EFFECT OF BOVINE SOMATOTROPIN ON THE LACTATIONAL AND REPRODUCTIVE PERFORMANCE OF LACTATING DAIRY COWS - A REVIEW

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ABSTRACT

Bovine somatotropin (bST) increases milk production in dairy animals. The maximum increase in milk production has been observed up to 41%. Somatotropin did not change milk composition significantly. During short-term application of bST, cows mobilized their body-reserves to support the increased milk production. Although DM intake of cows was increased in the long-term applications, however, gross efficiency of production was improved due to larger increase in milk production than DM intake. Somatotropin did not adversely affect the health and reproductive performance of the cows. Repartitioning of nutrients in body-tissue was primarily responsible for the increase in milk-production but defining the exact mechanism by which bST exerted its effect still requires additional research.

Key words: Bovine somatotropin, Milk production, Milk composition, DM = Daily Mineral.

INTRODUCTION

The effects of somatotropin on the performance of lactating animals have been the subject of interest for over 50 years. It was initially demonstrated that injections of crude pituitary extracts increased milk-production in dairy cows. However, limited quantities of native pituitary somatotropin made field-applications impractical. The advent of recombinant DNA technology allowed the production of relatively large quantities of synthetic bST. Since then, a lot of research has been conducted to see the effect of bovine somatotropin on various production-parameters of dairy cows (Peel et al., 1985; Richard et al., 1985; McGuffey et al., 1990). Milk yield had been increased upto 41% with daily injections of bST (Bauman et al., 1989). Cows adjust their voluntary feed-intake to support increased milk-yield (Eppard et al., 1987). Somatotropin did not affect the cows' health and reproductive performance (Eppard et al., 1985a). Coordinated changes in many tissues and physiological processes occurred to support the increases in the synthesis of lactose, fat and protein in the mammary glands. Changes in the irreversible loss and oxidation rates of two key metabolites, glucose and free fatty acids, could quantitatively account for increases in lactose and milk-fat during the support-term administration of bST (McDowell et al., 1987). Similarly, changes in feed-intake accounted for increase in milk-production in the longer experiments (West et al., 1990). The present paper has the objective to review the effect of bST on different lactational and health aspects of dairy cows.

MILK PRODUCTION

Daily administration of exogenous bST derived from the extracts of pituitary glands, or even the growth hormone release factor from the extracts of the hypothalamus (Enright et al., 1988) of slaughtered cows or recombinantly derived bST, cause a higher milk-yield without altering the gross composition. Almost similar results of increased milk-yield in dairy cows by bST administration was reported in many studies (Asimov and Krouze, 1937; Pocius and Herbein, 1986; Richard et al., 1985; Soderholm et al., 1988; West et al., 1990). In a long-term study with Holstein cows, bST treatment increased the average fat-corrected milk (FCM) yield in a dose-dependent fashion from 23 to 41% over control production (27.9 kg/d) in lactating cows (Bauman et al., 1989). However, increasing increments of bST show less increase. In another experiment, 32% increase of milk-yield was reported in cows treated with 100 IU/day of bST over control (Eppard et al., 1985a); they also found a pattern of diminishing marginal response of milk-yield to increasing hormone dose. Similar results have been reported by other workers (Eisenbeisz et al., 1990; Elvinge et al., 1988; Soderholm et al., 1988).

Increase in milk production of cows given bST at their peak lactation was less than for those treated at mid to two third of their lactation (McDowell et al., 1987; Richard et al., 1985). The cows receiving 41.2 mg/d of bST in their early lactation reduced 10% more 3.5%

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FCM than the control group (Schneider et al., 1990). This increase was less than that reported by other workers in the cows treated with bST after their peak lactation (Elvinger et al., 1988; West et al., 1990). This indicated that, even though responses: to exogenous bST did occur, the response was much less than that after peak lactation. One explanation of this was that during early lactation the response might be limited by nutrient availability, because cows were in considerable negative energy balance. The other possible reason for this reduced response was limited supply of glucose for lactose rather than by the ability of cows to mobilize body-reserves in support of lactation (Richard et al., 1985). Administration of bST, either by daily injections or in a sustained release vehicle, had no significant differences in milk or solid-corrected milk of treated cows (McGuffey et al., 1990). In a previous study it was shown that bST administered by prolonged release formation was effective in improving milk-yield and productive efficiency of cows (Bauman et al., 1989).

MILK COMPOSITION

The complex composition and unique biophysical properties of milk can easily be disturbed by slight deviations in composition. Nevertheless, the cow receiving bST seems to have the ability to produce more milk with the same mammary gland, while retaining normal product composition. This has probably much to do with the physical limitations for the composition of milk, as mentioned by Walstra and Jenness (1984). First, milk is iso-osmotic with blood. In milk, lactose, K, Na, and Cl contribute to osmotic pressure. Variations in the lactose content of milk are small, but if they occur, osmolality is maintained by changing K+ directly and Na^+ and Cl^- inversely. Second, the milk is saturated with calcium phosphate and calcium citrate. Additional Ca, phosphate, and citrate are present in the form of a colloidal complex with casein. Third, to be readily digested, the final melting point of the milk-fat must not be higher than body temperature. Crystallization of fats with higher melting points might also occur in cells and alveoli, causing partial coalescence of fat globules in the udder. Therefore, a certain amount of short-chain and unsaturated long-chain fatty acids will be present in milk fat. However, these physiological phenomena do not fully guarantee unchanged milk properties.

Somatotropin did not influence milk-composition of dairy cows. No change in percentage of fat, protein or total solid milk was reported (Eisenbeisz et al., 1990). Fat, protein, and lactose contents of the milk are negligibly affected by bST when the cow is in positive energy-balance. This state is an important prerequisite when bST is administered (Vandenberg, 1991). Similar results had been found in other studies (Elvinger et al., 1988; Peel et al., 1985; West et al., 1990). They noted no change in percentage of milk-fat, protein and total solids with bST treated milk of dairy cows. Contrary to this in some studies, the protein and fat percentage of milk of cows treated with bST were influenced (Eppard et al., 1987). As the dose of bST increased, fat percentage of milk also increased but protein percentage declined in cows with negative energy balance. This can be concluded from various short and long-term experiments (Mcbride et al., 1989; Rohr, 1988; Sainoni et al., 1988). Sechen et al. (1989) found an increased secretion of N and C in milk and decreased urinary loss of N and tissue use of C from bST administration.

Administration of bST in a sustained-release vehicle biweekly or once every week is more practical than more frequent administration. On the average, the milk has fat and protein contents rather similar to those of milk from untreated cows. However, some cyclic effects in fat and protein contents are found. Bovine somatotropin may also cause an increase in the relative amount of long-chain fatty acids, and the somatic cell count was sometimes increased (Vandenberg, 1991).

Experiments show that there was no effect on percentage lactose of milk from bST treated cows (Bauman et al., 1985; Pocius and Herbein, 1986; Bauman et al., 1989; Phipps, 1988; Rijpkema et al., 1989). Lactose percentage decreased significantly at peak lactation but no change was noted at mid lactation in the milk of bST treated cows (McDowell et al., 1987). Changes in milk composition probably reflected the nutritional status of the cows at different metabolic stages of lactation. Protein concentration declined in cows with negative energy-balance, suggesting that protein synthesis by the mammary glands could have been limited by the supply of amino acids.

The information on milk-protein composition, in relation to the bST treatment of the cows, is summarized in Table-1. Caseins are present in milk in the form of micelles, together with Ca, phosphate, and citrate. The cows treated with bST do not seem to produce milk with a different casein-content (Escher and Vandenberg, 1987). The casein:total protein ratio has not changed in most cases, except in three investigations, in which a slight decrease occurs (Table-1). No real differences between the properties of the caseins i.e., the size of the micelles (Vignon and Ramet, 1988) and the various fractions in which calcium is present in milk (Desnouveaux et al., 1988), were observed from the milk of the bST treated and untreated cows.

An increase in the fat content of milk during bST administration is often caused by an extra mobilization of the fat-reserves of the animal, because of an energy shortage. This is most likely to occur just after the start of the treatment. This situation leads to an increase of the longer unsaturated fatty acids in the milk fat and to lower cholesterol and phospholipid contents (Table-2) in the milk (Bitman et al., 1984). Another study showed a slightly increased cholesterol content of the milk fat (Lynch et al., 1989). At very high daily doses of bST and a negative energy-balance, an increase of the proportion of the long-chain unsaturated fatty acids was found by Eppard et al. (1985b). At lower doses and a positive energy balance, the effects on the milk fat were not significant. In general, the fatty acid composition can be affected by the energy state of the cow and a negative balance will more easily occur in high producing cows, in particular, when bST is administered in higher doses and in early lactation.

The cation flux from blood plasma into the mammary gland and into the milk is increased with the milk yield, in order to maintain osmotic regulation; the concentration of the minerals is probably not affected (McBride et al., 1988). This has been confirmed for Ca, P, Na, Fe, Cu, and Mn by many workers (Eppard et al., 1985; Desnouveaux et al. 1988; Auberger et al., 1988; Bauman et al. 1989)

Little research has been conducted into the enzymes in milk, in relation to the administration of bST to the dairy cow. The activities of the aminopeptidase, endopeptidase and phosphatase (Desnouveaux et al., 1988), protease and lipase (Lynch et al., 1988) and lipoprotein lipase (Lough et al., 1989) in milk showed no significant differences between the milk from the treated and untreated groups.

Vitamin A, thiamine, riboflavin, pyridoxine, vitamin B_{12}, biotin, pantothenic acid, and choline have been investigated by Hartnell (1986) and no differences were observed, except for biotin, which was present in a slightly increased concentration in the bST milk.

The pH of the milk was not affected by bST injections in differerent studies (Baer et al., 1989; Battistotti and Bertoni, 1988; Escher and Vandenberg; 1987; Vandenberg and deJong, 1986; Vignon 1988; Vignon and Ramet, 1988).

Differences in Somatic cell count of milk of bST treated and untreated cows were found to be non-significant in most of the studies. However, this topic needs further investigation under various local conditions, because incidence of mastitis and higher SCC sometimes occur in highly producing cows, thus suggesting that special attention be paid to bST-treated cows.

FEED EFFICIENCY, DRY-MATTER INTAKE AND BODY WEIGHT

Dry-matter intake, feed efficiency and body weight were influenced by the bST treatment in dairy cows. The feed intake of cows treated with bST changed after eight week of treatment, and it had increased upto 13.4% by week 22 (Peel et al., 1985; Soderhalm et al., 1988). The voluntary intake of cows receiving bST increased gradually and, by 10th week of treatment, the animals attained positive energy-balance (Bauman et al., 1989). A gradual increase in feed intake of cows treated with bST for a longer period of time was observed (Eisenbeisz et al., 1990; Elvinger et al., 1988; McDowell et al., 1987; West et al., 1990). Cows receiving bST consumed 4 to 10% more feed, but increase in milk production was larger than this and, therefore, it showed that bST treated cows increased the efficiency of production by 11 to 17% over control animals (Soderholam et al., 1988). Increase in gross efficiency of production by bST treatment had also been reported by many other workers (Bauman et al., 1989; Eisenbeisz et al., 1990; Elvinger et al., 1988; West et al., 1990). In all these

Table – 1: Summary of the effect of bST treatment on content and composition of milk proteins, compared with control

Attribute	Result	References
Total protein	Similar	1, 2, 3, 4, 5, 6, 7, 8
	Decreased	9
	Increased	10, 14, 15, 16
Casein content	Similar	1, 2, 3, 10, , 11, 13, 17, 18
	Decreased	9
Relative casein composition	Similar	1, 6, 7, 8
Whey protein content	Similar	1, 3, 6, 7, 8
	Increased	2, 11
	Decreased	9
Relative whey protein composition	Similar	6, 7,12, 13
Casein:total protein ratio	Similar	1, 3, 7, 8, 9,
	Decreased	2, 10,11

[1]Auberger et al.,(1988), [2]Baer et al. (1989), [3]Desnouveaux et al. (1988), [4]Eppard et al. (1988), [5]Sechen et al. (1989), [6]Vignon (1987), [7]Vignon (1988), [8]Vignon and Ramet (1988), [9]Escher and Vandenberg (1987), [10]Barbano et al.(1988), [11]Kindstedt et al. (1988), [12]Lynch et al. (1988), [13]Pabst et al. (1987), [14]Bauman et al. (1989) [15]Phipps (1988), [16]Samuels et al. (1988), [17]Escher and Vandenberg (1988a), [18]Leonard et al. (1988)

Table – 2: Summary of the effect of bST treatment on content and composition of milk-fat compared with those of control cows

Attribute	Result	References
Total fat	Similar	1, 2, 3, 5, 10, 11, 12, 13, 18, 19, 24
	Increased	4,6*, 7, 20, 21, 22
Refractive Index	Similar	7, 23
Properties of:		
Short-chain fatty acids	Similar	6, 14, 24
	Reduced	1,4, 6*, 8
Medium-chain fatty acids	Similar	6,14,17, 24
	Reduced	1, 4, 6*
Long-chain fatty acids	Similar	6, 14, 17, 24
	Increased	1, 6*
Long-chain unsaturated fatty acids	Similar	6, 14, 17
	Increased	1,4,6*,8
Cholesterol	Increased	15
	Reduced	4
Phospholipids	Reduced	4

*At high bST dose and negative energy balance.

[1]Baer et al. (1989), [2]Barbano et al. (1988), [3]Bauman et al. (1989), [4]Bitman et al.(1984), [5]Eppard et al. (1988), [6]Eppard et al. (1985b), [7]Escher and Vandenberg (1988), [8]Farries and Profittlich (1988), [9]Farries (1989), [10]Firkins et al. (1989), [11]Jenny et al. (1989), [12]Lebzien et al. (1989), [13]Leonard et al. (1988), [14]Lynch et al. (1988), [15]Lynch et al. (1989), [16]Oldenbroek et al. (1989), [17]Pell et al. (1988), [18]Rijpkema et al. (1987), [19]Rohr (1988), [20]Rock et al. (1989), [21]Rowe-Bechtel et al. (1988), [22]Sainoni et al. (1988), [23]Vandenberg and deJong, (1986), [24]Vignon, (1987),

studies, although DM intake of cows increased gradually in the long run, but higher increases in milk production led to improved efficiency of production.

Dry-matter intake and digestibility by cows was not affected by bST treatment in short-term studies (Eppard et al., 1985a; Pocius and Herbein, 1986; Schneider et al., 1990). However, these studies also indicated increased efficiency of production in bST treated cows.

Body weight of cows receiving bST was not affected significantly (Elvinger et al., 1988; McGuffey et al., 1990; Peel et al., 1985; West et al., 1990).

HEALTH AND REPRODUCTION

Somatotropin did not adversely affect the health and reproductive performance of cows (Bauman et al., 1989). It was reported that the health and reproductive parameters, including clinical observation, physical examination, somatic cell count, conception rate, services per conception and gestation-length were at or better than resident-herd average (Bauman et al., 1989). Other workers did not observe any adverse effects of bST on the reproductive performance of cows (Eisenbeisz et al., 1990; Elvinger et al., 1988). In a long-term study, it was demonstrated that bST had no discernible effects on mammary health, based on somatic cell count and incidence of clinical mastitis (Eppard et al., 1987). Cows receiving bST showed an average of 96% conception rate, 2.0 services per conception and 116 days open, which were comparable to control-groups. No subclinical or clinical evidence of ketosis or milk fever was observed. Somatropropin treatment had no significant effect on gestation-length or birth weights and growing rate (first 28 days) of calves. Milk yield for the first sixty days, post-partum, was compared for the period just prior to start of treatment and the lactation subsequent to treatment: no treatment effects were observed. Cows were in excellent health during lactation, as was borne out by lactational performance.

MODE OF ACTION

Nutrient Partitioning

Somatotropin increased milk-yield in dairy cows through its coordinated effects on a number of body-tissues and physiological metabolites. A summary of the biological activities of somatotropin has been given in Table-3.

In a long-term study with dairy cows, a homeorhetic control (the coordination of changes in metabolism necessary to support a given physiological state e.g., pregnancy, lactation) involved in the orchestration of ‘partitioning of nutrients’ to support the requirements for milk synthesis was considered (Bauman et al., 1989). The term ‘nutrient partitioning’ is most commonly used to describe the manner in which absorbed nutrients are directed to various tissues and organs in support of productive functions. In a more general sense, the definition should also take into account other partitioning, such as between digested versus undigested nutrients or between production functions versus the overhead costs of maintaining the animal. Because these may also be affected by bST, they must all be considered as components of the nutrient partitioning process.

The results of ‘nutrient partitioning’ in long-term studies were based on the fact that increased milk yield could not persist through the treatment-period unless coordinated changes occurred in body-metabolism, so that steady-state conditions were maintained. These changes must have involved the metabolism of lipid, carbohydrates and amino acids, because milk-composition was not altered during the treatments. Other studies using bST demonstrated that milk-composition was unaltered when cows were in positive energy balance (Elvinger et al., 1988; Peel et al., 1985; Soderholam et al., 1988).

Diabetogenic and Lipolytic Effects of bST

The diabetogenic and lipolytic effects of bST have been reviewed by Bauman et al., 1989, and Johnsson and Hart, 1986. In some trials bST treatment of animals elevates circulating concentrations of NEFA, insulin, and glucose (Johnsson and Hart, 1986) and, in others, it does not (Bauman and McCutcheon, 1986), except where treatment drives animals into a negative energy balance, in which case NEFA are chronically elevated. This may relate to the capacity of treated cows for milk production. Treatment of low-yielding beef cows with bST elevates circulating glucose, but high-yielding dairy cows did not respond in the same manner (Bines et al., 1980). It was suggested that bST treatment

Table – 3: A summary of the biological activities of somatotropin[1]

	Biological activity	Brief details
1.	*Cell division*	
	Promotion	Numbers of cells in muscle, liver, spleen, mammary, and other tissues, DNA polymerase.
2.	*Protein metabolism*	
	Promotion	Nitrogen retention; uptake of amino acids and incorporation into protein; RNA polymerase, elongation of mRNA; polyamine synthesis.
3.	*Carbohydrate metabolism*	
	Promotion	Tissue glycogen deposition; pancreatic release of insulin; peripheral insulin resistance; plasma glucose concentrations.
4.	*Lipid metabolism*	
	Promotion	Fatty acid release from adipose tissue; oxidation of fatty acids.
	Inhibition	Fat synthesis; adipocyte enlargement.
5.	*Mineral metabolism*	
	Promotion	Deposition of calcium and phosphorus in bone; calcium turnover; retention of sodium, potassium, and phosphorus.

[1]Machslin (1976).

increased the availability of glucose in each group, but it was completely utilized for additional milk secretion by high-yielding cows only (Johnsson and Hart, 1986). It is therefore hypothesized that the diabetogenic and lipolytic effects have not been seen in high-yielding cows, because of the increased drain on circulating nutrients caused by high milk secretion-rates. Some other studies do not agree with this hypothesis, like the experiment of Brumby and Hancock (1955), in which no effects on blood glucose were observed, in cows treated with pituitary-derived bST. However, substantial (up to 45%) responses in milk-yield were observed following bST treatment. These observations lead to two conclusions. First, the absence of altered blood-metabolite concentrations in some bST studies (Bauman and McCutcheon, 1986) is not simply a function of greater mammary nutrient-drain in high-producing cows. Second, and more important, significant lactational responses to bST do occur, in both high and low producing cows, in the absence of 'lipolytic' and 'diabetogenic' changes. It follows that these changes are not an intrinsic component of the mechanisms by which bST promotes increased lactational performance. Marked metabolic changes must be occurring to permit substantial lactational responses to bST while, at the same time, allowing treated animals to maintain their homeostatic balance, as measured by circulating metabolite concentrations.

Effect Of bST on Carbohydrate Metabolism

Treatment of lactating cows with bST induces marked increases in milk-yield and, since lactose content of the milk is not altered, this requires a substantial increase in supply of glucose to the mammary gland. DeBoer and Kennelly (1989) reported that treatment with bST injection had no effect on glucagon, insulin or glucose metabolism. They had, therefore, concluded that factors other than bST might play a role in production. Nevertheless, the changes in glucagon, insulin and glucose metabolism were consistent with the concept of homeorhetic actions of bST.

The increased supply of glucose to the mammary gland can be achieved in a number of ways. First, bST inhibits the uptake of glucose by peripheral tissues (e.g., adipose) and reduces whole-body glucose oxidation to CO_2 (Baman et al., 1988). The overall effect of these changes is that utilization of glucose by peripheral tissues is greatly reduced, thus sparing glucose for lactose synthesis. Second, bST treatment appears to increase gluconeogenic rates, thereby directly increasing the supply of glucose via de novo synthesis (Bauman et al., 1988). The extent to which these mechanisms contribute to the increased supply of glucose for lactose synthesis undoubtedly varies according to the animal's particular circumstances.

Effect Of bST on Amino-Acid Metabolism

Oxidation of amino acids decreased with bST treatment, as it caused a concomitant increase in oxidation of NEFA in growing heifers. The net effect is an increase in whole body protein-synthesis and a decrease in lipid accretion, consistent with the production-effects of exogenous bST in growing animals (Boyd and Bouman, 1989). Increase in milk-protein secretion by a short-term bST treatment occurs due to reduction in oxidation of amino acids and increased mobilization of labile protein reserves, whereas in long-term studies increase in voluntary feed intake also contributes towards more milk-protein secretion.

Effect of bST on Lipid Metabolism

The principal effect of bST is to partition nutrients in such a way that lipid accretion is reduced and fatty acids made available for oxidation. This has the effect of 'sparing' nutrients, such as glucose and amino acids, and is achieved by reciprocal effects on lipo-genesis and lipolysis. The bST treatment caused an increase in plasma free-fatty-acids (FFA) concentrations, without altering blood ketone, suggesting that lipolysis was increased without corresponding increase in fatty acids oxidation by the liver (Pocius and Herbein, 1986). They had opined that bST acted by partitioning FFAs towards milk production. It was also reported that there was an increase in plasma FFA in the blood of bST treated animals (Lough et al., 1989). However, they did not find any difference in lipoprotein lipase-activity in milk, mammary tissues and acetate metabolism in cows injected with bST. It raised the possibility that higher serum triglyceride concentrations induced by bST might have increased the availability of preformed lipids to the mammary glands for increased rate of milk-synthesis without an increased mammary lipase activity. It was also demonstrated that bST exerted its metabolic effects, resulting in the provision of substrate to the mammary gland for milk biosynthesis (McDowell et al., 1987). They further noticed that bST exerted different metabolic effects, depending on the physiological state of the animal. They, thus, concluded that bST exerted a homeorhetic control, resulting in the provision of nutrients to the mammary gland at the expense of the body-tissues for milk synthesis. Similar hypothesis had been extended by another worker (Soderholm et al.,1988).

One of the most obvious in-vivo responses to bST is increased sensitivity to lipolytic stimuli. Thus, circulating NEFA following an acute intravenous epinephrine challenge are elevated in bST-treated dairy cows and growing cattle. These changes occur, whether or not the treated animals are in positive or negative energy balance (i.e., whether or not basal circulating NEFA are altered). The enhanced lipolytic sensitivity of treated cows was also co-ordinated with their increased fat yields (McCutcheon and Bauman, 1986). Although bST enhances the antilipolytic effects of insulin, it appears to antagonize the ability of insulin to stimulate lipogenesis. Treatment with bST appears to reduce the activity of several key lipogenic enzymes in vitro (Schaffer, 1985; Magri et al., 1987; Vernon et al., 1988) and to inhibit the transport of glucose into adipocytes. The latter effect was not mimicked by insulin-like growth factor (IGF)-I or IGF-II treatment, suggesting that it was a direct effect of bST (Schoenle et al., 1985). As a consequence of these reciprocal effects on lipolysis and lipogenesis, bST partitions nutrients in such a way that lipid accretion is reduced or lipid reserves mobilized. Thus, in lactating animals, the size of lipid reserves tends to decline (particularly during the early phases of treatment) but in growing animals, rate of lipid deposition is reduced in adipose tissue (Bauman and McCutcheon, 1986; Boyd and Bouman, 1989). Moreover, the rates of NEFA oxidation to CO_2 are increased (Dunshea et al., 1989; Tyrrell et al., 1988) so that NEFA make a proportionately greater contribution to the animal's energy requirements. This in turn means that glucose and amino acids, which might otherwise be oxidized to provide energy, are available for milk lactose and protein-secretion or for tissue protein deposition.

Effect of bST on Voluntary Feed Intake

Bovine somatotropin increased the voluntary intake of cows after several weeks of treatments (Eisenbeisz et al., 1990; Politis et al., 1990). This observation raised another possibility for mechanism of action for bST in the long-term treatment. This observation supported the simple contention that an animal ate to maintain energy homeostasis, so that daily energy intake matched daily energy output. In the earlier weeks of treatments, body tissues were mobilized to subsidize the increased demands of the mammary glands and the substantial increase in milk energy output. Voluntary feed-intake then increased to meet the additional demands of the mammary gland and the rate of live weight-loss was first stabilized and then reversed.

Effect Of bST on Mammary Gland Tissues

There was no evidence to indicate that bST has a direct effect on mammary gland tissues during established lactation. Direct infusion of bST into mammary artery did not affect rate of milk-synthesis (Peel et al., 1985). It was also demonstrated that bST did not bind to the receptors in bovine mammary tissue (Gertler et al., 1984). It was probable that bST affected mammary gland mechanism indirectly via stimulation of the synthesis of somatomedins or other protein-factors by the liver. These factors might then act directly on mammary gland. Chronic bST administration had been shown to stimulate a significant elevation of somatomedin concentrations by 22nd week of treatment (Peel et al., 1985).

The somatotropin treatment increased the blood flow to the mammary glands of the ruminant animals. The relationship between mammary blood-flow and milk-yield approximates 500:1 under normal conditions (Linzell, 1974). In lactating ewes (McDowell et al., 1988), the ratio was increased from ca. 460:1 before to ca. 505:1 during administration of pbST. Studies with dairy cows indicated an increase in the ratio from ca. 520:1 to ca. 580:1 during administration of pbST (McDowell et al., 1987). Estimates were made 3 to 5 days after commencing daily injections of pbST and it was assumed that the mass of mammary tissue was not affected by the pbST.

The increase in blood flow to the mammary gland appears to be partially attributable to an increase in cardiac output (Davis et al., 1988a), as had been suggested by Mepham et al. (1984). Davis et al. (1988b) expressed the view that it would be unlikely that the increase in mammary blood-flow occurring during treatment with bST would be the cause of increased milk production. Instead, increased blood flow would likely be the result of altered metabolic activity of the mammary glands, as indicated by a measured rise in oxygen-consumption by the glands of cows injected with pbST. Another possible cause of increased blood-flow during administration of bST may be IGF-I. Glim et al. (1988), by using the immunofluorescent techniques, reported that IGF-I was present in small blood vessels, including the capillaries, located within the stroma of the mammary gland, before and after commencement of daily injections of bST. They further reported that increase in plasma IGF-I occurred in response to exogenous bST, which could explain the increased blood flow to tissues, including the mammary gland. The increased flow of blood to the mammary glands would result in the supply of additional nutrients, thereby facilitating increased milk synthesis.

Latest model for mechanism of action for bST on mammary gland was reported that in bST injected cows, milk plasmin was maintained at low concentration, and milking performance was enhanced (Politis et al., 1990, Sarwer et al., 1995). Cessation of bST injection at drying-off led to a rapid elevation of milk plasmin to control values. They had, therefore, hypothesized that bST suppressed plasmin production involution and allowing the persistence of milk production.

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