Feeding the High Producing Dairy Cow: Biotechnology, Body Condition and Reproduction

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Introduction

A major determinant of success (sustainable) in business is the continued achievement of gains in efficiency. This is most frequently measured as improvements in outputs (products produced) relative to inputs. In animal agriculture, feed generally represents the major input component while tissue gain (growth) or milk yield are the primary useful outputs. In dairying, efficiency is generally measured as the ratio of salable milk to feed consumption (kg milk sold/kg feed consumed). Thus improvements in efficiency are achieved when producers can increase milk yield relative to the quantity of appropriately formulated diets consumed by their cows or reduce the cost of supplying the required nutrients. The main goal is to efficiently produce dairy products without adversely affecting the condition, health, or reproductive function of the animal or adversely affect the environment.

Of the feed consumed by the dairy cow, only about 30% of the dietary energy and protein are available to the animal for productive functions (milk synthesis). The remaining (70%) energy is lost as fecal (30%), urinary (3%), gaseous (5%) and heat (25%) energy. Protein loss is fairly evenly split between fecal and urinary losses (each about 33%). Thus, major improvements in animal efficiency could be achieved if these losses can be reduced. Considerable effort is being directed towards reducing these losses through improved ration formulation and genetic engineering of rumen microorganisms (increased cellulase activity), and feeds (increased amino acid content, increased digestibility). For any of these methods to be successful, the energy and nutrient needs of the host and the rumen microorganisms must be satisfied. Although important, this aspect will not be covered in this review. Instead, this review will focus on the post-absorptive use of energy and nutrients.

Biological Efficiency

For any appropriately formulated diet, the biological efficiency of lactation increases as milk yield increases. This is true even though the quantity of feed required (and hopefully consumed) to meet the metabolic demands for the increased yield also increases. This improvement occurs through an alteration in the relative proportion of nutrients and energy used to maintain the cow and to produce the milk.

Evaluation of a 650 kg cow producing 32 or 50 kg of 3.5% fat corrected milk (FCM) per day provides an example of this increased efficiency (NRC, 1989). Energy and nutrients required to maintain a cow (to support her non-productive needs) are functions of body weight. The maintenance energy requirements of a 650 kg cow is 10.3 Mcal/d. This remains constant regardless of the quantity of milk produced by the cow. Energy required to synthesize milk depends on the quantity and composition of the milk produced. Energy requirements for the production of 32 and 50 kg FCM/d are 22.1 and 34.5 Mcal/d, respectively. Total energy (maintenance plus production) needs of the cow do increase as milk production increases (from 32.4 to 44.8 Mcal/d when yield increases from 32 to 50 kg FCM/d) and the cow must therefore consume more feed. However, as a percent of total energy requirement, the portion being used for productive functions (milk yield) increases (from 68 to 77%). This increased efficiency has been called a dilution of maintenance requirements (Bauman and McGuire, 1994).

Dramatic achievements in productive efficiency of milk production by healthy cows have been obtained through selective breeding practices and, more recently, through the use of bovine somatotropin (bST). The dairy herd at the Southern Experiment Station (SES) of the University of Minnesota in Waseca provides an excellent example of the achievements obtained through selective breeding. In 1964, Dr. Charles Young paired cows in the herd by genetic merit and assigned each member of the pair to either a control and select group. Control cows and their subsequent female offspring have been bred with semen from bulls that were breed average bulls for milk production in 1964. Select cows and

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their subsequent female offspring have been bred with semen from four of the best bulls each year. Under identical environment and similar management conditions, current production of the two lines differ by some 4,500 kg per lactation. Although body weight and thus maintenance requirements of the select cows has also increased, the select cows do partition a greater percentage of their daily energy needs into milk than do the control cows (61 vs 71%).

Several studies have demonstrated that administration of bST can increase milk yield by 10 to 15%. The extensive numerous studies of the bST treated cow demonstrate that her nutrient and energy requirements are the same as a non-treated cow of similar body weight that produces the same amount of milk. Thus, this increase also results in improved efficiency. For a 650 kg cow producing 36 kg FCM/d without bST administration, this represents an 2% increase (71 vs 73%) in the proportion of energy used for productive purposes. Although the increase is smaller than that achieved by 30 years of selective breeding, the improvements with bST have occurred in a much shorter time period.

Energy and Nutrient Balance

The genetically superior and the bST-treated cow are more efficient than their herdmates that produce less milk. They also have a greater metabolic demand for nutrients and energy. These high producing cows will not be able to consume sufficient energy and nutrients during early lactation and must rely on mobilization of body tissue to compensate for the shortage. The high producing cow can mobilize significant quantities of tissue in response to the metabolic demand for energy and nutrients. During this period of tissue mobilization, cows are in negative energy and nutrient balance. The properly conditioned, well-fed cow generally experiences little, if any, adverse effects of negative energy balance during early lactation. However, excessively thin or over-conditioned cows or cows that experience prolonged periods of negative energy balance can experience health problems which may decrease milk production and may impair fertility.

Cows with insufficient tissue reserves will not be able to achieve their genetic capacity to produce milk. Over-conditioned cows are at a greater risk of calving difficulties and metabolic disorders. Cows that experience prolonged periods of negative energy balance frequently are more difficult to re-breed and have a difficult time replenishing their mobilized tissue before dry-off. If replenishment of this mobilized tissue is insufficient, performance in the subsequent lactation will be diminished. Excessive replenishment will result in fat, over-conditioned cows which also tends to increase the risk of metabolic disorders in the subsequent lactation.

Body Condition

As selection for milk yield and use of production enhancers continue to increase milk yield per cow, management techniques, especially the inter-related nutritional and reproductive aspects, must also improve. A relatively easy method to assess the overall effectiveness of the nutritional program on a farm is to monitor the body condition (BCS) of the cows. Methods commonly utilized in the U.S. (Wildman *et al.*, 1982; Edmonson *et al.,* 1989) score cows from 1 (severe under-condition) to 5 (severe over-condition). Although BCS is a subjective evaluation, it can provide a relatively accurate assessment of the energy reserves of cows in a herd. This is especially true when the measurements are repeated at regular intervals and the collected data utilized to assess changes in the status of individual animals.

Several recommendations for frequency of measurement, desirable scores and acceptable ranges at various stages of lactation are available (Reneau and Linn, 1989; Sniffen and Furguson, 1991).

	Reneau & Linn		Sniffen & Furguson	
Stage of Lactation	Desired Score	Acceptable Range	Desired Score	Acceptable Range
Calving	3.5	3.0 - 4.0	3.50	3.25 - 3.75
Early lactation	2.5	2.0 - 2.5	3.00	2.50 - 3.25
Mid-lactation	3.0	3.0 - 3.5	3.25	2.75 - 3.25
Late lactation	--	--	3.50	3.00 - 3.50
Dry-off	3.5	3.0 - 3.5	3.50	3.25 - 3.75

The subjective nature of BCS lends itself to some relative disagreement among the recommendations. However, the objectives remain consistent; cows at either extreme have a greater risk for metabolic disorders and disease, decreased milk yield, poor conception rate and calving difficulties than properly conditioned cows.

Reproduction

Changes in the endocrine profile of the lactating cow occur during negative energy and nutrient balance to assist the cow in coping with these deficiencies. Of major importance are changes in the relationship between bST and insulin-like growth factor-I (IGF-I) and the IGF-I binding proteins (McGuire *et al.,* 1995). During periods of adequate nutrition, administration of bST will increase concentrations of IGF-I in the blood. This stimulation of the IGF-I system signals the mammary gland that the nutrient supply is favorable for increased milk yield. When the nutrient supply is marginal, the ability of bST to stimulate IGF-I is reduced and a diminished signal is sent to the mammary gland. During negative energy balance, concentrations of bST in the blood increase but the ability of bST to stimulate IGF-I is lost (the relationship between bST and IGF-I is uncoupled). Although the increased bST stimulates mobilization of adipose tissue to support metabolic needs, the mammary gland is not stimulated to produce additional milk during this period of nutrient and energy inadequacy.

In addition to affecting the ability of the cow to produce milk, these changes and others can adversely affect reproductive performance of the cow and delay conception. Increased milk yield can have detrimental effects on fertility including increased days open, more services per conception and greater incidence of reproductive problems (Butler and Smith, 1989; Grohn *et al.*, 1994). Negative energy balance can delay and/or impair development of the ovarian follicle and the corpus luteum (CL). This impaired development reduces the circulating concentration of progesterone. Progesterone plays a critical role in forming a favorable uterine environment for the developing embryo. Circulating concentrations of IGF-I and progesterone are positively correlated and it is speculated that IGF-I may mediate the effect of negative energy balance on progesterone (Spicer *et al.*, 1990). This mediation may exist as endocrine, paracrine, autocrine, or some combination of these pathways (Brier and Gluckman, 1991). Vandehaar *et al.*, (1995) have provided evidence which suggests that endocrine alterations are the most likely mode of action of IGF-I mediation of the adverse effects of negative energy balance on reproductive performance.

Delayed Breeding

The traditional recommendation for breeding has been to achieve a calving interval of 365 d. This provides a calf per year and attempts to maximize profits associated with the greater milk yield by early lactation cows. Recent evidence suggests prolonged breeding intervals (delayed breeding) may be more profitable for the bST-treated cow (Galton, 1996 as cited by Roenfeldt, 1996). This Cornell study evaluated calving interval (13.2 vs 18 months) and bST treatment (0 vs 500 mg/14 d). The shape of the lactation curve was altered by bST treatment. The treated cows were more persistent and produced more milk in late lactation than the untreated cows. Annual herd health costs declined because the 18 month calving interval spread calving costs out over a longer time period. Extending the calving interval reduced reproductive costs due to reduced number of services per year.

These promising preliminary results may provide the producer with a viable alternative to the 365 d calving interval. However, because the results are preliminary and because the lactation curve for each cow differs, the decision to delay breeding should be weighed carefully and made on an individual cow basis.

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