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Supplementation of Holstein Cows with Low Doses of Bovine Somatotropin (bST) Prepartum and Postpartum Affects Physiological Adaptations and Milk Production

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ABSTRACT : Major objectives were to evaluate effects of three schemes of bST-supplementation of Holstein cows (142.8 mg/14 d, POSILAC) during the prepartum and/or postpartum periods through 63 d (±3 d) of lactation. Measures evaluated the potential of treatments to improve body weight (BW) and body condition score (BCS), provoke changes in plasma concentrations of somatotropin (ST) and IGF-I, and improve milk yield, milk composition (percentages of protein and fat, and somatic cell counts), and several calving variables. Multiparous Holstein cows were randomly assigned to a 2×2 factorial arrangement of treatments (TRT) to give four groups (I = no bST, n = 26; II = bST postpartum, n = 25; III = bST prepartum, n = 27; IV = bST prepartum and postpartum, n = 25). During the prepartum period, cows in groups I and II were not supplemented but those in groups III and IV were supplemented every 2-wk beginning 21 d before expected calving date through calving. During the first 63 DIM only cows in groups II and IV were supplemented with bST. From 64 DIM through the end of lactation cows in all groups were supplemented with the full lactation dose of bST (500 mg/14 d). The BW and BCS were recorded weekly throughout the prepartum and postpartum periods and every 2-wk beyond 70 DIM. Blood samples were collected 3-times a week for analyses of ST and IGF-I. Milk yields were recorded daily though 150 DIM. Prepartum supplementation of bST did not affect BW or BCS, but mean concentrations of ST were increased 12.2% and were 15.5% greater at calving. Overall, mean concentration of IGF-I was not affected by treatment but concentrations were greater at 1 and 2 wk before calving in bST-supplemented cows. During the first 63 DIM the BW and BCS were not affected by treatment. Significant effects of bST-supplementation were detected on concentrations of ST, IGF-I and on milk yield compared to non-supplemented cows in group I. Postpartum concentrations of ST were greater in bST-supplemented cows (TRT II and IV; +41.9 and 54.6%). However, concentrations of IGF-I were greater only in cows in group IV (+25.9%) during the postpartum period. Overall, the three bST-supplemented groups had greater actual milk yield than the control group (I) during the first 63 and 150 DIM. The actual milk yields during 63 and 150 DIM were 6.5 and 4.6 kg/d greater for cows in group IV than cows in group I and the 305-d ME milk yield also was 15.6% greater. No adverse effects of TRT were observed on calf birth weight, colostrum immunoglobulins, ease of calving or other measures evaluated. (**Key Words** : bST, Holstein Cows, Hormones, Milk Production, Transition Period)

INTRODUCTION

The transition from gestation to lactation (3 wk prepartum to 3 wk postpartum, herein defined as the transition period) is the most critical phase of the productive life of the dairy cow. Immediately before calving the requirements for glucose, amino acids and fatty acids by the fetus accounts for ~40-85% of the dairy cows post-absorptive supply of these nutrients (Bell, 1995; Goff and Horst, 1997). These prepartum demands occur at the time of about a 30-35% decrease in feed intake as parturition approaches. After parturition there is a similar trend in utilization of these nutrients by the mammary system to support increased milk production. Because of increased nutrient and energy demands for body maintenance and to support rapidly increasing milk production, there is extensive mobilization of body reserves (adipose and muscle tissues) to meet the additional demands and for appropriate function of vital systems (Chilliard, 1999). Thus, a slow and inadequate increase in feed consumption during the early postpartum period imposes a great challenge for

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the dairy cow because of the substantial negative nutrient and energy balance (Grummer, 1995).

Management strategies during the transition period to improve DMI and the subsequent milk production, and possibly the health status of cows, include improved nutritional management and housing. In addition, supplementation of low doses of bST has been evaluated, in part, because of its ability to positively affect the physiological adaptations. Furthermore, the bST supplementation may also accelerate and/or increase DMI and improve immune function during this critical phase. Gulay et al. (2003, 2004a, 2004b) showed that supplementing dairy cows with low doses of bST during both the prepartum and postpartum periods (142.8 mg bST/14 d) had positive effects on some hormones, metabolism and milk production. It is well-documented that supplementing bST during lactation results in increased milk production and DMI (Bauman and Vernon, 1993; Bauman, 1999). The bST acts, in part, by decreasing muscle use and overall body oxidation of glucose, by decreasing the whole body oxidation of amino acids if cows are in positive energy balance, and by increasing the overall oxidation of non-esterified fatty acids when cows are in negative energy balance (Bauman and Vernon, 1993). Thus, through the direct and indirect actions of somatotropin (ST) the use of bST during the transition period results in improved milk production (Gulay et al., 2004a) and apparently improves early postpartum health of dairy cows (Gulay et al., 2007).

Although the milk production and milk composition responses to bST-supplementation are documented (Gulay et al., 2003, 2004a, b), the associated metabolic adaptations and responses to different prepartum and/or postpartum bST-supplementation schemes have not been critically evaluated. This evaluation is necessary to determine if alternate supplementation schemes may be equally effective or even better at provoking desired positive responses. Therefore, objectives of this research were to evaluate bST-supplementation of Holstein cows (142.8 mg bST/14 d, POSILAC) during the prepartum and/or postpartum periods and also the effects of season of calving (SEA) on milk production, milk composition (percentages of protein and fat, and somatic cell counts), body weight (BW) and body condition score (BCS), changes in plasma concentrations of ST and IGF-I, and some calving variables.

MATERIALS AND METHODS

Animals and treatments

This research was approved by the Institutional Animal Care and Use Committee of the University of Florida. It was conducted at the Dairy Research Unit (DRU) of the Department of Animal Sciences located 17 km north of the University campus. One hundred three multiparous Holstein cows were assigned randomly to a 2×2 arrangement of treatments based upon the prepartum and/or postpartum time periods during the transition period and/or early lactation that cows were supplemented with low doses of bST. The amount of bST (POSILAC®; 500 mg/dose; Monsanto Co., St. Louis, MO) supplemented was 142.8 mg/14 d; about 28.5% of the dose approved for the enhancement of lactation. The supplementation began at about 21 d (3 wk) before expected calving date (ECD) and continued through calving day. The postpartum bST-supplementation began within 24 h after calving regardless of time of the previous prepartum injection. Cows were supplemented 2-times prepartum and 5-times postpartum; supplementation of the low dose was discontinued at 56-58 DIM. The arrangement of treatment (TRT) groups and cow numbers per group were: I (controls, n = 26); II (bST postpartum, n = 25); III (bST prepartum, n = 27); and IV (bST prepartum and postpartum, n = 25). The bST was supplemented by injection in the left or right ischiorectal fossa before a.m. feeding and milking. Beyond 63 DIM and through the remainder of their lactation all cows, including controls (I), were supplemented with a full dose of bST (500 mg bST/14 d). This latter use of bST during lactation was the management practice for the entire 450 dairy cow herd at the DRU. The average number of previous lactations for cows in each of the four TRT groups (I, II, III and IV) were 2.32, 1.84, 2.16 and 2.16. Actual days that cows in these four TRT groups were managed prepartum were 20, 19, 19 and 19 d (±1.46 d). The BW and BCS of the cows at the time that they were assigned to TRT ranged from 598 to 889 kg and 3.0 to 4.5.

During the experimental period (21 d prepartum to 63 d postpartum) the cows in all four groups were managed and fed together in a calving pen prepartum and in a free-stall barn postpartum. The diets were fed *ad libitum* to allow 5-10% daily feed refusals. Prepartum and postpartum diets were formulated following National Research Council (NRC, 2001) recommendations for these physiological stages and consisted of an anionic close-up prepartum diet and a cationic TMR fresh-cow diet postpartum (Table 1). The dry matter (DM) and nutrient contents of individual ingredients used to formulate these diets were obtained by wet chemistry analysis at the NEDHIA Forage Laboratory, Ithaca, NY. In addition, the DM content of the corn silage was measured weekly at the DRU and the quantity of corn silage included in the TMR was adjusted each week to maintain the desired amount of DM from corn silage.

Colostrum and milk samples

A sample of colostrum (COL) was collected from all cows (n = 103) at the first postpartum milking. These samples were analyzed using a commercial hygrometer

Table 1. Dry matter concentrations and chemical composition of anionic close-up diet (CUD) and fresh-cow TMR fed to Holstein cows[1]

Item	Anionic CUD[2]	Fresh-cow TMR[2]
Ingredient	------------ DM basis (%)	---------
Corn silage	44.2	21.7
Sorghum silage	-	8.3
Alfalfa hay	-	7.3
Cottonseed hulls	8.8	5.5
Whole cottonseeds	6.7	7.7
Citrus pulp	8.5	7.7
Corn meal	13.0	20.1
Molasses	-	2.6
Soy plus[3]	2.2	6.5
Soybean meal	7.0	9.4
Springer minerals	7.4	-
Lactating cow mineral	-	3.3
White salt	0.3	-
Zinc chloride	1.2	-
Magnesium sulfate	0.7	-
Nutrient	------------- Percentage[4]	-----------
DM	49.41	56.66
CP	13.80	17.45
Sol CP[5]	29.42	30.51
NDF	37.42	34.74
ADF	24.49	22.36
NSC	36.12	39.88
EE[6]	4.18	4.56
TDN (%)	66.60	72.75
NE_L (Mcal/kg)	1.47	1.60
Ca^{+2}	1.66	0.65
P^+	0.34	0.38
Na^+	0.21	0.30
K^+	1.02	1.33
Cl^-	1.09	0.23
S^{-2}	0.40	0.18
Calculated DCAD[7]	-5.78	+38.75

[1] Values expected for diets formulated (NRC, 2001) on dry matter basis.
[2] CUD (53:47 forage:concentrate); fresh cow TMR (43:57 forage: concentrate).
[3] Trademark of West Central, Ralton, IA.
[4] DM Basis. [5] Soluble protein as percentage of the CP.
[6] Ether extract. [7] Meq (Na+K)-(Cl+S)/100 g of diet DM.

(Colostrometer, Nasco, Fort Atkinson, WI) and scores obtained reported as mg of immunoglobulins/ml of COL (Fleenor and Stott, 1980). Milk samples were collected at 2-wk intervals from all cows (n = 103) during three consecutive milkings (08:30, 15:00 and 01:30 h) during the first 10-wk of lactation. Samples (50 ml) were analyzed for milk fat (FAT), protein (PROT) and somatic cell counts (SCC) at Southeast Milk Laboratory, Inc. (Belleview, FL). Milk yield (MY) was recorded at each daily milking from 3 to 150 DIM.

Body weight and body condition score

Body weight (kg) and BCS (1 to 5, thin to fat; Edmonson et al., 1989) were recorded during the experiment. Each cow was weighed and BCS estimated at the time of group assignment (~3 wk prepartum) and then on the same day each week (8:00-12:00 h) before the a.m. feeding or milking through 70 DIM. Thereafter, BW and BCS were obtained, as previously described, but at 2-wk intervals until the cows completed 150 DIM. Scoring of BCS was in 1/4 point intervals by the same three trained personnel throughout the experiment.

Blood collection, handling and storage

Blood samples were collected from the tail vein of all cows (n = 103) 3-times each week before the morning feeding or milking (06:30-10:00 h) through 70 DIM. Cows were sampled at 2, 4, 7, 9, 11 and 14 d after injection of bST throughout the trial and also at calving. Vacutainer® brand needles (2.54 cm; 20 gauge) and tubes containing sodium heparin (10×100 mm collection tubes, Becton-Dickinson, Fairlawn, NJ) were used for blood collection. Blood samples were placed in an ice-bath immediately after collection and processed within 2 h. Samples were centrifuged at 3,000 RPM at 5°C for 30 min (RC-3B refrigerated centrifuge, H600A rotor, Sorvall Instruments, Wilmington, DE) to separate plasma, which then was transferred into labeled 5 ml (12×75 mm) polypropylene tubes, capped, and frozen at -20°C until analyzed. The plasma samples were used for analysis of ST and IGF-I.

Double antibody radioimmunoassay procedures were used for assay of ST (Garcia-Gavidia, 1998) and IGF-I (Abribat et al., 1990). IGF-I was extracted from plasma using an ethanol, acetone and acetic acid mixture (Daughaday et al., 1980; Enright et al., 1990). In individual assays the standards and samples were assayed in triplicate and duplicate, respectively. The intra-assay and inter-assay coefficients of variation for ST and IGF-I were 0.8 and 1.9%; and 12.5 and 4.0%, respectively.

Statistical analyses

Data were analyzed as separate prepartum and postpartum data sets. However, data for groups I and II (no-bST) and groups III and IV (bST-supplemented) during the prepartum period were merged based upon the prepartum bST supplementation scheme. The time periods considered prepartum were -3 to 0 wk and -21 d to calving. For the postpartum period, dependent variables were analyzed in three phases; from 0-63 DIM, 0-150 DIM and 64-150 DIM. Least squares analysis of variance using the GLM procedure of SAS® (SAS Institute, 2007) was used to determine effects of TRT (periods of bST-supplementation) and calving season (SEA; I- August, September, October; II- November, December, January, February) on the dependent variables.

The PROC MIXED procedure was used to estimate individual daily and/or weekly least squares means for

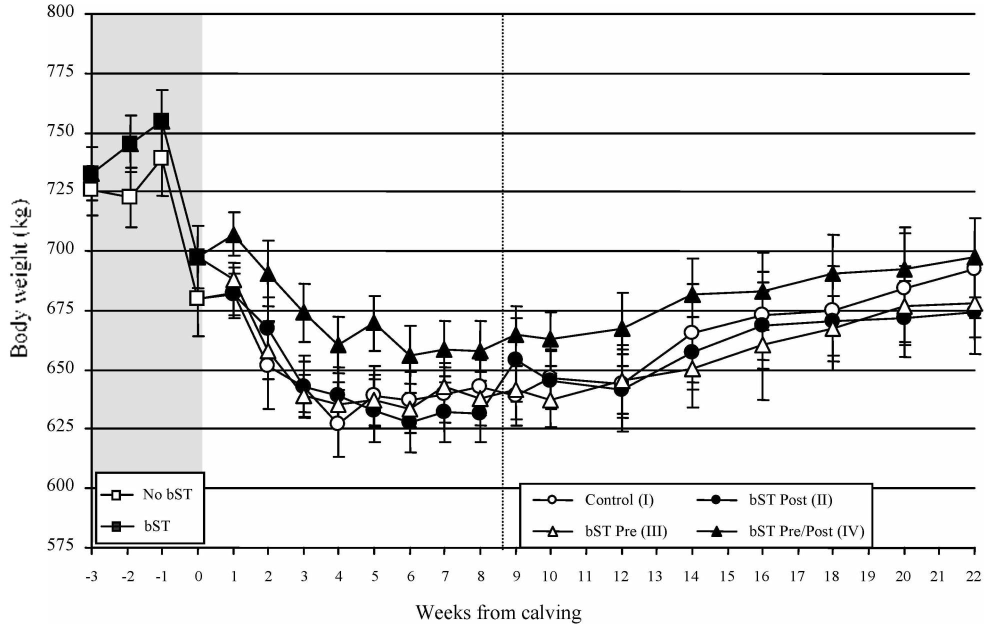

Figure 1. Least squares means and SE for BW of Holstein cows during the prepartum and postpartum periods (-3 wk through 22 wk). The bST was supplemented every 2 wk beginning 3 wk prepartum or at calving and continued through calving or 63 d (±3) postpartum. Control cows received no bST until 64 d postpartum. From 21 d prepartum through calving the TRT groups were combined based upon supplementation of bST or not to form two prepartum groups (I+II and III+IV), represented by shaded area. Vertical dotted line indicates the time period when cows in all TRT groups began receiving the full dose of bST (500 mg bST/14 d).

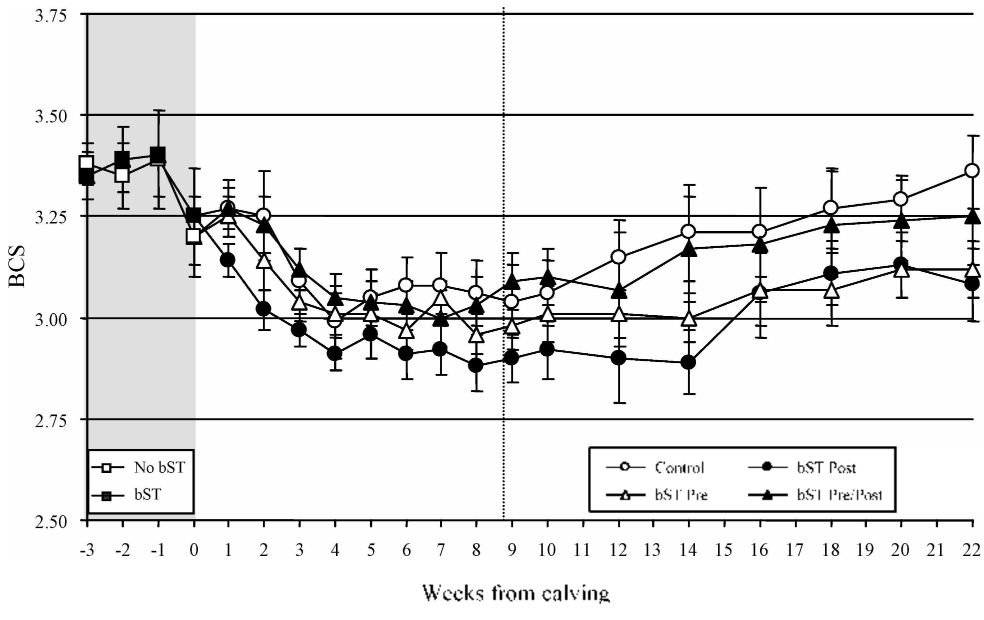

Figure 2. Least squares means and SE for BCS of Holstein cows during the prepartum and postpartum periods (-3 wk thorough 22 wk). The bST was supplemented every 2 wk beginning 3 wk prepartum or at calving and continued through calving or 63 d (±3) postpartum. Control cows received no bST until 64 d postpartum. From 21 d prepartum through calving the TRT groups were combined based upon supplementation of bST or not to form two prepartum groups (I+II and III+IV), represented by shaded area. Vertical dotted line indicates the time period when cows in all TRT groups began receiving the full dose of bST (500 mg bST/14 d).

specific variables and treatments (Littell et al., 1998). The mathematical model used included effects of bST, SEA, and the two-way interaction (bST×SEA) on the dependent variables MY, FAT, PROT, SCC, COL, BW, BCS, ST, and IGF-1. Least squares means were obtained using the overall model with the inclusion of the covariate week or day, to the highest order significant, as appropriate. Sources of variation included in this model were tested using cow in

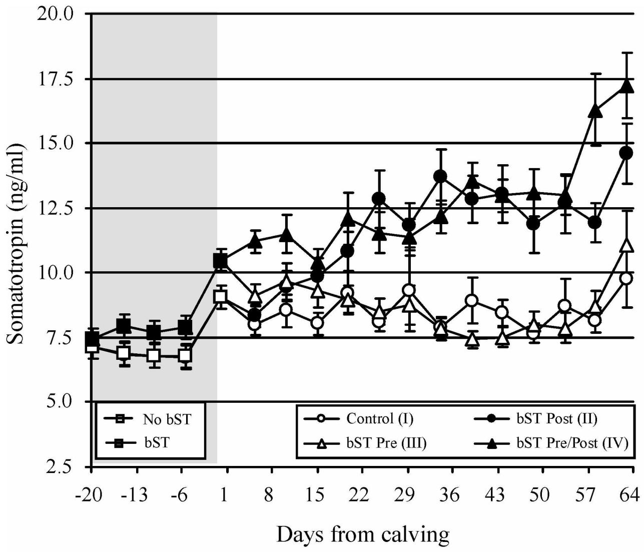

Figure 3. Least squares mean concentrations and SE for ST in plasma of Holstein cows prepartum and through 64 DIM. The bST was supplemented every 2 wk beginning 3 wk prepartum or at calving and continued through calving or 63 d (±3) postpartum. Control cows received no bST until 64 d postpartum. From 21 d prepartum through calving the TRT groups were combined based upon supplementation of bST or not to form two prepartum groups (I+II and III+IV). represented by shaded area.

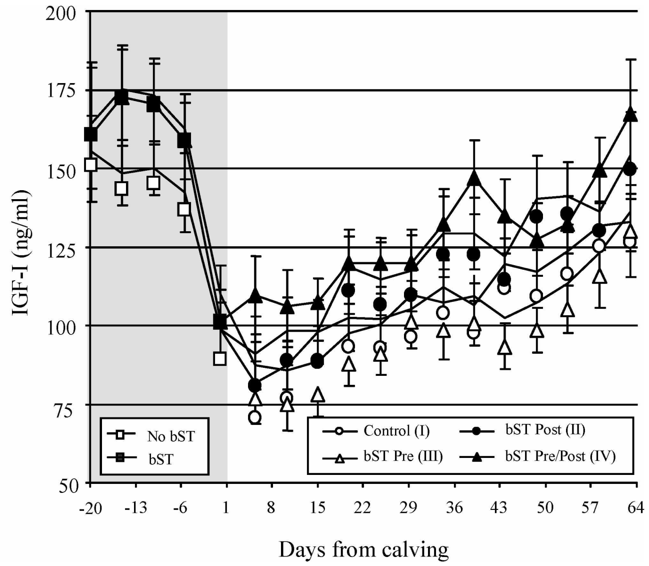

Figure 4. Least squares mean concentrations and SE for IGF-I in plasma of Holstein cows prepartum and through 64 DIM. The bST was supplemented every 2 wk beginning 3 wk prepartum or at calving and continued through calving or 63 d (±3) postpartum. Control cows received no bST until 64 d postpartum. From 21 d prepartum through calving the TRT groups were combined based upon supplementation of bST or not to form two prepartum groups (I+II and III+IV). represented by shaded area.

(bST×SEA) as the error term.

For the current experiment the 305-d ME MY data obtained from DHIA records also were analyzed. The model included TRT, cow in (TRT), TRT*SEA, DIM, DIM×DIM, cow age, and the previous lactation 305-d ME milk yield as a covariate. Orthogonal contrasts and single degree of freedom non-orthogonal contrasts obtained from PROC MIXED were used to compare means of TRT groups for variables, as appropriate.

RESULTS

Changes in BW and BCS, and concentrations of ST and IGF-I

Prepartum : No effects of TRT, SEA or the two-way interaction were detected for BW or BCS in the two combined groups. However, dairy cows that calved during the hotter months (SEA I) had lower mean BCS than cows that calved during the colder months ($p<0.01$; 3.21 vs. 3.62). Mean BW and BCS changes during the prepartum period showed similar patterns of change over time for the two prepartum groups, and BW decreased markedly after calving (Figures 1 and 2). However, the mean calving BW and BCS of cows in the two groups did not differ due to TRT.

The bST-supplementation during the prepartum period (two injections) significantly affected plasma concentrations of ST in cows ($p<0.02$; Figure 3); mean prepartum concentrations were 12.2% greater (8.2 vs. 7.3 ng/ml) in supplemented cows and also were greater at calving (15.5%; 10.5 vs. 9.1 ng/ml). No SEA or two-way interaction effects on ST concentrations were observed. Overall, no TRT, SEA or two-way interaction effects were observed on IGF-I concentrations during the prepartum period. However, concentrations of IGF-I were greater in the bST-supplemented group of cows between -2 and -1 wk before calving (16.8%; 175 vs. 149 ng/ml; $p<0.05$), but not just before calving. Furthermore, there was a sharp and significant ($p<0.01$) decrease in plasma concentrations of IGF-I observed in cows in both the bST-supplemented and non-supplemented groups during the week before calving (Figure 4).

Postpartum : For the time period 0-63 DIM, no effects of TRT, SEA or the two-way interaction were detected for BW or BCS. During this time period losses in BW and BCS across TRT did not differ and changes in both measures occurred mostly during the first month of lactation. At 28 DIM the mean decreases in BW and BCS, relative to their pre-calving means, for cows in groups I, II, III and IV were 15.07, 13.48, 15.28 and 11.88% for BW and the corresponding decreases in BCS were 13.08, 15.40, 13.38 and 12.23%. Mean losses in BCS of cows at calving during SEA I and II were 0.18 and 0.58 compared to their respective mean prepartum BCS. Beyond 28 DIM cows essentially maintained their BW and BCS and beyond 63 DIM there was a slow but steady recovery in BW and BCS

Table 2. Milk yield, milk composition, Col immunoglobulins, BW, BCS and plasma concentrations of ST and IGF-I of multiparous Holstein cows supplemented or not with bST prepartum and/or postpartum

Variable	Treatments				SEM
	I	II	III	IV	
	Control (n = 26)	bST post (n = 25)	bST pre (n = 27)	bST pre/post (n = 25)	
BW (kg)[1]	716.5		732.6		4.11
BCS[1]	3.39		3.42		0.05
ST (ng/ml)[1]	7.28^{a}		8.18^{b}		0.25
IGF-I (ng/ml)[1]	139.5		152.5		6.47
BW (kg)[2]	648.4	647.1	649.4	673.9	11.1
BW (kg)[3]	658.7	653.6	652.3	678.3	10.4
BCS[2]	3.12	2.97	3.06	3.10	0.06
BCS[3]	3.16^{a}	2.98^{b}	3.05^{ab}	3.12^{ab}	0.05
ST (ng/ml)[2]	8.68^{a}	12.32^{b}	9.27^{a}	13.42^{b}	0.47
IGF-I (ng/ml)[2]	109.63^{a}	127.44^{ab}	108.38^{a}	138.07^{b}	8.08
MY (kg/d, 3-63 DIM)	34.8^{a}	37.0^{ab}	38.3^{ab}	41.3^{b}	1.9
MY (kg/d, 3-150 DIM)	36.1^{a}	37.6^{ab}	38.0^{ab}	40.7^{b}	1.7
MY (kg/d, 305-d ME)[4]	$9,947^{a}$	$10,474^{ab}$	$11,115^{ab}$	$11,499^{b}$	678
Milk fat (%)	3.82	3.78	3.85	3.72	0.08
Milk protein (%)	2.90	2.83	2.80	2.80	0.05
SCC	513	609	312	522	119
Colostrum (mg/ml)	105	91	98	104	3

[1] From 21 d prepartum through calving the TRT groups were combined based upon supplementation of bST or not to form two prepartum groups (I+II and III+IV).
[2] From 0-63 DIM. [3] From 0-150 DIM.
[4] n = 102 (26, 25, 27 and 24 cows for TRT I, II, III and IV). [a, b] $p<0.05$.

as lactation progressed (Figures 1 and 2).

For data accumulated over 3-150 DIM, no TRT, SEA or the two-way interaction effects were detected for BW, but the BCS of cows in groups I and II differed ($p<0.03$, Table 2). Indeed, as depicted in Figure 2, the mean BCS of cows in group II was consistently less than for non-supplemented controls (I) throughout the postpartum period. On the last day measurements were made (150 DIM), mean BW and BCS for cows in groups I, II, III and IV were 693 and 3.35; 674 and 3.08; 678 and 3.12; and 697 kg and 3.25, respectively. These values corresponded to 10.6, 5.5, 6.8 and 5.5% mean increases in BW, and 12.0, 5.8, 3.6 and 6.5% mean increases in BCS compared to those at 28 DIM.

Least squares analyses for ST detected significant effects of TRT ($p<0.01$; Table 2). Overall, the mean concentration of ST increased (~43%) in cows in the bST-supplemented groups (II and IV vs. I and III; Figure 3). Data depicted in Figure 3 shows the difference was observed mainly beyond 10-15 DIM. In addition, a SEA effect ($p<0.01$) was detected but there was no interaction between bST and SEA. Across TRT groups, concentrations of ST were greater (~11%) in cows that calved during SEA II (colder months) than in cows that calved during SEA I (hotter months). For mean plasma concentrations of IGF-I the increase detected for cows in TRT IV was greater than for cows in the two non-supplemented groups ($p<0.02$, Table 2). Increase in mean IGF-I concentration in cows in TRT II was observed beyond 15 DIM (Figure 4).

Milk production and composition

Least squares analyses for milk yield detected a significant effect of TRT during 3-63 DIM; cows in group I produced less than cows in group IV ($p<0.01$; Table 2), but cows in groups I, II, and III did not differ from each other and no SEA or two-way interaction effects were observed. The mean milk yield during 3-150 DIM of cows in groups I vs. IV differed ($p<0.05$; Table 2) but, as observed for 3-63 DIM, no SEA or two-way interaction effects were detected and milk yields of groups II, III, and IV did not differ. Mean increase in the milk yield of cows in TRT IV was 12.8% (4.64 kg/d) greater than for the non-supplemented controls (I). During 64-150 DIM, the time period when all cows received the lactation dose of bST (500 mg bST/14 d), no differences in mean daily milk yields were detected ($p>0.10$). Yet, by calculation from data in Table 2, about 42% of the increase in mean daily milk yield observed for the time period from 3-150 DIM for cows in group IV vs. I (~286 kg) was accounted for by the increase in milk production during the 64-150 d time period. The positive effects of bST-supplementation prepartum and postpartum were realized through 150 DIM.

Least squares analyses of milk components detected no effects of TRT for any of the measures evaluated (FAT, PROT or SCC, Table 2). However, significant effects of SEA were detected for percentages of FAT ($p<0.03$) and PROT ($p<0.01$) in milk, but not for SCC. Cows that calved during the colder months (Nov-Feb, SEA II) had greater mean percentage of FAT and lower percentage PROT than cows that calved during the hotter months (Aug-Oct, SEA I). Milk FAT and PROT percentages for cows during SEA I and II were 3.70 and 3.89%, and 2.96 and 2.71%, respectively. No two-way interaction effects were detected for any of the milk components (Table 2).

Importantly, no TRT or interaction effects were detected on concentration of COL immunoglobulins, but there was a SEA effect ($p<0.01$). The COL produced by cows during the colder months (SEA II) had lower mean immunoglobulin concentration than in cows that calved during the hotter months (SEA I; 109.9 vs. 89.6 mg/ml). For calf BW and difficulty of calving, no TRT, SEA or interaction effects were detected. The BW of calves and calving scores, on a 1-5 scale, were 40.3, 37.9, 39.0, and 39.1 kg and 2.0, 1.2, 1.2 and 1.0 for groups I, II, III, and IV, respectively (Table 2).

DISCUSSION

A major goal of this research was to determine whether responses to bST-supplementation during either the prepartum or postpartum periods was better, equally effective or less effective than responses when bST was supplemented during both periods or not supplemented at all. The results of the current study showed that the milk yield response of control cows and those of the three bST supplementation schemes differed. Cows supplemented with bST during both periods had greater mean milk yield during 3-63 DIM than control cows (I) (+6.5 kg/d; 18.7%) and these absolute and percentage increases also were greater than observed during 3-150 DIM (+4.6 kg/d; 12.7%). The two single period bST-supplementation schemes appeared intermediate in their response compared to controls and did not differ from each other, but effects were not significant; positive but non-significant results were obtained for milk yield. Overall, the positive additive effects of bST-supplementation during both the prepartum and postpartum periods resulted in a significant increase in milk yield during the first-half of the lactation and about a 15.6% increase in the 305-d ME milk yield.

In general, these results on responses to bST supplementation do not agree completely with previous studies. Perhaps observed differences resulted from apparent dose response and/or the timing of bST-supplementation. For example, in some previous studies (Stelwagen et al., 1991; Bachman et al., 1992; Simmons et al., 1994) no increase in milk yield occurred when greater amounts of bST were supplemented prepartum. In contrast, the same amounts of bST-supplemented during the early postpartum period gave inconsistent results for milk yield (Stanisiewski et al., 1992; Eppard et al., 1996; Moallem et al., 1997, 2000; Santos et al., 1999). Generally, when greater amounts of bST were supplemented early in the postpartum period negative effects were observed (Eppard et al., 1996; Moallem et al., 1997, 2000), whereas lesser doses (5 or 14 mg bST/d) supplemented during 14-60 DIM resulted in increased milk yields (+1.2 or 1.3 kg/d) during the 46-d period of supplementation (Stanisiewski et al., 1992). Furthermore, when bST (142.8 mg/14 d) was supplemented from 3 wk prepartum through 42 DIM, as during the current study, the milk yield increased during 3-63 and 3-150 DIM (Gulay et al., 2003, 2004a, b). A consistent finding, confirmed by the current study, is that lower doses of bST-supplementation can be used during either the prepartum or the postpartum periods without apparent negative effects on milk yield. However, the greatest increase in milk yield and improved efficiency of milk production (Gulay et al., 2004b) occurred when bST was supplemented during both the prepartum and the postpartum periods. It is likely that improved general health status of supplemented cows may have contributed to the improved milk production observed (Gulay et al., 2007).

The effects of season on milk production were as expected and agreed with results typically seen for cows managed in the sub-tropical climate of Florida. Importantly, no SEA by bST-supplementation interaction was detected. This indicated that cows in all four TRT groups responded similarly within the two seasons evaluated. It seems likely that effects of SEA on milk production were due to the stress of elevated temperature and humidity on DMI and on heat dissipation, more so than because of seasonal differences in quality of feedstuffs used to formulate the prepartum and postpartum diets fed. The feed components used to formulate the experiment diets fed were purchased and stored in a large roofed structure. The corn was grown, harvested and ensiled in two large bunker silos at the DRU. There was no obvious evidence to indicate that the quality of the purchased components or farm grown corn used to make the silage differed markedly during the duration of the experiment. The corn silage fed during experiment was from the same bunker silos. Furthermore, to ensure that the same quantity of corn silage DM was used in preparation of the daily TMR fed, the corn silage DM was measured weekly and the amount of corn silage used to prepare the TMR was adjusted weekly, based upon the current DM content. Thus, no apparent bias in results obtained likely resulted from differences in diets fed to experiment cows.

For both BW and BCS, there were similar patterns of change over time in the bST-supplemented and non-supplemented cows (Figures 1, 2; Gulay et al., 2003; 2004b). However, the bST-supplemented cows gained BW and BCS as soon or sooner as non-supplemented cows did during the postpartum period, yet they produced more milk. Apparently there was greater milk production without the

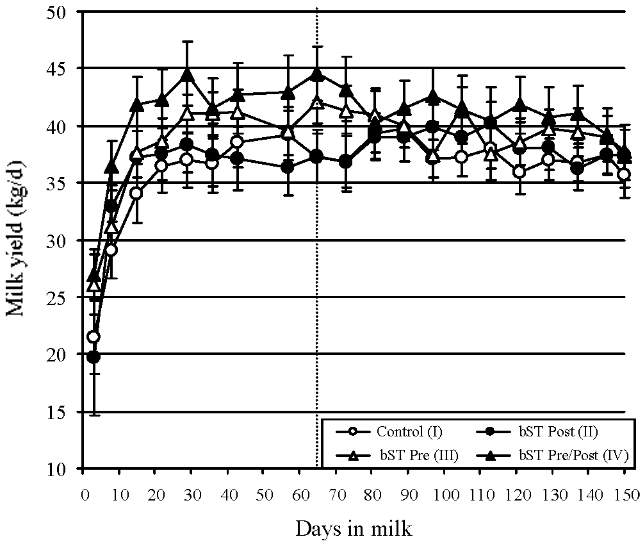

Figure 5. Least squares means and SE for MY of Holstein cows during the first 150 d of lactation. The bST was supplemented every 2 wk beginning 3 wk prepartum or at calving and continued through 63 d (±3) postpartum. Control cows received no bST. Vertical dotted line indicates the time period when cows in all TRT groups received the full dose of bST (500 mg bST/14 d).

need to substantially increase the extent of tissue mobilization. A unifying interpretation consistent with the current and previous BW, BCS and milk production results is that there was greater efficiency of utilization of nutrients and a more rapid and/or a greater increase in DMI during the early postpartum period. These early postpartum changes likely resulted from a more rapid and greater increase in milk production as a consequence of the direct and indirect actions of hormones and growth factors acting as mediators.

Many of the adaptations that support the rapid increase in milk production are directly and indirectly mediated by ST (Bauman, 1999). Supplemental-bST during the prepartum and postpartum periods increased ST concentrations in the peripheral circulation during both time periods in cows. Although concentrations of ST increased less due to prepartum bST-supplementation, concentrations increased rapidly after calving and were about 2-times greater than in non-supplemented cows by 42 DIM. This pattern of change was only seen in the cows supplemented with bST during the postpartum period (II and IV; Figure 3). The mean concentrations of ST in these two groups were 41.9 and 54.6% greater than in non-supplemented control cows (I; Table 2); increases similar to the 57 and 87% increases at 28 and 56 DIM reported by Gulay et al. (2004b). Clearly, postpartum bST-supplementation caused a rapid and sustained increase in concentrations of ST in plasma during the period of supplementation.

The indirect actions of ST that favor metabolic adaptations that enhance milk production of cows are largely mediated by the somatotropin-dependent insulin-like growth factors ((IGF-I and IGF-II) and IGF binding proteins (IGFBPs; I-VI); Bauman (1999)). Thus, one consequence of increased concentrations of ST is a corresponding increase in the concentration of IGF-I, both prepartum and postpartum. The expected decrease in IGF-I concentrations as cows approach calving was observed for cows in all four TRT groups (Figure 4). This decrease probably was associated with reduced DMI, and hence, reduced energy and protein intake around calving that led to reduced synthesis and secretion of IGF-I. Although the postpartum changes in concentrations of IGF-I in control and bST-supplemented cows varied, they seemed to follow a similar pattern of change during the first 63 DIM. Greater concentrations of ST apparently caused increased synthesis and release of IGF-I from liver even though the specific somatotropin receptor involved in this action (GHR-1A) may be less during the transition period (Kobayashi et al., 1999). Elevated concentrations of ST provoked by bST-supplementation during the postpartum period in the current and previous studies, and the increased milk yield and actual increase in DMI would have resulted in greater intake and availability of energy and protein to support increasing milk production. Thus, the overall changes in concentrations of IGF-I observed supported greater milk production and likely improved efficiency of milk production, as reported (Gulay et al., 2004b).

In contrast to positive effects on milk yield, only small and unimportant effects of bST-supplementation were observed on milk composition. The PROT (2.8-2.9%) and FAT (2.4-5.5%) percentages of cows in all TRT groups were not affected by timing of bST-supplementation and were within the typical range for healthy Holstein cows (Goff, 2002). Based upon increased milk production, the total yields of fat and protein would more than offset any small changes in percentages of these components. The SCC did not differ and cows in all the bST-supplemented groups had less difficulty calving. Furthermore, no differences in apparent concentration of COL-immunoglobulins or calf birth weight were observed. This confirmed that short-term supplementation of bST during the last 3 wk prepartum did not adversely affect the calf or the subsequent quality of COL produced. No reasons for apparent improved calving status are apparent, unless associated with improved health status (Gulay et al., 2007).

Overall, results of the current experiment indicated that bST-supplementation during both the prepartum and postpartum period resulted in better milk production compared to non-supplemented cows or those supplemented during only one of the two periods. In general, these results agreed with previous studies and doubtless resulted from the complex actions directly and indirectly mediated by increased concentrations of ST and/or synthesis and secretion of IGF-I. These increases likely affected DMI and efficiency of milk production without an increased need to mobilize even greater amounts of tissue protein and lipids, as indicated by lack of negative effects on BW and BCS. Other direct and indirect actions of ST and IGF-I on mammary and other tissues also may be involved but were not identified in this study. Positive effects on cow health (Gulay et al., 2007) around calving likely contributed to the improved milk production. Supplementing cows with low doses of bST (142.8 mg bST/14 d) during only one of the time periods did not positively or adversely affect milk production compared to non-supplemented controls (I).

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