5; a cow scoring 3.0 would only need an additional 1.5 Mcal/NEL to score 3.5 at the end of the lactation. These adjustments may be met by feeding an extra 2.5 lb. and 1.25 lb. of corn, respectively.

Table 7. Target Body Condition Scores*

Stage	Ideal Score	Range
Dry off	3.50	3.25-3.75
Calving	3.50	3.25-3.75
Early lactation	3.00	2.50-3.25
Mid-lactation	3.25	2.75-3.25
Late lactation	3.50	3.00-3.50
Growing heifers	3.00	2.75-3.25
Heifers at calving	3.50	3.25-3.75

*Source: Ferguson, *et al.*[6]

Feeding Considerations

Managing EB and BC for optimum reproductive efficiency requires strategic planning. Key dietary manipulations and management principles include the following:

- Put additional weight on thin cows during late lactation if possible. Cattle are energetically efficient at this time. The efficiencies are 75% and 60% (NRC, 1989)[16] for the late lactation and dry period, respectively.
- Cows still thin at dry off should receive extra feed during the first half of the dry period. Four to five lb. additional corn will allow thin cows to gain approximately 0.50 lb./day. More herds are finding this necessary with higher production and the adoption of BST. This approach requires three dry cow groups: far offs, thin cows, and springers.
- Do NOT allow fat cows to lose condition during the dry period. Excessive mobilization of body fat sets them up for fatty liver disease. Actually, they need to gain one to 1.50 lb./day to support a rapidly growing fetus.
- Reduce NEB during the transition fresh cow period. Maximizing DMI is the only way to practically accomplish this goal. Provide feed *ad libitum* to maximize feed intake. Energy intake follows feed intake (i.e., DMI). Dry matter intake depends on many variables. They fall into three general categories: (1) environment, (2) cow, and (3) ration. Table 8 summarizes these variables.

Table 8. Variables that Influence Dry Matter Intake

Environment	Cow	Ration
Temp-Humidity Index	Milk production	Physical texture
Ventilation	Body size	Palatability
Feedings per day	Hormonal status	Fiber content
Water	Breed	Nutrient balance
Sprinklers, fans	Body condition	Moisture content
Social structure	State of health	Forage quality

Summary

Energy balance (EB) and body condition (BC) profoundly affect reproduction in high-producing dairy cows. Cows in the most NEB will have poor DMI. Proper energy management is a key priority for optimizing milk production and reproduction. Negative energy balance is an important factor affecting when a cow will return to estrus, how much progesterone she produces during the breeding period, and optimum follicular and corpora luteum development. Managing energy balance and body condition for optimum reproductive efficiency requires strategic planning. The overall objective should revolve around maximizing DMI and, thus, avoiding significant periods of NEB. The crucial point is simple: Maximize DMI.

References

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