PHYSIOLOGY AND MANAGEMENT

Production Responses to Bovine Somatotropin in Northeast Dairy Herds[1,2]

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ABSTRACT

The commercial response to bovine somatotropin was examined in northeast dairy herds from 1990 to 1998 (4-yr preapproval and 4-yr postapproval). With DHI records and Monsanto customer files, a control group (never purchased Posilac) and a bovine somatotropin (bST) group (used on at least 50% of cows) were identified. A total of 340 herds were involved and, over the 8-yr period, there were over 80,000 cows, 200,000 lactations, and 2 million test days. Herd management comparisons demonstrated the response to bST was relatively constant each year of the postapproval period. Assuming 100% of cows were supplemented, response to bST over a 305-d lactation equaled 894 kg of milk, 27 kg of milk fat, and 31 kg of milk protein. Comparisons of lactation curves were used to identify where the bST response occurred in the lactation cycle. Analysis demonstrated the responses in milk, milk fat, and protein yield were minimal in the early phase of lactation, and then gradually increased until reaching a plateau over the last half of the lactation cycle. Persistency of lactation was also improved by bST, indicating the opportunity exists to extend lactation with combined use of bST and altered reproductive management. Average age and days in milk did not differ between control and bST herds. Thus, stayability and herd-life of animals were not altered by bST treatment. Somatic cell count (SCC) linear scores were minimally affected in herds utilizing bST and the pattern of SCC over the lactation cycle was unaffected. Overall bST improved lactation yield and persistency consistently over the 4-yr postapproval period with no effects on cow stayability and herd-life.

(**Key words:** bovine somatotropin, milk, milk components, stayability)

Abbreviation key: TDM = test-day model.

INTRODUCTION

Somatotropin is a key control in the regulation of nutrient use during lactation (4, 14). Interest in bST began in 1932 when Asdell (1) demonstrated a milk response in lactating goats treated with crude pituitary extract. Shortly thereafter, Asimov and Krouze (2) examined the response to crude pituitary extract in over 2000 cows and consistently observed that a single injection induced a temporary increase in milk yield. As techniques in protein chemistry improved, it was firmly established in the 1940s that the galactopoietic agent in the pituitary extract was somatotropin (see review 32).

Bovine somatotropin represents one of the first products of biotechnology applicable to animal agriculture. The first short-term study with recombinantly derived bST was conducted in 1982 (5), and the first longer-term study reported a few years later (6). Since then, scientists around the world have utilized recombinant bST and examined various aspects of the biology. As a result, bST is among the most extensively investigated agriculture technologies, and to date more than 25 countries have approved bST with regard to animal use and human safety. In the United States, FDA approved the prolonged-release formulation of bST made by Monsanto Co. (St. Louis, MO) and commercial sales began in February 1994. Use has progressively increased by American dairy farmers and by 1998 more than 100 million units (2-wk formulation) of bST had been sold.

Scientific experiments and field studies with bST have been remarkably consistent, showing that bST enhances milk yield and increases productive efficiency (see reviews 3, 7, 8, 9, 15, 21, 22). However, no one has examined the commercial response to bST over the postapproval period. Adoption of bST was quite

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rapid in the northeast and our objective was to examine response to bST in northeast commercial dairy herds. To do this we employed two approaches with the test-day model (**TDM**)—one involving comparisons of herd management and the other involving comparisons of lactation curves. Comparisons utilized DHI records over an 8-yr period (4-yr preapproval and 4-yr postapproval) and contrasted a group that used bST with a group of nonusers.

METHODS

Identification of Groups

The initial step was to use Monsanto's customer files to randomly identify herds in the northeast that fell into two groups. The control group represented nonusers of bST. The criterion for this group was that herd owners and managers had never purchased Posilac (tradename for the 2-wk formulation of bST) from Monsanto. The second group were herds that used bST. Criteria for herds in this group were: 1) purchase of Posilac commenced between February 4 and June 30, 1994; 2) purchases of Posilac occurred at least every 60 d on a continuous basis from July 1994 through March 1998; and 3) purchases of Posilac were sufficient to treat at least 50% of milking cows (evaluated at 6-mo intervals) from July 1994 through March 1998.

The next step was to match the two groups of herds with the northeast dairy records. To do this DHI records from Northeast DHI, Vermont DHIA, and Pennsylvania DHIA were utilized. These were matched at Cornell University. From this a total of 340 herds were identified for the study.

Test-Day Model

Because of potential effects of calving year, season, management, and environment on lactation performance, a linear model that accounts for the biological variation of these influences was applied to the production data (11, 29). Residuals from the TDM are simultaneously adjusted for herd test day, age, days in milk, calendar month fresh, and stage of pregnancy effects. Test-day residuals include the random genetic cow effects and treatment effects. The TDM assumes that global conditions are inappropriate for evaluating management or animals located in different herds. The model accommodates the fact that conditions vary from herd to herd as well as from environment to environment and conditions change over time within herd. The model used to describe milk, fat, protein, or somatic cell linear score on test day was:

$$Y_{ijklmno} = t_i + a_{jk} + d_{jl} + f_{jm} + c_{jn} + e_{ijklmno}$$

Where:

t_i = the ith test day observed for a herd,
a_{jk} = the kth age in months for the oth observation, where j = 1,2 divides the herd data into halves, the oldest data having separate fixed effects solutions from the newest data,
d_{jl} = the lth day in milk for the test day of the oth observation where l describes the 10-d intervals and ranges from 1 to 45 for the 1st and multiple lactations,
f_{jm} = the mth month of freshening associated with the oth observation,
c_{jn} = the nth day pregnant where n = 1 is the 1st 5 mo of pregnancy, n = 2 is the 6th mo, ..., and n = 5 for the 9th and greater mo of pregnancy for 1st and 2nd lactations, and
$e_{ijklmno}$ = the residual for the oth observation of a cow in the nth period of pregnancy, the mth month fresh, the lth day in milk, the kth age in months in the jth period and tested on the ith herd test day.

The observation y is a vector of all milk, fat, protein, or somatic cell linear score observations for a cow and the elements of y are assumed correlated. The fixed effects equations for the linear model are:

$$x'R^{-1}x\beta = x'R^{-1}y,$$

where R describes the relationships among the test-day observations in the y vector on a cow. If a cow is tested n times, R is an n × n matrix describing the residual variance-covariance structure of the n test days for the cow. R is assumed to have an autocorrelation structure such that $R/\sigma^2 = r$ is an autocorrelation matrix, where ρ_{ij} is the correlation between tests i and j and equals:

$$\rho^q \text{ and } q = |(t_i - t_j)/30|,$$

where t_i and t_j are days in milk for test i and j, respectively, and ρ = 0.73, 0.58, 0.69, and 0.65 for milk yield, fat yield, protein yield, and somatic cell linear score, respectively.

The model was fit to the data and residuals were obtained as $e = y - x'\beta$. The residuals were standardized to a common variance for all test days.

TABLE 1. Average herd parameters on test day.[1]

	Control herds (n = 176)		bST herds (n = 164)		
Variable	Preapproval	Postapproval	Preapproval	Postapproval	Overall (n = 340)
Cows in milk, n	74.9	75.7	84.9	90.5	81.1
Milk, kg/d	27.2	28.8	28.7	33.0	29.2
Fat, g/d	998	1048	1043	1179	1061
Fat, %	3.67	3.64	3.63	3.57	3.63
Protein, g/d	871	907	916	1048	907
Protein, %	3.21	3.15	3.19	3.17	3.18
SCC, linear score	3.22	3.08	3.10	3.17	3.14
Age, d	1663	1580	1585	1510	1594
DIM	166	151	169	150	161

[1]Study included preapproval period (January 1990 to February 1994) and postapproval period (July 1994 to March 1998).

RESULTS

General characteristics of the 340 herds are presented in Table 1. Data represent averages for milking cows on test day. For example, cow number represents the herd average for cows milking on test day and does not include dry cows. In addition, data are separated into the preapproval and postapproval periods for both control and bST groups. In general, the two groups were similar, especially during the preapproval period. Over the 8-yr period herds averaged 81 cows milking on test day with herds in the bST group being 10 to 15 cows larger than control herds. On test day, milking cows averaged 1594 d of age, 161 d postpartum, and a milk yield of 29.2 kg/d.

Analysis by Comparing Herd Management

One method to estimate the effect of bST with the TDM is to compare changes in milk related to overall herd management for the two groups. With a large number of herds, changes in production due to factors such as feed quality, weather, genetics, animal care, and herd health should be similar or change at the same rate in both sets of herds. Results for yields of milk, fat, and protein are presented in Figure 1, where yearly averages are compared to 1993, the year prior to bST approval. The response patterns were similar for all three variables as expected given that fat yield and protein yield are highly correlated with milk yield. Performance improved over the 8-yr period, as indicated by the positive slope for all 3 variables. Control and bST groups improved in a parallel manner during the preapproval period. However, the bST group had a marked increase in average daily yields of milk, fat, and protein, which coincided with the approval of bST. Thereafter, improvements over the postapproval period for herds in the bST group were again parallel to that observed for the control group. The response to bST supplement is reflected by the difference between bST and control groups during the postapproval period and represents an average per cow on test day. Clearly this difference remained relatively constant throughout the postapproval period (Figure 1).

The ANOVA for TDM comparisons of herd management is presented in Table 2. The response to bST (overall difference column) represents an average for all milking cows in the herd. Thus, the average is based on the assumption that all cows milking on test day have been supplemented with bST. Obviously, on each test day only a percentage of the milking herd has received bST; not every cow is eligible to be treated (first 60 d postpartum), and producers do not treat every eligible cow. Results indicate that daily yields of milk, fat, and protein were increased in response to bST; over the postapproval period this daily increase equaled 2.9 kg of milk, 88 g of milk fat, and 100 g of milk protein.

Stayability and cow health are also of interest and DHI test-day records provide us information on age, DIM, and SCC for the milking cows. Differences between groups were minimal for these variables (Table 2). Use of bST resulted in nonsignificant test-day herd averages, which numerically differed by less than 3 d in age and 0.2 d in DIM. Comparisons of herd management indicated bST herds had a small but significant increase in SCC linear score (Table 2). However, the SCC linear scores for preapproval and postapproval periods were low for both groups ranging from 3.08 to 3.22 (approximately 106,000 to 117,000 SCC/ml) (Table 1).

There were distinctive year-to-year changes for age and DIM over the preapproval and postapproval periods, but these changes were similar for both control and bST groups (Figure 2). In contrast, SCC remained relatively constant over the study period and there were no distinctive year-to-year changes for either group (data not presented).

Analysis by Comparing Lactation Curves

A second approach is to compare lactation curves to identify where in lactation the differences occurred in bST herds. Because of parity differences in lactation curves, we examined this for primiparous and multiparous cows, and as expected, the lactation curves for milk yield were more persistent for primiparous cows (Figure 3). Lactation curves were similar for the preapproval and postapproval periods within parity groups for the control herds. In contrast, there were marked differences for the postapproval period in bST herds, which resulted in an overall improvement in persistency over the last two thirds of lactation. By taking differences between the preapproval and postapproval

TABLE 2. Test Day Model comparisons of herd management differences.

Variable	Control herd differences[1]	bST herd differences[2]	Overall difference[3]
Milk, kg/d	0.90 ± 0.12	3.02 ± 0.12	2.93**
Fat, g/d	−42 ± 5	46 ± 5	88**
Protein, g/d	−25 ± 4	75 ± 4	100**
SCC, linear score	−0.04 ± 0.02	0.16 ± 0.02	0.20**
Age, d	−7.8 ± 4.8	−5.1 ± 4.8	2.7
DIM, d	8.2 ± 1.3	8.4 ± 1.3	0.2

**$P < 0.01$.

[1]Control herd averages for postapproval period minus preapproval period.

[2]Bovine somatotropin herd averages for postapproval period minus preapproval period.

[3]Represents response to bST. Calculated by bST herd differences minus control herd differences.

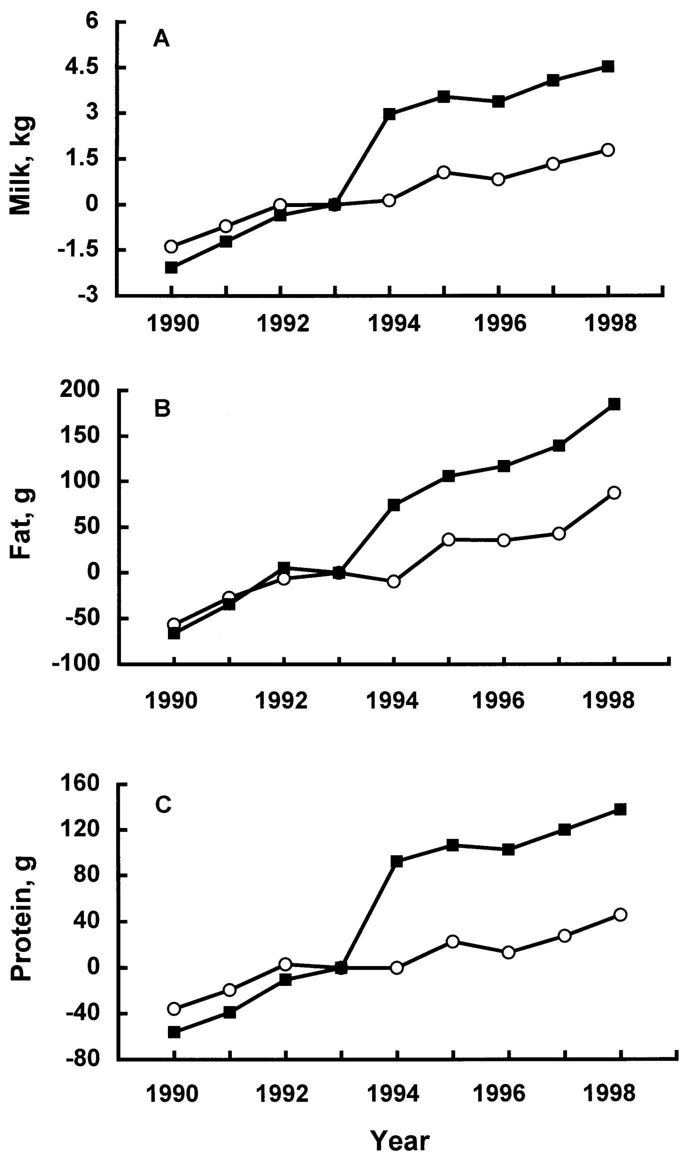

Figure 1. Comparisons of herd management for daily yields of milk, milk fat, and milk protein for control (circles) and bST (squares) herds. Values represent averages for all cows milking on test day and SE equals 0.1 kg for milk, 3 g for fat and 3 g for protein. For ease of comparison, yearly test-day averages are compared to 1993, the year prior to bST approval.

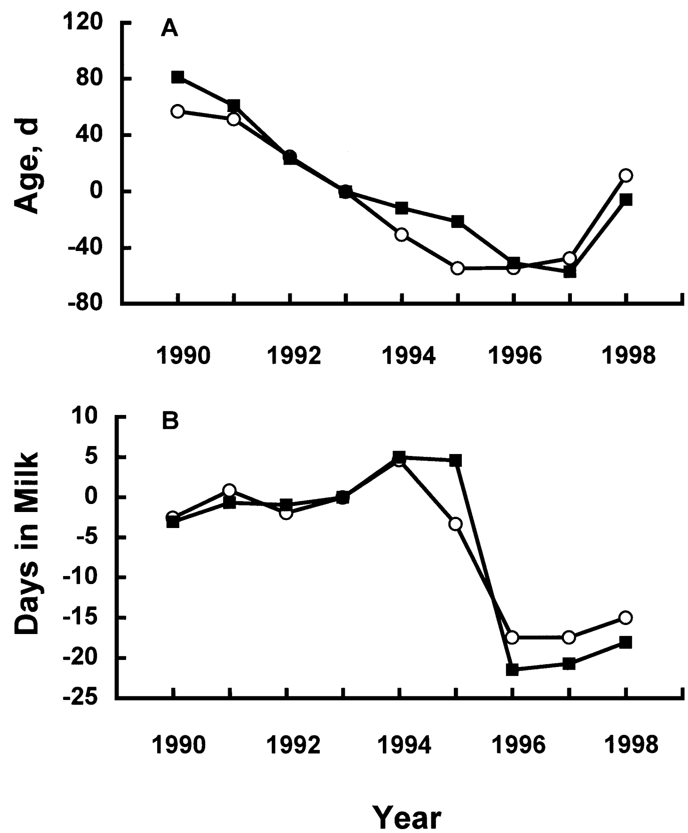

Figure 2. Comparisons of herd management for average age and days in milk for control (circles) and bST (squares) herds. Values represent averages for all cows milking on test day and SE equals 4 d of age for 1 d for DIM. For ease of comparison, yearly test-day averages are compared to 1993, the year prior to bST approval.

periods for control and bST herds, the response to bST can be estimated. This is shown in Figure 3 (panels E and F) for primiparous and multiparous cows. Milk response to bST was minimal in early lactation and then gradually increased until reaching a plateau that was maintained over the last one-half of lactation. Over the plateau region the milk yield response was slightly greater in primiparous cows as compared to multiparous cows, but overall averaged approximately 3.6 kg of milk/d. This response represents a minimum estimate and assumes that all cows are receiving bST supplement. If producers were only treating 70 to 75% of eligible cows the milk response to bST in the plateau region would be approximately 5 kg/d.

Lactation curves of TDM analysis for yields of milk fat and milk protein are shown in Figures 4 and 5. In general, patterns and comparisons for lactation curves were similar to those observed for milk yield. The patterns of lactation curves for the control herds were nearly identical for the preapproval and postapproval periods (Figures 4A and 5A). For bST herds, there were obvious changes in the lactation curves with an increase in the persistency for the postapproval period for both milk fat and milk protein (Figures 4B and 5B). The temporal patterns of the response to bST calculated from comparisons of preapproval and postapproval lactation curves were also similar to the milk yield response. Assuming 100% of cows in the bST

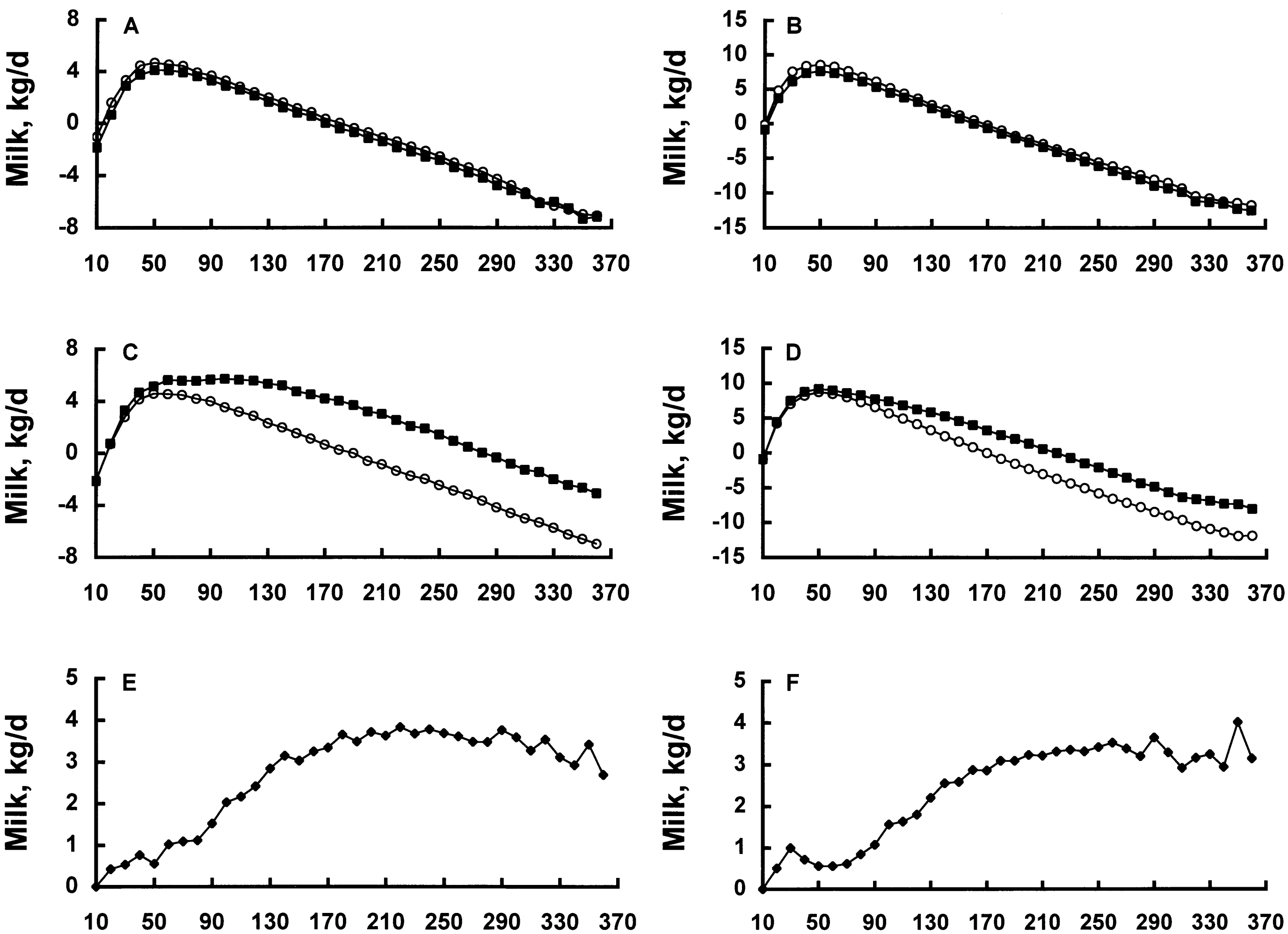

Figure 3. Comparisons of lactation curves of milk yield for control and bST herds during the preapproval period (January 1990 to February 1994) and the postapproval period (July 1994 to March 1998). Data for primiparous cows (Panels A, C, and E) and multiparous cows (Panels B, D, and F) are presented for preapproval period (circles), postapproval period (squares), and differences (diamonds). Panels A and B are control herds, panels C and D are bST herds, and panels E and F are milk response to bST (SE < 0.2 kg/d). Test-day model comparisons are expressed so that solutions sum to zero across the lactation. For graphic purposes solutions for test day 10 were set equal for the preapproval and postapproval periods for the bST herds.

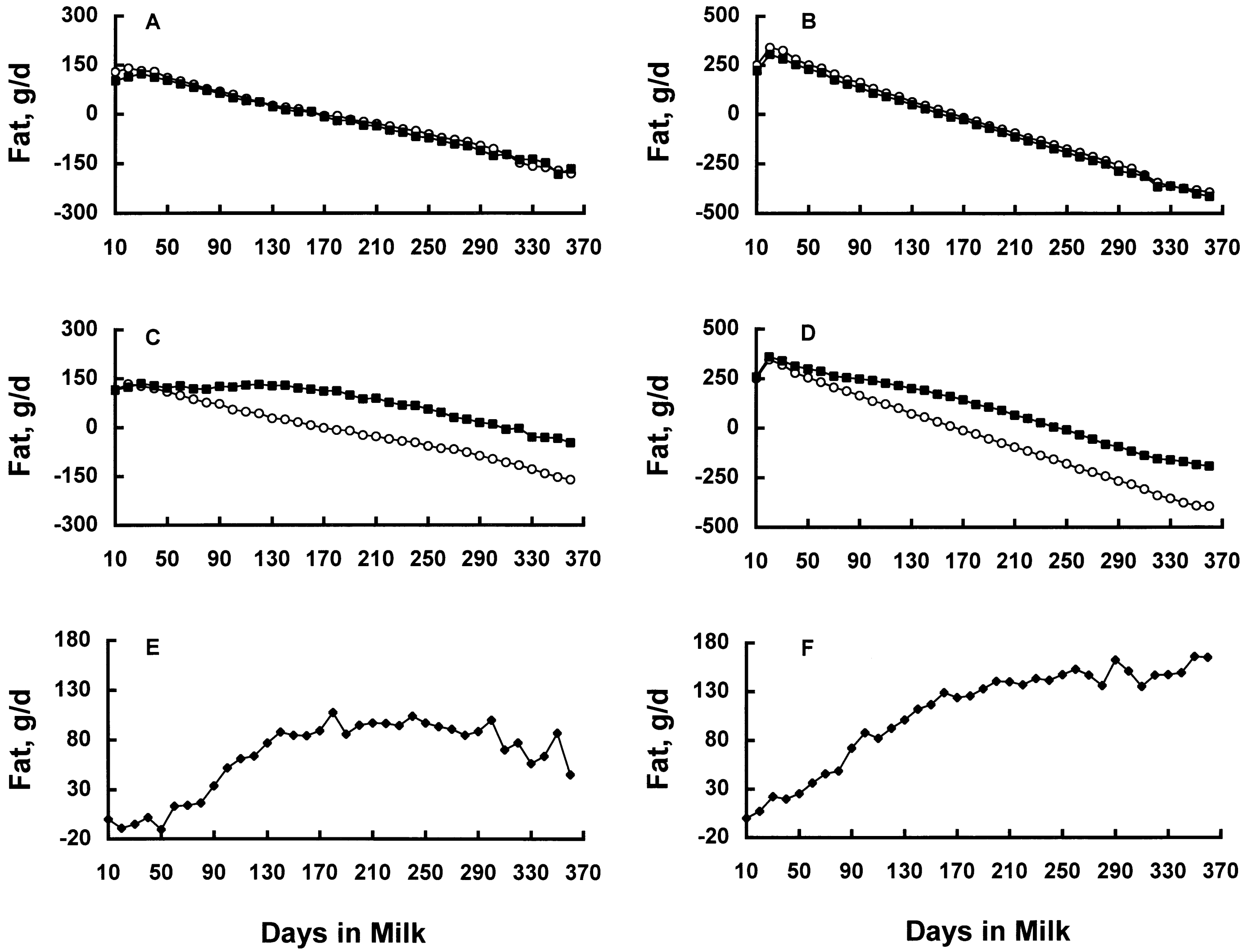

Figure 4. Comparisons of lactation curves of milk fat yield for control and bST herds during the preapproval period (January 1990 to February 1994) and the postapproval period (July 1994 to March 1998). Data for primiparous cows (Panels A, C, and E) and multiparous cows (Panels B, D, and F) are presented for preapproval period (circles), postapproval period (squares) and differences (diamonds). Panels A and B are control herds, panels C and D are bST herds, and panels E and F are milk fat response to bST (SE <5 kg/d). Test-day model comparisons are expressed so that solutions sum to zero across the lactation. For graphic purposes solutions for test day 10 were set equal for the preapproval and postapproval periods for bST herds.

herds are receiving supplement, the daily response to bST over the last half of lactation represented an increase of approximately 130 g of milk fat and 115 g of milk protein.

The patterns over the lactation cycle for milk content of SCC are presented in Figure 6. The SCC were greatest at the initiation of lactation, and then progressively declined over the first 60 d postpartum (Figure 6). Thereafter, SCC were relatively constant through the remainder of lactation for primiparous cows, but gradually increased over the last two-thirds of lactation in multiparous cows. However, comparisons within groups indicate that there were no changes in the temporal pattern of SCC between the preapproval and postapproval periods for either control or bST herds.

DISCUSSION

The TDM is increasingly used in genetic evaluations, but it is also a powerful tool that allows evaluation of the effect of particular management practices (11, 29, 30). We used the TDM and evaluated the management practice of bST supplementation by using two approaches; one involved comparisons of herd management and a second involved comparisons of lactation curves. Our study represents the most extensive investigation to examine the impact of bST on dairy cow performance and stayability. There were over 27,500 cows on each test day. Over the 8-yr period, the study involved over 80,000 cows, 200,000 individual lactations, and 2 million cow test days.

Milk production increases occurred with bST treatment as indicated by both TDM approaches. Herd management comparisons demonstrated that the milk yield response to bST was relatively constant for each of the 4 yr of the postapproval period (Figure 1A). Furthermore, increases in yield of milk fat and milk protein paralleled the milk yield increases (Figure 1B and C) so that milk composition was unaltered (Table 1). Across the interval of 1990 to 1998 improvements in overall management of northeast dairy herds occurred, and this is clearly evident in control herds (Figure 1). These same improvements occurred in the bST herds, but these herds also had an additional increase in yield of milk and milk components due to bST supplement. For all herds, the non-bST related improvements over the 8-yr period represented a daily increase per cow of approximately 3.4 kg of milk, 201 g of milk fat and 111 g of milk protein. This reflects an improvement in the quality of management and genetics of the herds.

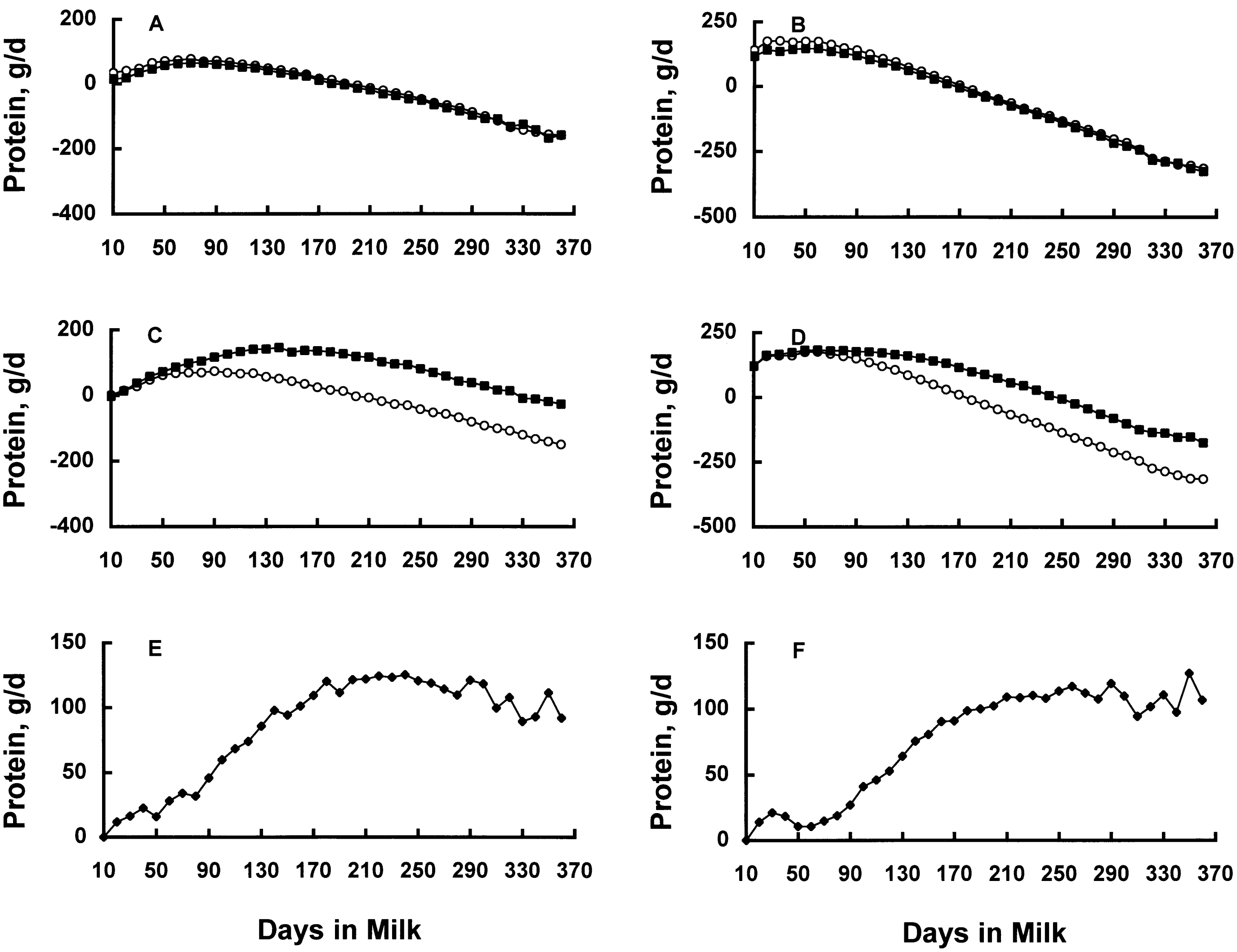

Figure 5. Comparisons of lactation curves of milk protein yield for control and bST herds during the preapproval period (January 1990 to February 1994) and the postapproval period (July 1994 to March 1998). Data for primiparous cows (panels A, C, and E) and multiparous cows (panels B, D, and F) are presented for preapproval period (circles), postapproval period (squares), and differences (diamonds). Panels A and B are control herds, panels C and D are bST herds, and panels E and F are the milk protein response to bST (SE <5 kg/d). Test-day model comparisons are expressed so that solutions sum to zero across the lactation. For graphic purposes solutions for test day 10 were set equal for the preapproval and postapproval periods for bST herds.

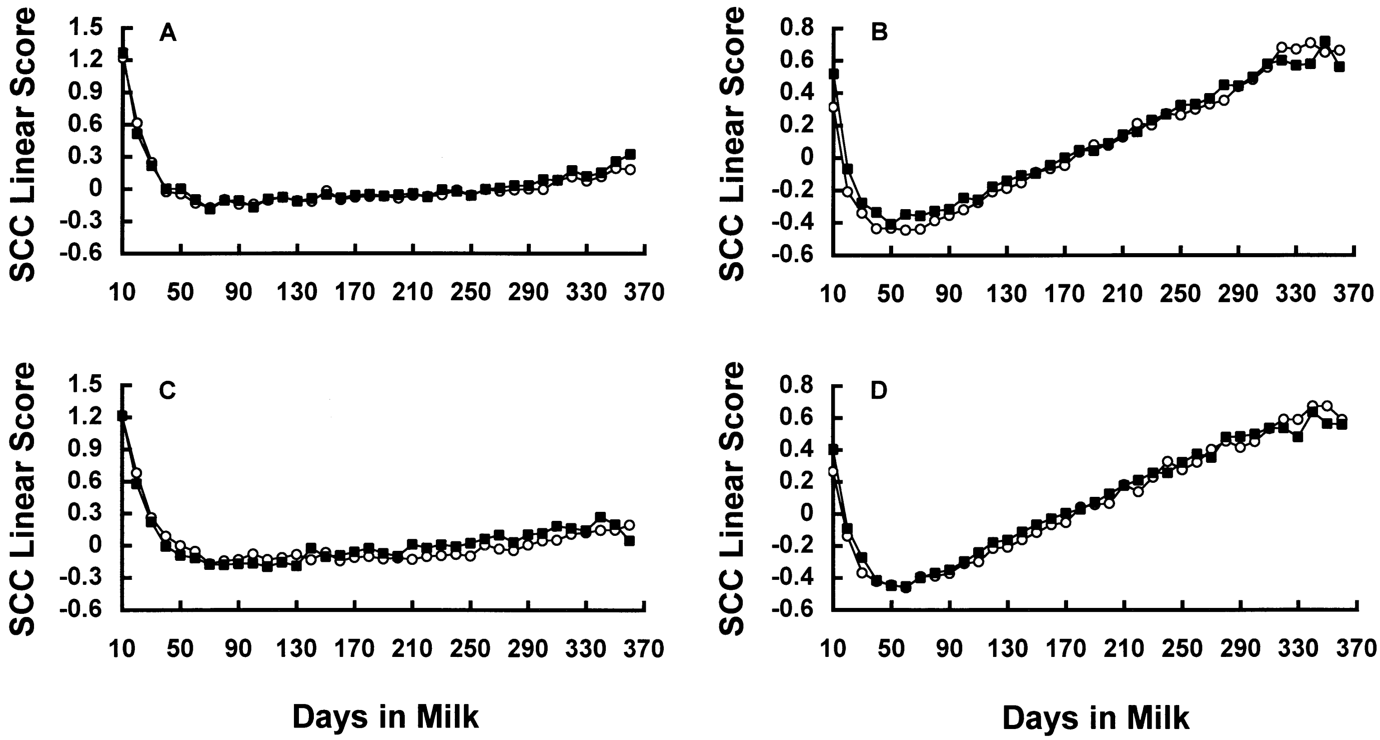

Figure 6. Comparisons of lactation curves of milk somatic cell counts (linear score) for control and bST herds during the preapproval period (January 1990 to February 1994) and the postapproval period (July 1994 to March 1998). Data for primiparous cows (panels A and C) and multiparous cows (panels B and D) are presented for the preapproval period (circles) and postapproval period (squares). Panels A and B are control herds and panels C and D are bST herds. Test-day model comparisons are expressed so that solutions sum to zero across the lactation.

With differences observed in herd management comparisons (Table 2) and assuming a 305-d lactation, the response to bST represented an average increase of 894 kg of milk, 27 kg of milk fat, and 31 kg of milk protein. These represent minimal estimates of the response to bST as they assume that 100% of eligible cows are receiving bST supplement. If only 75% of eligible cows are supplemented, then the lactational milk increase to bST would be about 1200 kg. Nevertheless, our observed response to bST is consistent with summaries from scientific experiments and field studies (see reviews 3, 7, 8, 9, 15, 21, 22). It has also been established that the magnitude of the lactational response to bST supplementation is related to the quality of herd management (3, 9, 15, 21). The analytical approaches used in the present study don't allow for an evaluation of quality of herd management. However, herds which are less well managed would not have a substantial milk response or economic return from bST, so we would expect they would not be continuous bST users over the postapproval period.

Comparisons of lactation curves with the TDM demonstrated that bST effects were similar for yields of milk, milk fat, and milk protein for both primiparous and multiparous cows (Figures 3, 4, and 5). The temporal patterns indicated that yield response to bST was minimal in the early phase of lactation, and then gradually increased until reaching a plateau, which was maintained over the last half of the lactation cycle. In the present study, the timing of the initiation of bST treatment and the proportion of cows actually receiving bST supplement are unknown. Thus, these data represent minimum responses to bST. Use of bST is recommended to commence at 60-d postpartum and continue until dry off. The small increases in yields of milk and milk components observed during the first 60 d postpartum may be due to a limited number of the cows treated during this period. Scientific studies show that when treatment is initiated at 60 d postpartum, an immediate large increase in milk yield occurs, and this response is maintained or increases slightly with continued treatment (3, 7, 8, 9, 15, 21, 22). In contrast to this pattern, we observed a gradual increase in milk response over a 3-mo period following 60 d postpartum. The pattern we observed is probably related to a delay in the initiation of bST treatment for many cows. In discussions with producer groups throughout New York during recent Extension Winter Dairy Management

Schools (January 1999), it was apparent that delaying initiation of bST use until later in lactation was a common practice.

The increased lactation persistency that occurred with bST supplement offers the opportunity for herd managers to consider extended lactations. On a herd basis this results in a decrease in the proportion of cow days in the high health risk period (first 60 d postpartum) and can increase economic return (18, 29). However, based on age and DIM (Figure 2) bST herds are not altering their reproductive program to adopt a practice of extended lactations.

Animal health and well-being are also of interest with bST use, and there are several reviews of the scientific literature (3, 7, 12, 20, 23). In general, these summaries have indicated no apparent adverse effects of bST; treated cows are comparable to nontreated cows at the same level of performance. This result is supported by recent studies with commercial dairy herds. Analysis of business records of 259 New York dairy farms indicated that veterinary costs per cow were not different between bST users and nonusers (27). Furthermore, extensive analysis of four Michigan dairy farms demonstrated that therapy for clinical mastitis and culling rate for mastitis did not differ for groups treated with bST (16). In the present study, the clearest indication of animal well-being is lactational performance. The increases in yield of milk and milk components and the consistency of this response over the 4-yr postapproval period indicate animal well-being in the bST herds (Figure 1). In addition, the similarity of increases in lactational performance over the preapproval and postapproval periods related to overall management suggests that control and bST herds did not differ in animal well-being. Average age and DIM are additional variables related to animal well-being that are available from DHI records. These variables did not differ between control and bST herds. Thus, stayability and herd-life of animals were not altered by bST treatment. Consistent with this, a recent study of over 5000 cows in 32 Midwest herds found that culling patterns were unaffected by bST use (24).

Somatic cell counts are commonly measured to provide information on milk quality and mammary health. Infection is the major factor affecting SCC and it elicits a dramatic increase. In addition, a number of factors have minor effects on SCC in uninfected mammary glands and these include stage of lactation, season, age, and milk yield (13, 17, 25). Several large data sets have summarized the effect of bST on somatic cell counts and observed negligible effects (19, 20, 28, 31). The present study was much more extensive, and with TDM comparisons of herd management we were able to detect a small increase in average SCC in bST herds (Table 2). This increase is consistent with the positive correlation reported between SCC and the yield of milk and milk protein (see review 26). However, the increase represents a negligible effect on SCC and is substantially smaller than effects observed for season, age, breed, and parity in uninfected cows (13, 17, 25, 26).

More revealing for SCC were the comparisons of lactation curves (Figure 6). As has been reported previously (e.g., 17, 25), there were distinct patterns for SCC over the lactation cycle, and these differed between primiparous and multiparous cows. However, there were no differences between the preapproval and postapproval period for either control or bST herds. For all groups the greatest SCC occurred in early lactation (Figure 6). This has also been observed by many others (e.g., 13, 17, 25) and is consistent with the fact that the majority of mastitis and other herd health problems occur over the first 45 d postpartum (10). Of course, this is a period when bST supplements are not used. Overall, data indicate that bST use had no effect on SCC of any biological importance.

CONCLUSIONS

Analysis of control and bST herds clearly demonstrated that use of bST increased yields of milk, fat, and protein. The response was relatively constant for each of the 4 yr of the postapproval period. Comparisons of lactation curves indicated bST use improved persistency; peak milk response occurred over the last one-half of the lactation cycle. Somatic cell counts were slightly increased in bST herds, but the pattern of SCC over the lactation cycle was unaffected by treatment. Furthermore, stayability and herd-life of cows was not altered by bST treatment based on herd averages for age and DIM.

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