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Review

Long-term effects of recombinant bovine somatotropin (rBST) on dairy cow performances [1]

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Summary

Long-term (18-32 week) effects of recombinant BST (bovine somatotropin) injected daily (650 cows, 20 assays) or as prolonged release preparations (790 cows, injected each 14 or 28 d., 23 assays) are reviewed. Daily injections of 10-15, 20-27 or 31-50 mg BST increased milk yield of 3.9, 5.2 or 5.6 kg/d (respectively). Somidobove (320, 640 or 960 mg BST each 28 d.) increased milk yield 2.2, 3.1 or 4.2 kg/d, and Sometribove (500 mg/14 d.) 4.4. kg/d. Mean milk composition was unchanged, but cycled between injections in the case of prolonged release preparations. Dry matter intake increase for high BST doses was 1.5-1.7 kg/d in 32-week experiments, and 0.8 kg/d in 18 week-experiments. Energy balance and body condition score decreased during the first 3 months of BST treatment, due to delayed DM intake increase. In two experiments body lipids were sharply decreased in BST cows. Feed efficiency was increased (6-17 p. 100) according to dilution of maintenance requirement in total needs and to decreased body tissue deposition. There was no clear interaction of BST response with cow parity and milk yield potential, but a trend towards decreased response after several months of BST. High energy-high protein complete mixed rations tended to increase BST response, but inter-assay variability was high. Responses tended to be lower (2.5 ± 1.8 kg milk/d) at pasture in European conditions.

Key words : Somatotropin, dairy cow, energy utilization, long term, Europe.

Knowledge of the long-term (several months) effects of BST (bovine somatotropin, or growth hormone) in dairy cows has increased rapidly since 1985, thanks to the increasing production of BST by recombinant DNA techniques. Since reviews by Peel and Bauman (1987), Chilliard (1988) and Hart (1988) a great number of new results have appeared, both from America (1988, Am. Dairy. Sci. Assoc. Meeting) and Europe (see below). These results are more or less the first concerning the effects of BST in prolonged release preparations, that allow large scale field experiments in practical conditions.

(1) This paper was first presented at the seminar on « Use of Somatotropin in Livestock production » (Commission of the European Communities, programme of coordination of agricultural research, Bruxelles, 27-29 September 1988).

This paper reviews the effects of long-term BST injections on dairy cow performances : milk production and composition, dry matter intake and energy balance, body weight and body condition changes, feed efficiency, in connection with BST dose levels, BST release preparations, cow parity, milk production potential, lactation stage, feeding and management factors.

I. Short-term experiments

Most of these experiments (1973-1986) were done by injecting the natural pituitary somatotropin. The first experiment with recombinant BST was published by BAUMAN *et al.* (1982).

During 18 short-term assays (less than 4 weeks, after the second month of lactation) the mean milk production response to BST (25-50 units/day) was 4.0 (± 1.3) kg/day, whereas dry matter intake (− 0.5 ± 1.1 kg/day) and calculated energy balance (− 4.2 ± 2.1 Mcal/day) decreased (CHILLIARD, 1988). Effects on milk composition differed according to the energy balance of the treated cows (table 1) in accordance with the well known general effects of energy balance on milk fat and protein contents (JOURNET and CHILLIARD, 1985 ; RÉMOND, 1985). Lactose content tended to increase (+ 0.6 ± 1.1 g/l) whatever the energy balance of the cows.

TABLE 1

Short-term (5-21 d.) effects of BST on performances of dairy cows with different calculated energy balances (CEB) (a).

Effets à court terme (5-21 j) de la BST sur les performances des vaches laitières selon leur bilan énergétique calculé (a).

CEB of BST cows	Milk yield *		Milk fat * (g/l)	Milk protein * (g/l)	DMI (d) * (kg/d)	CEB *
	kg/d	%				
3.3 (± 1.4) (b)	+ 4.5 (± 1.6)	+ 19.6 (± 7.9)	+ 0.8 (± 2.3)	− 0.8 (± 0.8)	− 0.2 (± 1.1)	− 3.7 (± 2.3)
− 3.6 (± 3.9) (c)	+ 3.5 (± 0.7)	+ 17.3 (± 8.6)	+ 3.1 (± 2.5)	− 2.1 (± 1.7)	− 0.8 (± 1.0)	− 4.8 (± 1.8)

(a) See CHILLIARD (1988) for references ; (b) 9 assays, 47 cows, CEB of BST cows > 1.1 Mcal/d. ; (c) 9 assays, 46 cows, CEB of BST cows < 0.4 Mcal/d. ; (d) Dry matter intake (mean ± s.d.).
(*) BST-control.

The milk response (p. 100 or kg/day) was lower during the first two months of lactation than after peak yield (6 vs. 12-30 p. 100) (CHILLIARD, 1988). Response to increasing doses of BST was curvilinear (EPPARD *et al.*, 1985).

II. Long-term effects of recombinant BST injections

A. *Milk production and composition*

1. *Daily injections*

In 21 experiments on 969 dairy cows (mean duration of 32 weeks, beginning 5-13 weeks after calving) there was a dose-dependent response (table 2) : the mean (weighed

TABLE 2

Long-term effects of daily injections of recombinant BST on dairy cow milk yield.
Effets à long terme d'injections journalières de BST recombinée sur la production laitière des vaches.

Reference	BST (a)	N. cows	Weeks of BST	Milk yield (kg/d.) BST dose (mg/d.)				
				0	5	10-15	20-27	31-50
					BST-Control			
1 (b)	M	24	27	27.9		6.5	10.1	11.5
2	A	32	38	23.7		3.9	3.2	5.0
3	A	30	38	23.4		4.4	5.3	7.4
4 (b)	?	24	27	26.0		8.0	7.0	5.0
5 (b, e)	A	26	37	29.8		1.8	7.0	10.7
6 (b)	A	38	38	26.7		3.8	4.8	4.1
7 (b)	A	127	?	27.7		3.3	4.4	5.4
8 E	?	80	37	20.1		4.0	4.8	4.7
9 (b)	A	120	29	?		4.0	5.0	5.0
10	A	48	30	23.7		6.6	7.8	6.3
11	A	32	38	21.1	4.4	5.3	8.2	
12	U	32	33	21.0	3.3	2.2	4.4	
13 (d)	?	40	31	21.1		2.3	3.2	4.1
14	A	36	38	30.9		− 0.3	1.7	4.8
15 (b)	A	28	38	29.9		3.5	7.6	7.0
16 (b, f)	?	32	33	22.5	0.6	5.5	4.2	
17	A	30	38	27.4			4.5	
17 (e)		30		27.4			2.2	
18 (c)	?	32	20	31.7			4.3	
19 (d)	?	32	31	26.1			6.1	
20 (g)	M	96	12	32.5			6.1	
Mean			32	26.0	2.8	4.1	5.3	6.2
S.D.			7	3.8	2.0	2.1	2.1	2.4
N. cows		969		267	24	190	300	158
W. mean (h)				27.0	2.8	3.9	5.2	5.6

(a) A = American Cyanamid ; M = Monsanto ; U = Upjohn - (b) 3.5 p. 100 FCM - (c) 4 p. 100 FCM - (d) 305 d. lactation - (e) 2nd BST consecutive lactation - (f) 50 % of Jersey cows - (g) milking 3 times/day - (h) weighed mean (for cow number) - E = Europe.

(1) Bauman *et al.*, 1985 ; (2) Baird *et al.*, 1986 ; (3) Chalupa *et al.*, 1986, 1987 a ; (4) Hutchison *et al.*, 1986 ; (5) Annexstad *et al.*, 1987 ; (6) Burton *et al.*, 1987 ; (7) Chalupa *et al.*, 1987 b ; (8) Thomas *et al.*, 1987 ; (9) Chalupa *et al.*, 1988 ; (10) Eisenbeisz *et al.*, 1988 b ; (11) Elvinger *et al.*, 1988 ; (12) Munneke *et al.*, 1988 ; (13) Nytes *et al.*, 1988 ; (14) Palmquist, 1988 ; (15) Soderholm *et al.*, 1988 ; (16) West *et al.*, 1988 ; (17) Hemken *et al.*, 1988 ; (18) Rowe-Bechtel *et al.*, 1988 ; (19) Tessmann *et al.*, 1988 ; (20) Aguilar *et al.*, 1988.

for cow number) increase in milk production was 2.8 kg/day (+ 11 p. 100 over control cows) with 5 mg BST/day, and 5.6 kg/day with 31-50 mg BST/day (+ 21 p. 100 over control cows). Inter-assay S.D. was 2.0-2.4 kg/day, i.e. the variation coefficient (p. 100) of the response tended to decrease at higher doses, but was high (39 p. 100) even with 31-50 mg BST/d. The response to rBST was very rapid (maximum after one week or less). Few long-term assays have been conducted with the pituitary somatotropin (table 3). In two direct comparisons (Bauman *et al.*, 1985 ; Hutchison *et al.*, 1986), the response was lower than with the same dose (27 mg/day) of recombinant methionyl-BST.

The milk fat, protein and lactose contents were unchanged (mean values over the period). When significant changes are reported, they are of limited extent, and positive or negative in different studies.

Table 3

Long-term effects of pituitary BST on cow milk yield.
Effets à long terme de la BST hypophysaire sur la production laitière des vaches.

Reference	N. cows	Dose (mg/d.)	Weeks of BST	Milk yield (kg/d)	
				Control	BST-Control
Brumby and Hancock, 1955	2 × 3 (a)	50	12	13.1	5.8
Peel *et al.*, 1985	2 × 5 (a)	50	22	19.8	3.5
Bauman *et al.*, 1985	2 × 6	27	27	27.9	4.6
Hutchison *et al.*, 1986	2 × 6	27	27	26.0	2.0
Mean				21.7	4.0

(a) Sets of twin cows.

2. *Prolonged release preparations*

Different companies are producing somatotropin molecules whose precise structure, as well as excipients used for prolonged release systems, are still proprietary information. Moreover, BST dose and injection frequencies differ between companies. As a consequence, results for each product will be presented separately in this chapter.

Somidobove (Eli Lilly) was used at three doses (320, 640, 960 mg) and injected every 28 d., corresponding theoretically to 11, 23 and 34 mg rBST/d., respectively. Production responses (weighed means) on about 100 cows per dose (table 4) were 56, 60 and 75 p. 100 (respectively) of those obtained by daily injections in comparable amounts (table 2). Increasing the injection frequency (28, 21 and 14 d.) of the same total amount of BST did not change milk response to any large extent (McGuffey *et al.*, 1987 b ; Vérité *et al.*, 1988). Part of the difference with daily injections could also be due to feeding or management factors (see below). Milk fat and protein content were unchanged in most experiments. However increases were observed with 320/28 d. injections (Oldenbroek *et al.*, 1987 ; Vérité *et al.*, 1988 ; Vignon *et al.*, 1988).

TABLE 4

Long-term effects of Somidobove injections on dairy cow milk yield.
Effets à long terme d'injections de Somidobove sur la production laitière des vaches.

Reference	N. cows	Weeks of BST	Milk yield (kg/d.) BST Dose (mg/28 d.)			
			0	320	640	960
				BST-Control		
21	14	12	22.9			4.1
22 (a)	70	12	26.4	3.9	4.9	6.3
23 E (b)	48	24	20.9	0.9	3.3	2.9
24	16	16	29.8		2.4	
25 (c)	188	12-36	26.8	2.7	4.3	4.8
26 E	36	24	24.8	0.2	2.7	2.2
27 E	24	20	21.0		1.2	
28 E	40	12	16.3	− 0.3	0.1	0.4
29 E (d)	32	20	17.7		1.3	
Mean		18	23.0	1.5	2.5	3.4
S.D.		5	4.4	1.8	1.6	2.1
N. cows	468		129	99	136	104
W. mean (e)			23.6	2.2	3.1	4.2

(a) Mean of 14, 21 and 28 d. injection frequencies - (b) mixed breeds - (c) pooled data from 5 herds - (d) Montbéliarde cows - (e) weighed mean.

(21) McGUFFEY *et al.*, 1987 a ; (22) McGUFFEY *et al.*, 1987 b ; (23) OLDENBROEK *et al.*, 1987 ; (24) McGUFFEY *et al.*, 1988 ; (25) MEYER *et al.*, 1988 ; (26, 27) VÉRITÉ *et al.*, 1988 ; (28) VIGNON *et al.*, 1988 ; (29) PARRASSIN and VIGNON, 1988 ; E = Europe.

Sometribove (Monsanto) was used as a 500 mg/14 d. formulation, corresponding theoretically to 36 mg rBST/d. Milk yield increase in about 450 cows (4.4 kg/d., + 19 p. 100 over control, table 5) was 79 p. 100 of that obtained by daily injections (table 2). Higher responses (8-13 kg/d.) have been obtained with 1800 or 3000 mg/ 14 d. (EPPARD *et al.*, 1988). Milk composition was unchanged in most experiments. However milk protein content was significantly increased (+ 0.9 to 1.0 g/l) in 4 experiments (PHIPPS, 1987 ; BAUMAN *et al.*, 1988 ; SAMUELS *et al.*, 1988 ; WHITE *et al.*, 1988). This increase was observed during the end of lactation (PHIPPS, 1987) and it would be suitable to weight it for decreasing milk volumes to evaluate its quantitative significance.

A prolonged release preparation from American Cyanamid was also experimented (JENNY *et al.*, 1988) and gave 3.5 p. 100 FCM responses of 4.9-4.0 and 4.4 kg/d for injections of 140-350 and 700 mg each 14 d. during 26 weeks (9 cows/group). Milk production responses to different injection strategies are summarized in table 6.

Apart from the mean production and composition, it is of interest for milk recording and milk quality controls to know if there are some fluctuations during the period between two BST injections. The milk response to BST was indeed time-dependent (HUBER, 1987 ; OLDENBROEK *et al.*, 1987). Maximal response was observed

TABLE 5

Long-term effects of Sometribove (500 mg BST/14 d.) on dairy cow milk yield.
Effets à long terme de la Sometribove (500 mg BST/14 j) sur la production laitière des vaches.

Reference	N. cows	Weeks of BST	Milk yield (kg/d.)	
			Control	BST-Control
30 E (a)	90	33	19.2	3.7
31 E	64	33	24.9**	4.6
32	80	36	27.3*	3.1
33 (b)	40	?	? *	8.3
34 (b, c)	18	?	23.1*	6.9
35 E	60	33	21.7**	3.6
36	80	36	27.3	2.3
37	72	36	25.8	3.8
38 (d)	44	34	16.8*	5.6
39 E	48	33	19.2	2.1
40	126	36	23.8*	5.2
41 E	58	33	21.9**	3.9
42	42	24	28.1*	8.2
42 (e)	21	24	— *	6.6
43 E (f)	38	30	16.0	3.1
Mean		32	22.7	4.7
S.D.		4	4.0	2.0
N. cows	881		410	451
W. mean (g)			23.2	4.4

(a) Friesians - (b) 600 mg/14 d. - (c) 2nd consecutive lactation - (d) Jerseys - (e) IM injections - (f) Normandes - (g) weighed mean ; * 3.5 % FCM ; ** 4 % FCM.

(30) PHIPPS, 1987 ; (31) RIJPKEMA *et al.*, 1987, 1988 ; (32) BAUMAN *et al.*, 1988 ; (33, 34) EPPARD *et al.*, 1988 ; (35) GRAVERT *et al.*, 1988 ; (36) HUBER *et al.*, 1988 ; (37) LAMB *et al.*, 1988 ; ANDERSON *et al.*, 1988 ; (38) PELL *et al.*, 1988 ; (39) RÉMOND *et al.*, 1988 ; (40) SAMUELS *et al.*, 1988 ; (41) VEDEAU and SCHOCKMEL, 1988 ; (42) WHITE *et al.*, 1988 ; LANZA *et al.*, 1988 a; (43) LOSSOUARN, 1988. E = Europe.

TABLE 6

Effect of dose and frequency of BST injections on milk yield (kg/d).
Effet de la dose et de la fréquence des injections de BST sur la production laitière (kg/j).

Dose (mg) Frequency (days)	10-15 1	20-27 1	31-50 1	320 (a) 28	640 (a) 28	960 (a) 28	500 (b) 14
Mean	4.1	5.3	6.2	1.5	2.5	3.4	4.7
S.D.	2.1	2.1	2.4	1.8	1.6	2.1	2.0
N. cows	190	300	158	99	136	104	451
W. Mean	3.9	5.2	5.6	2.2	3.1	4.2	4.4

(a) Somidobove ; (b) Sometribove.

about one week after each injection (PHIPPS, 1987 ; LAMB *et al.*, 1988 ; RÉMOND *et al.*, 1988). Negative responses can be obtained during the 4th week in the case of 28 d. injection cycles (VÉRITÉ *et al.*, 1988, figure 1).

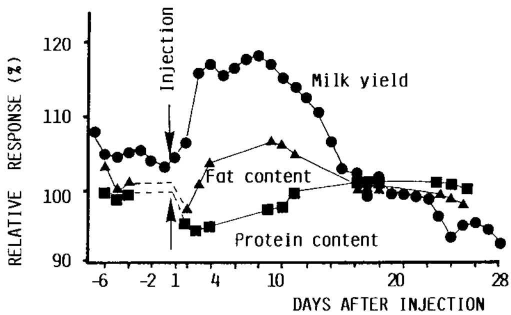

FIG. 1

Daily evolutions of milk yield and composition following prolonged release somatotropin injection (VÉRITÉ *et al.*, 1988).

Evolutions journalières de la production et de la composition du lait après injection de somatotropine à libération prolongée.

Values are related to the means of days − 7 to − 1 and 20 to 28, over five 28-day injection periods.

Cyclic responses in milk fat and/or protein contents between 14 d. or 28 d. injections have also been observed (PHIPPS, 1987 ; OLDENBROEK *et al.*, 1987 ; BARBANO *et al.*, 1988 ; BAUMAN *et al.*, 1988 ; LAMB *et al.*, 1988 ; RÉMOND *et al.*, 1988 ; VÉRITÉ *et al.*, 1988, figure 1) except by WHITE *et al.* (1988). The cyclic pattern is still not well known and varied between studies. Milk protein content was generally lower after each injection and higher (up to 2 g/l) just before the following injection (BARBANO *et al.*, 1988 ; RÉMOND *et al.*, 1988 ; VÉRITÉ *et al.*, 1988). Milk fat content can increase (up to 5 g/l) in parallel with milk yield (LAMB *et al.*, 1988 ; VÉRITÉ *et al.*, 1988), probably due to increased body lipid mobilization when yield is maximal (see below). Long chain fatty acid content of milk fat also cycled between two injections (FARRIES and PROFITTLICH, 1987 ; LYNCH *et al.*, 1988 ; VÉRITÉ *et al.*, 1988). There was (RÉMOND *et al.*, 1988) or not (BAUMAN *et al.*, 1988) cyclic change in lactose content.

B. *Dry matter intake (DMI) and calculated energy balance (CEB)*

In 14 daily-injection experiments, DMI increased from 0.6 kg/day for 10-15 mg BST/d, to 1.7 kg/day for 31-50 mg BST/d. The response variability was higher than 45 p. 100. In 6 Somidobove experiments, DMI increased from 0.2 to 0.8 kg/d., depending on the injected dose. Response in 9 Sometribove experiments was 1.5 kg/d. (table 7). DMI was not increased in one experiment with American Cyanamid preparations (JENNY *et al.*, 1988).

TABLE 7

Effect of dose and frequency of BST injections on DM intake (kg/d.).
Effet de la dose et de la fréquence des injections de BST sur l'ingestion de matière sèche (kg/j).

Dose (mg) Frequency (days)	10-15 1	20-27 1	31-50 1	320 (a) 28	640 (a) 28	960 (a) 28	500 (b) 14
Mean	+ 0.6	+ 1.7	+ 1.7	+ 0.5	+ 0.7	+ 0.7	+ 1.5
S.D.	0.7	0.9	0.8	0.5	0.4	0.4	0.5
N. cows	116	166	92	89	98	94	337
W. Mean	+ 0.6	+ 1.5	+ 1.7	+ 0.2	+ 0.8	+ 0.8	+ 1.5
References (c)	(1-3, 5-8, 10-11, 14-18)			(21-26)			(d)

(a) Somidobove ; (b) Sometribove ; (c) see table 2, 4, 5 ; (d) 30-32, 35-36, 40-41.

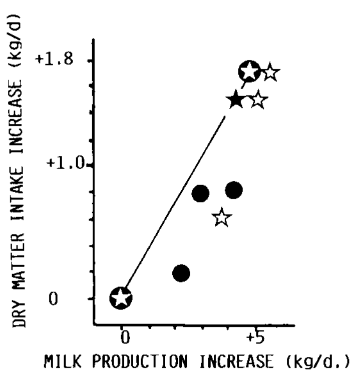

FIG. 2

Relationship between milk production and DM intake increases in untreated and BST treated cows.

Relation entre les accroissements de production laitière et d'ingestion de matière sèche chez des vaches traitées ou non par la BST.

✪ Increase in untreated cows yielding 25 and 30 kg/d. (FAVERDIN *et al.*, INRA, 1987).
☆ Daily BST injections
● Somidobove injections
★ Sometribove injections
See tables 6 and 7

Increase of DM intake in BST cows (20-50 mg/d and Sometribove) was exactly that predicted in untreated cows whose milk yield increased to the same extent (figure 2). This is in accordance with the view that BST cows are in some ways similar to genetically higher yielding cows (PEEL and BAUMAN, 1987 ; CHALUPA and GALLIGAN, 1988).

When not given by authors, EB (table 8) was calculated on a net energy basis from DMI, energy concentration of the diet, and 3.5 or 4 p. 100 fat corrected milk yield. These calculations should be considered cautiously, particularly when energy content of the diet was not given by authors in abstracts, and roughly estimated (1.5-1.65 Mcal/kg DM) according to diet composition.

TABLE 8

Effect of dose and frequency of BST injections on calculated energy balance (Mcal/d.).
Effet de la dose et de la fréquence des injections de BST sur le bilan énergétique calculé (Mcal/j).

Dose (mg) Frequency (days)	10-15 1	20-27 1	31-50 1	320 (a) 28	640 (a) 28	960 (a) 28	500 (b) 14
Mean	− 1.9	− 1.2	− 2.0	− 0.8	− 1.2	− 1.7	− 0.2
S.D.	1.3	1.6	1.1	1.2	0.8	1.0	0.7
N. cows	122	172	98	89	98	94	388
W. Mean	− 1.8	− 1.2	− 1.5	− 1.4	− 1.4	− 1.9	0.0
References (c)	(1-8, 10-11, 14-18)			(21-26)			(d)

(a) Somidobove ; (b) Sometribove ; (c) see table 2, 4, 5 ; (d) 30-32, 34-38, 40-42.

Daily BST injections decreased CEB from 1.2 to 1.8 Mcal/d (table 8). This decrease was smaller for medium dose BST injections where DMI increase was the higher relatively to milk yield increase (tables 6 and 7). In Somidobove experiments CEB decreased 1.4-1.9 Mcal/d., whereas it was unchanged in Sometribove experiments. This result could appear surprising since energy needs for 4.4 kg extra-milk are higher than 3 Mcal, which would suppose an energy value higher than 2 Mcal N.E./kg extra-DMI (cf. table 7). This is in fact not surprising if the net energy contents of the diets differ according to the milk production level of the cows. Indeed, if 20 kg DMI × 1.59 Mcal/kg = 31.8 Mcal, and 21.5 kg DMI × 1.62 Mcal/kg = 34.8 Mcal, the energy value of the extra 1.5 kg DM would be 2 Mcal/kg. On the other hand, EB calculations are somewhat imprecise due to the limitations pointed out above, and possibly to different methods used by authors in estimating the energy density of the diets.

The lower response in DM intake with Somidobove is probably due in part to the experimental periods (18 ± 5 weeks, table 4) which are shorter than in daily-injection (32 ± 7, table 2) or Sometribove (32 ± 4, table 5) experiments. Indeed, DM intake increase was always delayed, and did not become significant before 6-8 weeks of BST treatment (BAUMAN *et al.*, 1985 ; PHIPPS, 1987 ; ANDERSON *et al.*, 1988 ; EPPARD *et al.*, 1988 ; DHIMAN *et al.*, 1988 ; LANZA *et al.*, 1988 a). As a consequence, energy balance of treated cows was lower than that of control cows during the first 2 or 3 months of BST administration (BAUMAN *et al.*, 1985 ; PHIPPS, 1987 ; ANDERSON *et al.*, 1988 ; DHIMAN *et al.*, 1988 ; EPPARD *et al.*, 1988 ; HUBER *et al.*, 1988 ; LANZA *et al.*, 1988 a ; RÉMOND *et al.*, 1988 ; SAMUELS *et al.*, 1988).

From Sometribove data summarized by PEEL *et al.* (1988), it was possible to compute EB of the cows during the first 12 weeks and the last 22 weeks of eight 34-week experiments (table 9). CEB of treated cows was higher during the last 22 weeks (due to higher DM intake), and this can compensate completely for lower CEB during the first 12 weeks. However, delayed conception and increasing intercalving intervals (6-21 days in trials beginning during week 9 of lactation) were consequence of this lower CEB during the third month of lactation (see HARD *et al.*, 1988 ; PEEL, 1988 and PEEL *et al.*, 1988).

TABLE 9

Milk yield and calculated energy balance in 8 Sometribove experiments, during the first 12 weeks and the last 22 weeks of BST treatment (315 treated cows) (a).

Production laitière et bilan énergétique calculé dans 8 essais « Sometribove », pendant les 12 premières et les 22 dernières semaines des injections de BST (315 vaches traitées) (a).

Period	Milk yield (kg/d.)		Calculated energy balance *	
	Control	BST-Control	Mcal/d	Mcal/period
First 12 Weeks	29.5 (± 2.4)	4.6 (± 1.0)	− 2.1 (± 0.7)	− 176
Last 22 Weeks	21.0 (± 3.5)	3.4 (± 1.1)	+ 1.2 (± 1.0)	+ 185

(a) Data from PEEL *et al.* (1988) and references 30-32, 35-37, 40-41 of table 5.
* BST-Control - The same diet was used throughout each 34-week assay.

C. *Body weight, and body reserves of the cows*

In high yielding cows, body reserves (mainly lipids) are mobilized during the first 2 months of lactation, and deposited again during decreasing lactation (see CHILLIARD, 1987, for review).

Few data are available on body weight and body condition score changes in BST experiments, so results from tables 10 and 11 have to be regarded cautiously. Body weight and body condition change data are however roughly in accordance with energy balance data, if we take into account that experimental periods were shorter for Somidobove treatment (daily CEB × day number).

During Sometribove experiments, some authors also observed a lower body condition in BST cows during the first period of treatment, this difference being partly reversed during the following period, in accordance with CEB data (HUBER *et al.*, 1988 ; SAMUELS *et al.*, 1988). This was however not observed in another trial in European conditions (− 0.4 and − 0.6 points of body condition score during winter and grazing periods, respectively) (RÉMOND *et al.*, 1988). A lower body condition of BST treated cows (− 0.5 point) can also be reversed during the dry period before the next calving (PHIPPS, 1987).

TABLE 10

Effect of dose and frequency of BST injections on body weight change (kg) (d).
Effet de la dose et de la fréquence des injections de BST sur les variations de poids vif (kg) (d).

Dose (mg) Frequency (days)	10-15 1	20-27 1	31-50 1	320 (a) 28	640 (a) 28	960 (a) 28	500 (b) 14
Mean	− 14	− 23	− 43	0	− 5	− 18	NS
S.D.	36	33	17	14	13	10	—
N. cows	55	92	38	31	68	29	219
W. Mean	− 17	− 23	− 45	− 1	− 4	− 16	NS
References (c)	(1, 3, 6, 8, 11, 14-16, 18)			(23, 26-29)			(e)

(a) Somidobove ; (b) Sometribove ; (c) see tables 2, 4, 5 ; (d) BW change in BST cows - BW change in control cows ; (e) references 30, 32-34, 36, 38-39, 43 ; NS = no significant change.

TABLE 11

Effect of dose and frequency of BST injections on body condition score (d).
Effet de la dose et de la fréquence des injections de BST sur la note d'état corporel (d).

Dose (mg) Frequency (days)	10-15 1	20-27 1	31-50 1	320 (a) 28	640 (a) 28	960 (a) 28	500 (b) 14
Mean	− 1.0	− 0.8	− 1.7	− 0.1	− 0.2	− 0.4	− 0.5
S.D.	0.3	0.5	—	—	—	—	0.4
N. cows	15	95	7	9	22	7	297
W. Mean	− 1.0	− 0.5	− 1.7	− 0.1	− 0.1	− 0.4	− 0.2
References (c)	(15, 16, 18-20)			(26, 27 (e))			(f)

(a) Somidobove ; (b) Sometribove ; (c) see tables 2, 4, 5 ; (d) 0-5 scale ; (e) this trend was confirmed by McGuffey *et al.* (1988) and Meyer *et al.* (1988) ; (f) references 30, 36, 39, 40.

Body composition and body lipids have been measured using deuteriated water dilution technique in three BST experiments (table 12). In the two experiments exceding 6 months, body lipid deposition was 16 to 69 kg lower in BST treated cows whose milk production increased. Higher body fat mobilization (blood free fatty acids) was also observed. In another Somidobove experiment (McGuffey *et al.*, 1988), subcutaneous fat depth was decreased. Theoretical calculation shows that a 1 Mcal/d. decrease of energy balance (net energy) is equivalent to a 28 kg lipid deposition decrease over 38 weeks (assuming the same efficiency of metabolisable energy for milk secretion and body lipid deposition).

Increases in blood free fatty acids were also observed in some BST experiments (Rowe-Bechtel *et al.*, 1988 ; Rémond *et al.*, 1988), but not in others (Oldenbroek *et

TABLE 12

Effects of BST on body composition of dairy cows.
Effets de la BST sur la composition corporelle des vaches laitières.

BST-Control	Daily injections (a)			Somidobove (b)		Daily injections (c) 40 mg
	10 mg	21 mg	41 mg	320 mg 28 d.	960 mg 28 d.	
Milk yield (kg/d)	+ 3.5	+ 7.6	+ 7.0	+ 0.2	+ 2.2	Increased
Energy balance (Mcal/d)	− 0.9	− 1.4	− 2.7	+ 0.2	− 1.0	Decreased
Body weight change (kg)	− 42	− 45	− 66	+ 18	− 25	+ 2
Body lipids change (kg) (d)	− 16	− 69	− 50	+ 1	− 42	− 4
Body condition score change (e)	− 1.2	− 1.6	− 1.7	+ 0.2	− 0.2	—
Blood free fatty acids (% over control)	+ 36	+ 29	+ 54	+ 19	+ 97	—

(a) SODERHOLM *et al.*, 1988 ; 20 cows, BST over 38 weeks (15 cows).
(b) VÉRITÉ and CHILLIARD, unpublished : 21 cows, BST over 24 weeks (13 cows). Deuteriated water dilution technique was previously standardized on 20 slaughtered dairy cows (CHILLIARD and ROBELIN, 1983).
(c) BROWN *et al.*, 1988 : 16 cows, BST over 7 weeks (9 cows).
(d) Estimated by deuteriated water dilution technique. (e) scale 0-5.

al., 1987 ; HUTCHISON *et al.*, 1986). Transient increases were observed during the first months of BST when the energy balance of the cows decreased, but not during the remainder of the lactation when DM intake increased above controls (LANZA *et al.*, 1988 b, c).

Blood free fatty acids vary with feeding time. They can also change during the cycle between two BST injections (VÉRITÉ *et al.*, 1988) as well as long chain fatty acid content of milk fat (FARRIES and PROFITTLICH, 1987 ; LYNCH *et al.*, 1988 ; VÉRITÉ *et al.*, 1988), indicating higher body fat mobilization immediately after each BST injection. BST can indeed increase the lipolytic response in cows with low energy balances (SECHEN *et al.*, 1988 and reviews by VERNON, 1986, and CHILLIARD, 1987, 1988).

Cyclic variations of body weight (± 5-10 kg) were observed between Sometribove injections (PHIPPS, 1987 ; ANDERSON *et al.*, 1988), but not for DM intake (BAUMAN *et al.*, 1988). It is not known if this can reflect changes in gut or mammary contents, or in body composition.

D. *Feed efficiency*

Feed efficiency was increased 17 p. 100 (over control) by injecting daily 31-50 mg of BST. The corresponding values were 8 p. 100 for Somidobove and 6 p. 100 for Sometribove (table 13).

Digestibility of the diet components, maintenance requirement and efficiency of metabolisable energy for milk secretion were not significantly increased in BST short-term experiments (TYRRELL *et al.*, 1982 ; EISEMANN *et al.*, 1986), nor DM digestibility in long-term experiments (PEEL *et al.*, 1985 ; DHIMAN *et al.*, 1988 ; RÉMOND *et al.*, 1988).

TABLE 13

Effects of BST on feed efficiency in dairy cows.
Effets de la BST sur l'efficacité alimentaire chez la vache laitière.

Daily injections (mg/d.)		0	10-15	20-27	31-50
FCM/DMI (a)	W. Mean N. Cows	1.31 115	1.46 108	1.47 138	1.53 84
FCM/NEI (b)	W. Mean N. Cows	0.78 60	0.86 49	0.89 80	0.91 41
Somidobove (mg/28 d.) . .		0	320	640	960
FCM/NEI (c)	W. Mean N. Cows	0.76 77	0.81 68	0.82 77	0.82 77
Sometribove (mg/14 d.) .		0			500
FCM/NEI (d)	W. Mean N. Cows	0.78 367			0.83 408

(a) (Fat-corrected) milk/Dry matter intake. References 1, 3, 5-7, 10-11, 14-17 in table 2.
(b) (Fat-corrected) milk/Net energy intake. References 1, 3, 10-11, 14-15, 17 in table 2.
(c) References 23-26 in table 4 - (d) References 30-38, 39-42 in table 5.

Increase in feed efficiency resulted 1/ from dilution of maintenance requirement in the total requirement, due to milk yield increase, and 2/ from lower use of nutrients for body tissue deposition, relatively to milk secretion. These two reasons can explain the higher increase of feed efficiency with daily-injection experiments (table 13), since milk response and energy balance decrease were more pronounced than with prolonged release preparations.

E. *Interactions of BST response with animal and management factors*

1. *Parity*

Lower responses in heifers than in multiparous cows have been reported (MARSH *et al.*, 1987 ; HUBER *et al.*, 1988 ; ROWE-BECHTEL *et al.*, 1988 ; TESSMANN *et al.*, 1988 ; VÉRITÉ *et al.*, 1988 ; WHITAKER *et al.*, 1988). However there was no difference (or higher responses in heifers) in other studies (CHALUPA *et al.*, 1988 ; HARD *et al.*, 1988 ; LAMB *et al.*, 1988 ; PELL *et al.*, 1988 ; RÉMOND *et al.*, 1988 ; SAMUELS *et al.*, 1988).

2. *Milk production potential*

Most authors observed great individual variations in the response (kg/d.) to BST. It is not known if this variability is repeatable from one lactation to the next. It was not related to individual variations in milk potential (LANZA *et al.*, 1988 a ; SULLIVAN *et* *al.*, 1988) nor to predicted differences of the sires (McDANIEL and HAYES, 1988). Negative relationships with individual milk potential were however recorded by LEICHT *et al.* (1987) and OLDENBROEK *et al.* (1987). There was no interassay relationship between milk production of control groups and response to BST in data from tables 2, 4 and 5.

These observations on parity and milk potential effects show that percentage milk response to BST (relative to control) decreases when milk yield increases.

3. *Lactation stage and consecutive lactations*

Response to BST (kg/d) did not seem to be dependent on the stage of lactation (after the first month) at which treatment began (MEYER *et al.*, 1988). For a given initial stage, the persistency of the response during the remainder of the lactation was rather variable, but tended often to decrease (FURNISS *et al*, 1988 ; HUBER *et al.*, 1988 ; LOSSOUARN, 1988 ; PHIPPS, 1987 ; PEEL *et al.*, 1988, table 9 ; RÉMOND *et al.*, 1988 ; VÉRITÉ *et al.*, 1988), perhaps in relation to management factors, pregnancy stage, and the physiological need of the cow to maintain body reserves.

BST use during one lactation did not appear to influence yield at the beginning of the subsequent lactation (PHIPPS, 1987). The percentage of twin calves was increased in BST cows during 2 European experiments (PHIPPS, 1987 ; RIJPKEMA *et al.*, 1987). These observations need to be confirmed. On the other hand, milk responses to BST during a second consecutive lactation were of the same magnitude as during the first (ANNEXSTAD *et al.*, 1987 ; HEMKEN *et al.*, 1988 ; EPPARD *et al.*, 1988).

4. *Nutrition*

During short-term experiments, milk response to BST was not increased by post-ruminal infusions of glucose and casein (PEEL *et al.*, 1982), nor by the addition of sodium bicarbonate or branched-chain volatile fatty acids to the diet (KIK and COOK, 1986 ; CHALUPA *et al.*, 1984, 1985). Although a positive interaction was observed between BST and calcium soaps of fatty acids (SCHNEIDER *et al.*, 1987) it was not the case with a hydrolysed blend of fats (LOUGH *et al.*, 1988).

During long-term experiments there was no clear effect of concentrate level or cereal nature (table 14), except in TESSMANN *et al.* (1988). In this experiment, cows receiving low concentrate diet were in lower body condition at the end of BST treatment, and they had a lower persistency during the next BST lactation.

An effect of protein content and degradability was observed by McGUFFEY *et al.* (1988), but untreated control cows only received the low protein diet. The lower response in low protein diet was due to a lower persistency of the response during BST treatment, and the authors suggested it could be due to exhaustion of body protein reserves. Increasing the percentage of undegradable protein did not however increase the response to BST to the same extent in cows of lower milk potential (VÉRITÉ *et al.*, 1988).

Data from tables 2, 4 and 5 have been pooled according to feeding diets (table 15). The significance of the different means is poor, since all other experimental conditions were not comparable between assays. It seems however that higher responses could be obtained with several complete mixed rations of different energy content, given according to milk yield. Responses were lower in European feeding conditions. During the 3 winter flat rate concentrate feeding experiments, there was a lower body weight gain in

TABLE 14

Comparisons of different diets in long-term BST experiments.
Comparaisons de régimes dans les essais à long terme avec la BST.

Reference	Dose (mg)	N. Cows per group	Weeks of BST	Milk response (kg/d)	
				« Low » Diet (LD)	« High » Diet (HD)
A	25/d.	10	37	4.6 *	4.9
B	21/d.	6	30	7.8	7.8
C	21/d.	10	38	4.5	4.5
D	640/28 d.	8	16	2.4	5.3
E	500/14 d.	12	12	2.7	2.7
F	21/d.	16	31	4.0	6.1

A - THOMAS *et al.*, 1987 - LD = flat rate concentrate (9 kg/d.) over 24 weeks, then pasture. * Lower weight gain over 24 weeks - HD = complete mixed rations.
B - EISENBEIZ *et al.*, 1988 a. Corn vs. barley concentrate.
C - HEMKEN *et al.*, 1988. 40 % vs. 60 % concentrate.
D - McGUFFEY *et al.*, 1988 ; LD = 14 % protein, 30 % undegradable protein - HD = 17 % protein, 40 % undegradable protein.
E - RÉMOND *et al.*, 1988. 2.5 vs 5.4 kg/d concentrate (corn silage *ad libitum*, no difference in total DM intake).
F - TESSMANN *et al.*, 1988 ; 12-32 % vs 32-52 % concentrate (alfalfa silage diet).

TABLE 15

Summary of BST production responses according to feeding diets.
Récapitulatif des réponses en lait à la BST en fonction des régimes alimentaires.

Diet	1 CMD	2-4 CMD	F + C	Pasture
Daily injections (20-27 mg/d.)	4.7 (± 1.8) n = 11 (a) E = 1	6.6 (± 2.2) n = 7 (b)		
Somidobove or Sometribove		5.3 (± 2.0) n = 10 (c) E = 2	3.1 (± 1.3) n = 7 (d) E = 7	2.5 (± 1.8) n = 8 (f) E = 6
			4.1 (± 0.8) n = 3 (e) E = 3	

1 CMD = one complete mixed ration.
2-4 CMD = 2-4 complete mixed rations of different energent content, according to milk yields.
F + C = (*ad libitum* forages) + (concentrates) - E = European experiments.
(a) References 2-5, 8, 14-18 (table 2) - (b) References 1, 7, 10-11, 13, 19-20 (table 2) - (c) References 30-34, 36-37, 40, 42 (table 5) - (d) Concentrates according to milk yield - References 26-27, 29, 35, 39, 41, 43 (table 4 and 5) - (e) Flat rate concentrates - THOMAS *et al.*, 1987 ; FURNISS *et al.*, 1988 ; WHITAKER *et al.*, 1988 - (f) References 27-29 (table 4), 39, 43 (table 5), BRUMBY and HANCOCK, 1955 ; PEEL *et al.*, 1985, 1988 ; FURNISS *et al.*, 1988.

BST cows, but milk response was rather high. The low responses at pasture (table 16) could be due to higher lactation-pregnancy stages (VÉRITÉ *et al.*, 1988) or to low quality pasture during drought periods (LOSSOUARN, 1988).

5. *Environmental conditions*

MOLLETT *et al.* (1986) observed low response (+ 2 to + 4 p. 100) to 27-40 mg BST/d. over 27 weeks in 18 cows, and hypothesized that hot and humid climatic conditions may have affected treatment response. However COLLIER and JOHNSON (1988) summarized data from short- and long-term experiments in cold and hot conditions, and concluded that BST response was not impaired if feeding and management conditions were adequate.

TABLE 16

*Milk response (kg/d) to BST in Europe according to season * and feeding conditions.*

*Réponse en lait à la BST dans les essais européens en fonction des conditions saisonnières * et alimentaires.*

Season Diet	Winter Silage + concentrate	Spring and/or summer Pasture (+ Concentrate)	
			Pasture quality
FURNISS *et al.*, 1988 PEEL, 1988	4.8	4.5	Good
LOSSOUARN, 1988	5.6	2.8	Low
PARRASSIN and VIGNON, 1988	1.3	1.3	Medium
RÉMOND *et al.*, 1988	2.7	2.0	Medium
VÉRITÉ *et al.*, 1988	2.0	0.3	Good

* Including lactation stage or treatment duration effects.

III. Conclusions

BST has a great potential for increasing cow milk yield (about + 5 kg/d or + 1000 kg per lactation for a 200-day treatment with slow release preparations). However, responses can be much lower (1-4 kg/d), especially in European management conditions. So, percentage increase of lactation yield can vary from less than 5 to more than 25 p. 100, depending on milk production level of untreated cows, on treatment duration and on mean response to BST.

BST decreases energy balance and body reserve gain during the first 3 months of treatment. This leads to increased delay in conception and inter-calving interval, as in higher yielding untreated cows. Cycling of milk composition between injections will lead to increased milk recording and quality control frequencies, but this should be avoided by improving slow release delivery systems in the future.

Increase in feed efficiency (FCM/NEI) results simply from increased milk yield (decreasing the part of maintenance in total needs) and from decreased body tissue gain. If body gain over the period is similar to that of control cows, increase of feed efficiency will be of about 6 p. 100 for a 4 kg/d increase in milk yield.

Heifer response was lower in some experiments, but not in others. BST responses were highly variable between adult cows, but not related to individual milk potential. New knowledge is needed to explain this and to improve strategies for BST use. Feeding management is important for milk response to BST, as well as for improving body condition and reproductive performances of the BST treated cows. Present data indicate a lower response (2.5 ± 1.8 kg/d) to BST in pasture European conditions.

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Résumé

Effets à long terme de la somatotropine bovine recombinée (hormone de croissance) sur les performances des vaches laitières *

Les effets à long terme (18-32 semaines) de la somatotropine bovine (BST) injectée quotidiennement (650 vaches, 20 essais) ou sous forme « retard » (790 vaches, injections mensuelles ou bimensuelles, 23 essais) sont analysés. Des injections journalières de 10-15, 20-27 ou 31-50 mg de BST augmentent la production laitière de 3,9-5,2 ou 5,6 kg/j, respectivement. Le produit Somidobove (320, 640 ou 960 mg de BST tous les 28 jours) augmente la production laitière de 2,2-3,1 ou 4,2 kg/j, et le produit Sometribove (500 mg de BST tous les 14 jours) de 4,4 kg/j. La composition moyenne du lait n'est pas modifiée, mais la production laitière et les taux butyreux et protéique fluctuent entre les injections dans le cas des formes « retard » de la BST.

L'ingestion de matière sèche s'accroît de 1,5-1,7 kg/j pour les doses élevées de BST dans les essais de longue durée (32 semaines), et de 0,8 kg/j dans les essais de 18 semaines. Le bilan énergétique et la note d'état corporel diminuent pendant les 3 premiers mois de traitement en raison d'un temps de latence avant que l'ingestion de la ration n'augmente. Dans deux essais, le dépôt de lipides corporels a été fortement réduit par la BST.

L'efficacité alimentaire augmente de 6 à 17 p. 100 en raison de la dilution du besoin d'entretien dans le besoin total (ce qui explique 6 p. 100 d'augmentation), et en raison de la diminution du gain de poids des vaches (pouvant expliquer 10 p. 100 de cette augmentation). Il n'y a pas d'interactions claires entre la réponse à la BST et l'âge, ou le potentiel laitier des vaches, mais une tendance montrant que la réponse diminue après plusieurs mois de traitement. Les rations complètes en mélange, à hautes teneurs en énergie et en protéines, permettent une réponse en lait plus élevée, mais la variabilité entre vaches et entre essais est très élevée. Les réponses sont plus faibles (2,5 ± 1,8 kg de lait par jour) au pâturage dans les conditions européennes.

* La traduction française de cet article est disponible sur demande à l'auteur.

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