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Energy metabolism in lactating cows treated with recombinant bovine somatotropin under high environmental temperature

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Summary

In order to clarify the effects of r-bST on energy metabolism under high environmental temperature, we conducted energy metabolism trials using open-circuit respiration chambers with eight Holstein cows in mid lactation. Cows were given subcutaneous injections with r-bST (23 microgram/kgBW) or with buffer (as control) twice a day under two environmental temperatures, thermoneutral (18°C) and hot (28°C). Feed consisting of timothy hay and concentrates was given in restricted amount in thermoneutral and *ad libitum* in hot environment. In thermoneutral environment, FCM yield of the r-bST treated cows was higher than of in control, but ME intake and metabolisability of energy were similar between r-bST treated cows and control cows. Compared to the control, r-bST treatment differed on energy balance, but there was no effect on the efficiency of utilization of ME for lactation. In hot environment, r-bST treatment increased rectal temperature and respiration rate, and decreased ME intake. In spite of this, there were no significant differences between r-bST treated cows and of control in FCM yields, heat productions and the efficiency of utilization of ME for lactation.

Keywords: r-bST, high temperature, efficiency, nutrient partition, Holstein cows

Introduction

The recombinant bovine somatotropin (r-bST) is widely known to increase milk yield in cows under thermoneutral environment. The increase of milk production by r-bST was not considered due to the improvement of digestible and metabolisable energy (Kirchgessner *et al.*, 1991), but due to the change on nutrient partitioning from body tissue into milk (Tyrrell *et al.*, 1988). Even in hot environment, administration of r-bST has been reported also to improve milk yield (Johnson *et al.*, 1991). However, because the efficacy of r-bST on milk production depends on the level of milk yield, breed, heat stress and environment temperature is related to the heat production as an important factor (West *et al.*, 1990; Manalu *et al.*, 1991). Therefore it is necessary to determine the effect of bST on energy metabolism in hot environment.

Therefore, the present study was conducted to achieve knowledge of the efficacy of r-bST on energy utilization in Holstein cows in mid-lactation under high environmental temperature.

Materials and methods

Eight Holstein cows in mid lactation (mean 149±5 day *postpartum*) were used to determine the effects of r-bST under high environmental temperature. Mean milk yield of the cows just prior to the experiment was 28.6±1.7 kg/day and the mean body weight (BW) was 596±21 kg.

Cows were housed in a controlled climatic room with free access to water. They were milked twice daily at 9am and 6pm and the yields were recorded. During the experiment, milk samples were taken in the morning and evening for analysis of milk fat, protein, lactose and energy.

The experiment consisted of two 11-d periods and each was preceded by a 6-d preliminary period to allow the cows to adapt to experimental environment. In the first period, cows were maintained under thermoneutral environment (18°C, 60 relative humidity (RH)), and in the second period they were maintained under high temperature environment (28°C, 60 RH). The recovery period was 7-d under thermoneutral environment after the first period. Each cow was injected daily with r-bST (23 microgram/kgBW) and with buffer (as control), respectively, at 10am and 7pm through both 11-d periods. Subcutaneous injections were given between the shoulder blades.

The experimental feed consisted of 28% timothy hay, 10% alfalfa meal, 14% barley grain, 12% beet pulp, 12% corn, 9% soybean meal, 5% soybean hulls, 3% molasses, 2% wheat bran, 2% fish meal, 0.5% calcium salt fatty acid, 0.6% NaCl, and 0.1% minerals and vitamins. The feed was formulated to contain 94% OM, 16% CP, 2.6% EE and 34% NDF (DM basis) and was adjusted according to the Japanese Feeding Standard (AFFRC, 1999). Cows were maintained with restricted feeding during the thermoneutral and *ad libitum* feeding during the hot environments. Timothy hay was fed twice a day at 9.30am and 7pm, while others were divided equally into twelve containers of automatic feeder allowing two hours interval feedings. The cows were adapted to this feed for at least 14 d prior to perform preliminary period.

Energy balance was measured at the last three days of 11-d injection using open-circuit respiration chamber. Refusal, rectal temperature and respiration rate were measured daily just before 9.30am feeding.

The efficiency of utilization of metabolisable energy (ME) for lactation was calculated as ' kl = NEl (c) / (MEI - MEm)'. NEl(c) was calculated as ' NEl(c) = milk energy yield + energy retention (positive) + 0.8 x energy retention (negative) '(van Es, 1975) and MEm was regarded that MEm = 487 (18°C) or 487 x 1.1 (28°C) kJ/kg $BW^{0.75}$ (AFFRC, 1999). Deposit or mobilized protein of tissue for energy was calculated as ' protein energy = nitrogen balance (kg/day) x 6.25 x 23.3 (MJ/kg of protein) (Andrew *et al.*, 1994)'. Energy balance minus protein energy was assumed to be deposit or mobilized fat of tissue for energy. All data were analysed by GLM procedure (SAS, 1994) and treatment means were tested with F tests.

Table 1. Effects of r-bST and environmental temperature on performance of lactating cows.

	Pre-treatment			Thermoneutral			Hot		
Item	Control	rbST	SE[1]	Control	rbST	SE	Control	rbST	SE
Number of	4	4		4	4		4	4	
Days in				148	149	5	169	170	5
Body weight	611	581	21	617	587	24.0	621	579	24.0
DMI	20.1	19.1	0.8	20.1	19.1	0.8	17.3	13.4	1.5*
Milk yield	29.3	28.0	1.7	29.0	32.8	2.2^{+}	24.0	22.8	2.0
FCM	30.8	28.5	1.4	30.1	36.2	2.4**	24.1	23.9	1.9
Milk									
fat, %	4.42	4.14	0.29	4.31	4.69	0.30	4.06	4.28	0.27
protein, %	3.30	3.25	0.14	3.31	3.27	0.13	3.22	3.07	0.14
lactose, %	4.58	4.59	0.06	4.50	4.60	0.05	4.45	4.53	0.06

1) SE; standard error of means $^{+}$; p<0.10, * ; p<0.05, ** ; p<0.01

Results and discussion

The effects of r-bST and environmental temperature on performance of mid lactating cows are shown in Table 1. In thermoneutral environment, fat corrected milk (FCM) yield of r-bST treated cows (36.2 kg/day) was higher ($p<0.01$) than in control cows (30.1 kg/day), although dry matter intake (DMI) between r-bST treated cows and control cows was similar (19.1 *vs.* 20.1 kg/d). In hot temperature, the FCM yield in r-bST treated cows was similar to that of control cows (23.9 *vs.* 24.1 kg/day) although DMI of r-bST treated cows (13.4 kg/day) was lower ($p<0.05$) than in control cows (17.3 kg/day).

The effects of r-bST and environmental temperature on energy balance in cows are shown in Table 2. In thermoneutral environment, ME intake and metabolisability of energy were similar between r-bST (219 MJ/day; 61.2%) and control cows (226 MJ/day; 59.9%). The energy balance was different ($p<0.05$) between r-bST (-5 MJ/day) and control cows (+18 MJ/day) and this suggested that r-bST promoted body tissue mobilization. In the present study, the mobilized body tissue of r-bST treated cows was considered to be body fat (-9.7 MJ/day) rather than on body protein (+4.9 MJ/day). The efficiency of utilization of ME for lactation (kl) was similar in r-bST treated cows (65.6%) and in control cows (65.8%). This result confirmed the findings of Tyrrell *et al.* (1988) that bST treatment caused a redirection of energy to milk at the expense of body tissue as a conclusion of negative balance on nitrogen and energy in their experiment. On the other hand, Sechen *et al.* (1989) reported bST altered post-absorptive use of nitrogen and carbon as reflected by greater secretion in milk and lesser loss of nitrogen in urine.

Table 2. Effects of r- bST on energy balance.

	Thermoneutral			Hot		
Item	Control	r-bST	SE[1)]	Control	r-bST	SE
Energy intake (MJ/day)						
Gross energy (GE)	377	358	15	324	250	28*
Digestible energy (DE)	262	252	10	220	175	19*
Metabolizable energy (ME)	226	219	9	191	152	17*
Energy output (MJ/day)						
Fecal	115	106	6	104	75	10*
Urinary	11	10	1	10	8	1
Methane	25	23	1	20	15	2
Heat production	117	114	3	107	99	4
Milk energy (LE)	92	110	7*	74	73	5
Energy balance (MJ/day) (RE)	17.9	-4.7	7.1	10.8	-20.5	11.0*
as fat energy[2)]	13.0	-9.7	7.0*	10.2	-23.0	11.3*
as protein energy[3)]	4.9	4.9	0.5	0.6	2.4	0.7
Energy utilization (%)						
DE/GE	69.4	70.4	0.6	67.9	69.9	1.6
ME/GE	59.9	61.3	0.7	58.8	60.6	1.6
LE/ME	40.4	50.0	2.9**	38.6	48.1	3.1*
kl[4)]	65.6	65.4	1.3	66.7	63.1	3.1

[1)] SE; standard error of means * ; $p<0.05$, ** ; $p<0.01$

[2)] fat energy = energy balance (MJ/day) – nitrogen balance (MJ/day)

[3)] protein energy = nitrogen balance (kg/day) x 6.25 x 23.3 (MJ/kg of protein) (Andrew *et al.*, 1994)

[4)] the efficiency of utilization of ME for lactation (kl) = (LE± RE) . (MEI-MEm)

In hot environment, r-bST treatment tended to increase rectal temperature (40.1 *vs.* 39.3°C, $p<0.10$) and respiration rate (78 *vs.* 65 breaths/min, $p<0.10$), and decreased ME intake (152 *vs.* 191 MJ/day, $p<0.05$). Manalu *et al.* (1991) indicated that r-bST increased heat production in a range that could be dissipated by the cows. However, West *et al.* (1990) suggested that to optimise the efficacy of r-bST, it is needed to minimize the effect of heat stress under hot and humid weather. In our experimental condition, rectal temperature and heat production as a percentage of gross energy (GE) intake in r-bST treated cows (40%) were higher than in control cows (33%), and therefore r-bST treated cows could not accelerate heat loss to increase milk production. In spite of this, there were no significant differences between r-bST treated cows and control cows in milk energy (73 *vs.* 74 MJ/day), heat production (99 *vs.* 107 MJ/day) and their efficiency of utilization of ME for lactation (kl) (63.6 *vs.* 67.1%). The difference between r-bST treated cows and the control cows was observed in their energy balances (-21 *vs.* 11 MJ/day; $p<0.05$). The mobilized body tissue of r-bST treated cows was fat (-23.0 MJ/day), but not protein (+2.4 MJ/day), also in a thermoneutral environment.

It is indicated that bST promotes the mobilization of energy from body fat to milk in both types of environment condition. The high productivity by using bST even in hot environment could be achieved with an increasing heat loss, such as providing shade, fan and mist.

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