Dairy Session I

"Bovine Somatotropin: Its Application in Dairy Practice"

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Nutritional Aspects of Bovine Somatotropin (BST)

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As milk production increases 2 to 3 percent annually, nutrient demands for high producing cows will continue to be a major management challenge. Minnesota DHI data illustrate the shift in feeding programs and strategies as milk yield increases (Table 1). Bovine somatotropin (BST) is biotechnology that could increase milk yield 5 to 15 percent in the future. Mix (1987) predicted in the year 2000, average milk yield could be 16,335 pounds without BST or 20,418 pounds if BST was used by U.S. dairy farmers. Meeting the nutritional needs of BST treated cows must be understood by dairy farmers, dairy nutritionists, veterinarians, and agri-business personnel. By examining current feeding strategies in high producing herds, three-times-a day milking, and BST research, BST feeding strategies can be anticipated.

Table 1. Feeding comparisons in 1988 Minnesota Holstein DHI herds. (Sammon, 1989).

Measurement	Average	High
Milk Yield (lb)	16965	22928
Fat Test (%)	3.7	3.5
Grain (lb D.M.)	5928	7310
Dry Matter Intake (% BW)	3.2	3.5
Forage D.M. (% BW)	1.9	1.9
Milk:Grain (D.M.)	2.9	3.1
Grain (% D.M.)	42	46
Energy Index (% need)	110	104
Protein Index (% need)	125	116
Feed Costs ($)	763	840
Income Over Feed Cost ($)	1198	1790
Feed Cost/Cwt ($)	4.50	3.66

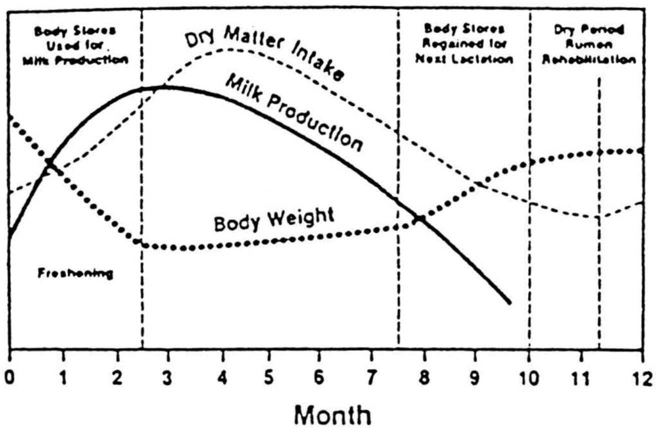
Nutritional Challenges for High Producing Cows.

As rolling herd averages exceed 22,000 pounds of milk with individual cows surpassing 35,000 pounds of milk, nutrient balance can be difficult to meet. Dairy managers must balance milk yield, nutrient intake, and body weight changes (Figure 1). Factors to consider in meeting these needs are listed.

1. Peak milk yield (volume) occurs 45 to 70 days postpartum.
2. Peak milk yield corrected for component level (FCM) will occur earlier than 45 days.
3. For each one pound increase in peak milk yield, total lactation yield should increase 200 to 225 pounds of milk.
4. First lactation heifers typically drop 6 percent in milk yield per 30 days (following peak yield) while older cows drop 9 percent.
5. Maximum dry matter intake lags peak milk yield by 4 to 8 weeks.
6. Each pound of additional dry matter consumed can increase milk yield 1.6 to 2.4 pounds depending on the stage of lactation and milk yield.
7. High producing cows can be in negative energy balance for 60 to 150 days postpartum. Severe weight loss can cause fatty liver syndrome, reduce reproductive performance, and lead to clinical ketosis.
8. Body condition or weight should be replaced prior to drying off for optimal feed efficiency. Each pound of body weight gained requires 2.33 Mcal of $N.E._L$ or 2.5 pounds of shelled corn dry matter or its equivalent.

Managing these biological curves will be essential for optimal cow health, production, and reproduction. Feeding strategies to meet those needs include: adding of supplemental fats and oils, using undegradable protein sources, selecting rumen buffers and additives to optimize rumen digestion, providing niacin to normalize body

Figure 1. Nutrient dynamics in the lactation-gestation cycle. (Hutjens, 1986).



weight loss, shifting to electronic grain feeders and total mix rations to stimulate dry matter intake, purchasing by-product feeds to optimize starch or soluble carbohydrate levels, maintaining total ration dry matter percent above 50 percent, monitoring body condition changes, and producing high quality forage to maximize nutrient intake. These practices can maximize rumen synthesis of desired products and supply the optimum balance of nutrients for lower digestive tract absorption.

Many similarities between genetically superior cows and cows treated with BST exist (Table 2). Both groups consume more feed dry matter, partition nutrients to the udder for milk synthesis, and no changes in digestibility, maintenance, or efficiency occur. Body weight changes and patterns are similar. Genetically superior cows that currently have high milk yield will have higher production due to BST use.

Nutritional and Management Aspects With BST

Research studies with short-term responses (Coppock, 1987) of lactating cows to BST resulted in sharp increases in milk production (25 to 31 percent) accompanied by small depressions in feed intake. Long-term studies found similar milk increases along with 3 to 15 percent increases in dry matter intake. The increased feed intake was not sufficient initially to provide the energy needed for higher milk yield. The increased yield due to BST is related to greater mammary gland use of nutrients from diet and body reserves. Based on a series of research studies and reports (Annexstad and Otterby, 1987; Bauman, 1987; Chalupa et al., 1987; Coppock, 1987; Huber, 1987; Chalupa and Galligan, 1988; Olson, 1988), the following nutritional and management guidelines should be considered when BST is administered to lactating dairy cows.

Cow Considerations

Criteria of cows selected for BST administration will

Table 2. Comparison between changes which occur when cows are treated with somatotropin and the differences between genetically superior and inferior cows. (Peel and Bauman, 1987).

Variable	Genetically superior cows	Somatotropin treated cows
Feed Intake	Higher intakes in genetically superior cows. Intake increases to peak over a several week period following parturition.	Feed intake increases over a several week period to match the increased milk production.
Digestibility of feed	Differences minor.	Differences minor.
Body Reserves	Greater use of body reserves in early lactation.	Increased mobilization of nutrient reserves to support increased milk yields in first weeks of somatotropin administration.
Maintenance	Differences minor.	No difference.
Partial Efficiency of Milk Synthesis	Differences minor.	No differences.
Mammary Glands	Larger quantities of secretory tissue. Activity per secretory cell not known.	Increased number of secretory cells and/or increased synthetic rate per cell is postulated.
Reproduction	Improved management needed to optimize reproductive performance in genetically superior cows.	Unknown. Reproduction normal in well-managed herd.
Efficiency	Increased because maintenance represents a smaller proportion of consumed nutrients.	Increased because maintenance represents a smaller proportion of consumed nutrients.

depend on expected economic responses. Results for cows injected at 20 days postpartum for two 10-day periods were higher (19%) compared to 60 days postpartum (17%). Early lactation may be a target time if body condition is favorable and early milk yield is unexpectedly low. Cows in negative nutrient balance do not respond as high as cows in positive balance. Cows fresh less than 120 days not pregnant, and thin may not warrant BST treatment. Favorable milk responses have been reported during early, mid, or late lactation (Meyer et al., 1988). Responses by first lactation cows may not be as great as second or greater lactation cows (Chalupa et al., 1987). Little information is available on cows giving over 88 pounds (40 kg.) of milk. Jersey cows treated with BST increased 33.3 percent with 7.4 percent greater feed efficiency (Pell et al., 1988).

Lactation Changes

Lactation curve response varies from 6 to 41 percent milk increase (Table 3). Field responses are anticipated to be 5 to 15 percent more milk. The shape of the lactation curve is changed immediately with a vertical shift upward and an increase in milk persistency. Milk composition does not change if nutrient needs are met. In a Vermont Jersey cow study, milk from BST-treated cows was 11 percent higher in whey protein and casein was slightly lower (Kindstedt et al., 1988). BST may be a tool to allow the dairy manager to manipulate the lactation curve of cows

Table 3. Responses of 3.5% FCM in cows supplemented with BST for 266 days beginning at day 28 to 35 of lactation. (Chalupa and Galligan, 1988).

Location	Control 0	BST (mg/day) 6.25	12.5	25	50
	lb/day				
Florida	47.1	+7.9	+ 9.9	+16.1	—
Kentucky	59.4	—	+ 7.5	+ 5.1	+ 8.8
Minnesota	64.0	—	+ 6.2	+15.0	+14.1
Ohio	63.6	—	+ 3.7	+ 5.3	+13.0
Pennsylvania	53.2	—	+15.0	+13.0	+15.2
Ontario	58.7	—	+ 8.4	+10.6	+ 9.0
United Kingdom					
T.M.R	48.4	—	+ 6.8	+13.6	+11.2
Flat amount of grain	42.9	—	+ 9.9	+ 9.7	+13.2
Mean	54.8	+7.9	+ 8.4	+11.0	+12.5

that drop too fast, experience long calving intervals, or gain excessive body weight.

Dry Matter Intake Responses

Feed intake initially does not increase and lags milk yield increases by 4 to 6 weeks. Body reserves or a higher quality ration must support high milk yields. Dry matter intake increases 3 to 15 percent after the initial lag to meet increased milk yield. Calorimetry and digestibility studies (Tyrrell et al., 1982) indicate BST-treated cows do not change digestive processes, maintenance requirements, or nutrient needs for milk synthesis. Increased heat production associated with BST is exactly the amount predicted based on milk yield and dry matter intake increases. Dissipating the additional heat could be a managemant concern under heat stress. Milk increases are primarily related to post-absorptive use of nutrients for milk synthesis. Current equations from the 1988 Dairy NCR for dry matter intake, nutrient needs, and milk synthesis will apply to the higher producing cows. Improvements in feed efficiency (pounds of fat-corrected milk per unit of net energy) are the result of diluting maintenance requirements and diverting nutrients from body tissue to milk (Chapula and Galligan, 1988).

Protein Considerations

Protein level and degradability in the ration will affect BST responses. McGuffey et al. (1988) reported BST-treated cows produced 9.7 pounds (4.4 kg) more milk with a 40 percent undegraded protein ration compared to 5.9 pounds (2.7 kg) of 3.5% FCM on a ration containing 33 percent undegraded protein. Cows fed 17 percent crude protein with BST produced 9 pounds (4.1 kg) more milk. Cows fed 14 percent crude protein rations increased 6.6 pounds (3.0 kg) with BST. Undegradability protein had a greater impact than level of protein. Canadian researchers (DeBoer and Kennelly, 1988) found similar results with rations higher in crude protein. Cows fed a 16 percent crude protein diet for 28 days and treated with BST produced 23.8 percent more milk (9.9 pounds or 4.5 kg) compared to controls while the cows receiving the 11 percent diet with BST increased milk yield 18.8 percent (6.6 pounds or 3 kg).

Energy Relationships

Energy intake and balance will be a key factor. Higher dry matter intake must be allowed and achieved. An additional 3 to 15 percent increase in total ration dry matter will require high quality forage, use of palatable feeds, excellent bunk management, shift to total mix diets, optimal fiber levels (19 to 20 percent ADF, 28 to 30 percent NDF), adequate non-structural carbohydrate (35 to 40 percent), and limiting ration moisture below 50 percent. Wisconsin data (Thessman et al., 1988) revealed cows on the lower forage diets produced more milk (heifers, 1,683 pounds or 765 kg more milk; older cows, 1,890 pounds or 859 kg more milk). More energy can be consumed by incorporating more grain and less forage.

Studies with supplemental sodium bicarbonate found BST and buffer responses were additive. Feed intake (increased 5.5 pounds), milk yield (increase 8.2 pounds), and fat test (increase .76 percentage points) responses were favorable compared to control cows (Chalupa and Galligan, 1988). Midlactation responses in BST-treated and buffer supplemented cows showed similar responses.

Added dietary fat is another method to increase energy intake. BST-treated cows increased 3.5% FCM by 6.8 pounds (3.1 kg) per cow per day. With one pound of protected fat and BST, cows produced 14.3 pounds (6.5 kg) more 3.5% FCM. In a Pennsylvania study (Lough er al., 1988), the addition of 5 percent fat (hydrolyzed blend of animal and vegetable fat) plus BST had little effect (64.5 pounds or 29.3 kg of milk) compared to BST-treated cows 67.3 pounds or 30.6 kg of milk). Control cows produced 57.9 pounds of milk (26.3 kg). Milk protein percent was decreased (3.30 vs 3.44) with added fat and tended to be lower with BST.

Body condition will need close monitoring because cows direct more nutrients to milk and away from body reserves. Minnesota researchers (Soderholm et al., 1988) measured body fat, body score, and body weight changes and found body fat decreased in BST-treated cows. Cows receiving BST gained 4 to 10 percent less weight than controls. Body condition scores were 3.7, 3.0, 2.7, and 2.4 for control cows, 10.3 mg, and 41.2 mg of BST supplemented cows, respectively. Restoring body condition is more efficient in late lactation. It may be more economical to replace some weight in the dry period at lower efficiencies than stop BST use in late lactation. Economics and cow condition should be carefully evaluated. Cows in negative energy balance can experience poorer reproduction performance (increased days to first heat, decreased estrus expression, and reduced conception rate).

Nutrient Metabolism

Lipid Metabolism

BST is lipolytic which increases body fat degradation (adipose tissue) and increases blood concentration of nonesterified fatty acids (Peel and Bauman, 1987). Cows in negative energy balance produce higher fat test milk. Milk fat composition shifted to a greater proportion of long chain fatty acids (from adipose tissue sources). When animals are in positive energy balance, milk fat percentage was not altered. Treatment with BST balances the rates of lipid synthesis and release to meet energy needs and preserves limited supplies of other key nutrients such as glucose and amino acids.

Carbohydrate Metabolism

Meeting the glucose need for lactose synthesis represents a major challenge, especially before feed intake increases. A reduction in glucose oxidation, mobilization of glycogen reserves, gluconeogenesis from propionate in the liver, amino acid conversion to glucose, and hydrolysis of adipose released glycerol are possible but limited sources.

Protein Metabolism

Milk protein yield increases as milk yield increases. The change in percentage of the milk protein is dependent on the amount of dietary protein consumed. Cows in positive nitrogen balance had no change in milk protein percent. Adding protein postruminally did not increase milk protein yield. If cows were in negative nitrogen balance, the percentage of milk protein declined when BST was administered. The primary source of additional amino acids prior to increased feed intake would likely be from mobilized body reserves.

Mineral Metabolism

Mineral demand is also increased with BST use. The rate of absorption from the digestive tract or mobilization of body reserves are two primary sources. Milk mineral content is not altered and blood concentrations of calcium and phosphorus were unchanged.

Three-Times-A-Day Milking Observations

Changing from two (2X) to three times (3X) per day milking can improve milk yield and profitability. Merrill (1988) reported a 10 to 15 percent milk yield increase is common when switching to 3X milking. Field and research observations related to feeding with 3X are summarized.

1. A .1 to .2 decrease in milk fat percent is typical because yield of milk fat is not as great as for milk yield.
2. Age of the cow does not have a definite effect. Response varies due to management and condition before and after the switch to 3X.
3. First calf heifers increase milk yield in early lactation, while older cows show increases after peak production (6 to 10 weeks postpartum).
4. Feed intake does not increase in proportion to milk yield increase. Body condition and weight loss are needed to meet energy needs. The average increase in milk production was 18 percent while dry matter intake increased only 4 percent. First calf heifers increased milk yield by 6 percent with little increase in feed intake.
5. Adequate weight gain, especially for first calf heifers, may not be possible during late lactation and dry periods.
6. No change in feed efficiency occurs when changes in body condition are considered.

The data on 3X indicate meeting nurtient needs of cows yield 10 to 15 percent more milk will be a challenge. Dairy managers report excellent milk yield response during the initial 18 months after 3X is started. However, low body condition scores and poorer herd health can limit success in the subsequent lactations.

Management and Economics

Quality of management will be **the** major factor affecting the magnitude of response (Figure 2). If management is less than excellent, the entire response curve could shift (Bauman, 1987). Current field recommendations for high producing herds can be applied at high levels of milk production. Diet formulation will be more comprehensive with even greater fine tuning (Table 4). Ecomonic response and profitability will be one factor determining the adaptation rate and use of BST (Table 5). Application of solid nutritional techniques and common sense will result in economical and successful use of BST biotechnology.

Figure 2. Proposed effects of management on the dose response curve in BST-treated dairy cows. (Bauman, 1987).

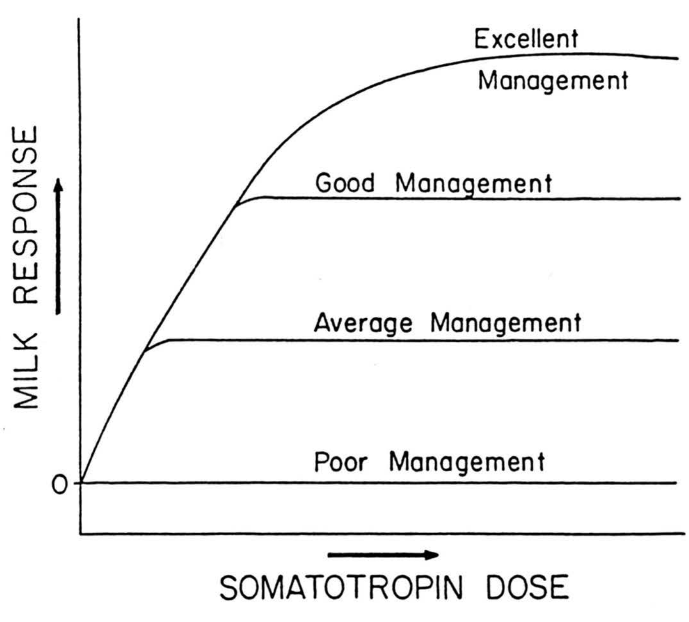


Table 4. Example ration for high producing cows with BST treatment.

I.	Ration Ingredients	Lb D.M.
	Alfalfa Haylage (20% C.P.)	13.5
	Corn Silage (.72 Mcal $N.E._L$)	13.2
	Shelled Corn (dried)	13.4
	Whole Cottonseed (linted)	5.5
	Protected Fat (100% fat)	1.0
	Blood Meal	2.8
	Soybean Hulls	2.7
	Soybean Meal (48%)	1.8
	Limestone	.2
	Commercial 16:16 Mineral	.6
	Buffer	.4
II.	Nutrient Composition of ration (100% D.M. basis)	
	Dry Matter (lb)	55.1
	Crude Protein (%)	18.4
	Undegraded Protein (% total protein)	41
	$N.E._L$ (Mcal per lb D.M.)	.81
	Fat (%)	7.0
	ADF (%)	19.7
	NDF (%)	30.9
	Calcium (%)	.80
	Phosphorus (%)	.48

Table 5. Economic comparison using BST with 1988 Minnesota DHI data at three levels of milk yield.

Milk yield (lb)	16,500	19,500	23,000
% increase BST	10	10	10
Milk increase (lb)	1,650	1,950	2,300
Milk price/cwt	$11	$11	$11
Gross income increase	$182	$215	$253
Base feed costs	$695	$762	$840
% increase feed costs	5	6	7
Feed cost with BST	$35	$46	$59
BST product cost	$90	$90	$90
BST labor cost	$25	$30	$35
BST Total Cost	$150	$166	$184
Net income/cow/yr	+$32	+$49	+$69
Added income (% IOFC)	+2.7	+3.3	+3.9

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