THE PERFORMANCE OF PREGNANT BEEF COWS RELYING ON SNOW AS A WATER SOURCE

A. A. DEGEN[1] and B. A. YOUNG

Department of Animal Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5. *Received 5 Apr. 1989, accepted 5 Jan. 1990.*

DEGEN, A. A. AND YOUNG, B. A. 1990. The performance of pregnant beef cows relying on snow as a water source. Can. J. Anim. Sci. **70**: 507–515.

Body mass change, water influx, metabolic heat production and rectal temperature were measured in four pregnant beef cows offered only snow as a water source (snow cows) and in four pregnant beef cows that also had access to heated water (water cows). The study was carried out during winter (December to March) in Alberta, Canada. There was no difference between treatment groups in any of these measurements indicating that the snow cows were obtaining adequate water to satisfy their requirements and that no added nutrient energy was required to melt the snow and bring the water to body temperature. Milk yield in the two groups, measured in early spring when water was available to all cows, was similar as was the growth rate of the calves. Milk yield averaged 8.2 kg d^{-1} during weeks 2–4 of lactation and 4.6 kg d^{-1} during weeks 14–16. Average daily gain from birth to weaning (6 mo) of calves suckling the snow cows was 0.74 kg and of calves suckling the water cows was 0.70 kg. It was concluded that there was no detrimental effect of withholding liquid water from pregnant beef cows when snow is available and that cows can use snow as their only water source for lengthy periods of time during winter.

Key words: Pregnant cows, snow, water, water influx, metabolic heat production

[Performance des vaches de boucherie gravides utilisant uniquement de la neige comme source d'eau.]

Titre abrégé: Ingestion de neige par les vaches gravides.

La variation de la masse corporelle, l'apport d'eau, la production métabolique de chaleur et la température rectale ont été mesurés chez quatre vaches de boucherie gravides pour qui la neige constituait la seule source d'eau (vaches désaltérées avec de la neige) et quatre vaches de boucherie gravides ayant également accès à de l'eau tempérée (vaches désaltérées avec de l'eau). L'étude a été réalisée durant l'hiver (de décembre à mars) en Alberta, au Canada. Aucune différence n'a été observée entre les deux groupes pour tous les paramètres étudiés, ce qui indique que la neige a été une source suffisante d'eau et que les animaux n'ont eu besoin d'aucune énergie supplémentaire pour faire fondre la neige et l'amener à la température du corps. Le rendement laitier, mesuré au début du printemps lorsque toutes les vaches avaient accès à de l'eau, a été similaire chez les deux groupes, tout comme le taux de croissance des veaux. Le rendement laitier a été en moyenne de 8,2 kg $jour^{-1}$ durant les semaines 2 à 4 de la lactation et de 4,6 kg $jour^{-1}$ durant les semaines 14 à 16. Le gain moyen quotidien des veaux sous la mère, de la naissance au sevrage (six mois), a été de 0,74 kg pour les veaux nés des mères du premier groupe, contre 0,70 kg pour ceux du deuxième groupe. On peut conclure que la consommation de neige ne produit aucun effet néfaste chez les vaches gravides et que ces dernières peuvent utiliser la neige comme source unique d'eau pendant de longues périodes durant l'hiver.

Mots clés: Vaches gravides, neige, eau, apport d'eau, production métabolique de chaleur

[1]Permanent address (A.A.D.): Isan Centre for Comparative Medicine and Desert Animal Research, Jacob Blaustein Institute for Desert Research, Ben-Gurion University of Negev, Beer Sheva, Israel 84105.

Cattle can adapt quickly to consuming snow when water is denied to them (Young and Degen 1980). They can then rely on snow as the only water source without any detrimental effects, at least for short periods. In fact, some commercial cattle ranchers in Alberta (pers. obs.) and Utah (J. E. Butcher, pers. commun.) use snow as a primary water source during winter.

Lactating ewes can fulfil their water requirements when they are offered only snow as a water source over a lengthy period (Degen and Young 1981). In this study we examined body mass change, metabolic heat production and water influx of cross-bred pregnant cows relying on snow as their only source of water for 3 mo during the Alberta winter. We also measured during the following spring the daily milk production of the cows and the birthweight and growth rate of their calves. The performance of these cows was compared with that of cows that were kept with the test cows but had daily access to liquid water.

MATERIALS AND METHODS

Cows and their Management

Eight cross-bred cows that had previously consumed snow as a water source for short periods (Young and Degen 1980) were used in this study. The cows, aged 4–5 yr, were predominantly of Charolais and Angus breeding and each had successfully raised a calf on pasture during the previous summer. They were bred to a cross-bred bull during July and August and all were pregnant during the study.

The cows were kept on a natural pasture as a group. From the end of November they were brought daily into individual feeding stalls and were offered daily 3.5 kg of brome grass hay (89.2% DM; 121 g protein per kg DM; 9.0 MJ metabolizable energy per kg DM) and 3.5 kg of barley grain (88.3% DM; 11.3 g protein per kg DM; 10.3 MJ metabolizable energy per kg DM). Feed samples were analyzed for DM and protein according to the Association of Official Analytical Chemists (1984) procedures 7.007 and 7.015, respectively. Metabolizable energy values were estimated from NRC (1984). The feeding period was from 08.00 h to 10:00 h and each cow was then given access to water (10°C) for 15 min. Water drunk was measured gravimetrically. With the onset of winter and the availability of permanent snow on the ground (21 Dec.), the cows were divided into two treatment groups matched for body mass and age. Water was withheld from one group of cows (snow cows), whereas the other group continued access to water (water cows) once-a-day as described above; all eight cows had access to a snow-covered field when not in the feeding stalls. There was no feed available to the cows while in the field.

Body Mass, Tritiated Water Space and Water Influx

The cows were weighed every 4th week. Total water influx of the cows was measured over 2-wk periods starting every 4th week. In the afternoon (14:00 h) immediately before the start of the measurement period, the cows were brought into an outdoor, snow-free, covered pen that was open-ended. At 17:00 h, urine samples were collected for determination of background specific radioactivity of tritium. Urination was induced by light manual stimulation ventral to the labia. Each cow was then injected intramuscularly with 2 mCi of tritiated water (New England Nuclear). No feed, water or snow was offered to the cows overnight and the following morning (07:30 h) when a second urine sample was collected to determine tritiated water space. The cows were then weighed and returned to their field. In order to estimate water influx, additional urine samples were collected just before feeding every second morning (07:30 h) thereafter. Dry matter content of all urine samples was determined by drying samples at 68°C for 4 to 5 d. Duplicated 0.2-mL urine samples were added to 10 mL of scintillation cocktail (Aqueous Counting Scintillant, Amersham), and counted for 20 min in a liquid scintillation counter (Nuclear Chicago, Mark IV, Searle Analytic Inc.); counts were corrected for dry matter content of the urine and for quenching.

The preformed water content of the feed was determined by oven drying samples at 70°C for 4 d. Metabolic water produced from the feed was calculated using diet composition and digestibility and from constants for metabolic water production suggested by van Es (1967). Snow intake was estimated as water influx minus the preformed and metabolic water in the feed. Snow intake by the water cows was similarly estimated with the added correction for liquid water intake. This method of estimating snow intake has been shown to be accurate for cattle (Young and Degen 1980).

Osmolality measurements were made on all urine samples by the freezing-point depression method (Osmette A. Precision System, Inc.).

Metabolic Heat Production and Rectal Temperature

Metabolic heat production and rectal temperatures of the cows were measured over 8-d periods, starting 4 d after the water influx measurements. A pair of cows, one snow cow and one water cow, was measured at a time. Measurements were done with the cows outdoors and again with the cows indoors in a temperature-controlled room (0°C). The measurements were made between 07:00 h and 10:00 h after which time the cows were fed, watered, if required by treatment, and returned to the field. During metabolic measurements the heads of the cows were secured in a hood to measure respiratory gaseous exchange continuously using an open-circuit respiratory system (Young et al. 1975). The volume of air drawn through each hood, 300–400 L min^{-1}, was converted to a dry volume at 0°C and 760 mm Hg pressure. Measurements on each cow were taken for 1–2 h after the cows had been contained in the hood for at least 1 h. Just prior to the metabolic measurements, rectal temperatures were taken using a thermistor probe and thermistor-telethermometer (Yellow Springs Instruments).

Milk Yield of Cows

Milk yield of the cows was estimated within 2 wk of calving and at 2-weekly intervals thereafter using the oxytocin injection method (Jeffery et al. 1971). Each cow received an intravenous injection of 20 IU oxytocin at about 08:00 h to induce milk let-down. Milk was collected by placing blunt-tipped sterile needles in all teats; tubing led from the needles to collecting pails. This milk was discarded. The cows were then fed and watered regularly but the calves were not allowed to suckle. The oxytocin injection and milking procedure was then repeated 8 h later and the volume of milk was measured. Milk production was calculated on a daily basis, assuming that milk secretion was constant over 24 h. Duplicate aliquots of this second milk collection were analyzed for percentages of fat, protein and lactose using an infra-red milk analyzer. The energy content of the milk was calculated assuming 38.49 kJ g^{-1} fat, 24.52 kJ g^{-1} protein and 16.53 kJ g^{-1} lactose (Kleiber 1975).

Calf Growth

Calves were weighed at birth and at 2-weekly intervals thereafter. Average daily gain of each calf was calculated. In addition, tritiated water space of the calves was determined to estimate body solids growth. We assumed that body mass minus tritiated water space equalled body solids. The procedure used for measurement of tritiated water space was as outlined for the cows except that plasma samples were used for tritium analysis instead of urine samples.

Analysis of Data

The experimental design consisted of repeated measurements (time; periods) on the cows on two treatments. Analysis of variance was used to test for differences between treatments and among periods. Since time was a factor, randomization was not used which can influence the variances and covariances among the periods (Milliken and Johnson 1984). To correct for this, the degrees of freedom were adjusted for the sources of variation of period and error (period) terms as outlined by Greenhouse and Geisser (1959). We accepted $P < 0.05$ as the minimal level of significance.

RESULTS

Minimum and maximum air temperatures are presented in Table 1. The winter was relatively mild for central Alberta. Snow

Table 1. Minimum and maximum daily air temperatures (°C) during the study. Values are means ± SD

Period	Mean minimum	Mean maximum	Low minimum	High maximum
29 Nov. — 20 Dec.	−16.1 ± 10.6	−5.7 ± 9.4	−34	+7
21 Dec. — 17 Jan.†	−16.4 ± 9.6	−9.5 ± 11.3	−33	+2
18 Jan. — 13 Feb.†	−11.1 ± 6.1	−2.8 ± 8.4	−28	+10
14 Feb. — 12 Mar.†	−12.2 ± 3.8	−3.9 ± 6.6	−20	+9
13 Mar. — 9 Apr.	−6.0 ± 4.5	+4.8 ± 5.3	−19	+12
10 Apr. — 7 May	+5.1 ± 3.6	+19.9 ± 5.9	−1	+29
8 May — 4 June	+6.0 ± 3.8	+19.0 ± 5.0	0	+28
5 June — 2 July	+9.0 ± 2.7	+23.0 ± 4.1	+4	+32
3 July — 30 July	+11.0 ± 2.9	+25.5 ± 4.6	+6	+33
31 July — 27 Aug.	+10.9 ± 3.1	+24.0 ± 2.9	+5	+30
28 Aug. — 24 Sept.	+6.8 ± 2.8	+22.2 ± 4.2	+2	+30
25 Sept. — 15 Oct.	+4.6 ± 3.7	+19.3 ± 4.4	−1	+28

†Complete ground cover of snow.

completely covered the ground from about 21 Dec. to 13 Mar. and a depth of 20–40 cm was usually present.

The cows consumed 67.55 MJ of metabolizable energy (ME) daily. Because of differences in body mass, the daily ME intake for the snow cows ranged from 619.9 to 718.5 kJ $kg^{-0.75}$ and for the water cows from 618.1 to 707.6 kJ $kg^{-0.75}$. The amount of preformed water obtained from the feed was 0.79 L d^{-1} and metabolic water produced was 2.20 L d^{-1} for a total of 2.99 L d^{-1}.

There was no difference in body mass or tritiated water space between the two treatment groups; however, there were differences over time within both groups (Table 2). During the early part of the winter and prior to the withholding of water from the snow treatment, all cows lost body mass. Thereafter all cows increased their body masses until calving. Tritiated water space increased concomitantly with body mass; however, tritiated water space as a fraction of body mass increased at a faster rate. Body mass decreased during lactation in all cows. Two months after the trial ended, 29 Aug., the mean body mass for the snow cows was 408±28.6 kg and for the water cows was 405±41.3 kg.

Total water influx changed over time with the lowest in mid-winter and the highest in spring and summer when the air temperatures were relatively high and the cows were lactating (Table 3). However, there was no difference between treatment groups. Urine osmolalities were measured only in the winter and the values were observed to be directly related to water influxes (Table 3). No difference was found between treatment groups.

There was no difference between treatment groups in metabolic heat production or rectal temperature (Table 4). Metabolic heat production increased in late pregnancy and early lactation. Metabolic heat production averaged 466 kJ $kg^{-0.75}$ daily and rectal temperature averaged 38.2°C.

Milk yield and its composition were the same for the two treatment groups and both showed the same changes over time (Table 5). There was a steady decrease in milk yield, energy per unit milk and total energy produced. Protein showed an initial decrease and then remained constant, while lactose showed an increase and then decreased over time.

The birth weight of the calves from the snow cows averaged 44.0±7.8 kg and of the calves from the water cows averaged 39.3±4.0 kg. There was no difference in body mass gain or body solid gain in the calves from the two cow treatment groups. Average daily gain from birth to weaning of the calves from the snow cows was 0.74±0.16 kg and of the calves from the water cows was 0.70±0.09 kg and daily body solid gains were 0.19±0.04 kg and 0.18±0.03 kg, respectively.

Table 2 Body mass and tritiated water (TOH) space of pregmant and lactating cows ($n = 8$) having access to water (water) or only to snow (snow) as a water source during winter

		Starting period										
	Treatment	29 Nov.	21 Dec.†	18 Jan.	14 Feb.	13 Mar.‡	10 Apr.	8 May	5 June	SEM	*T*§	*P*¶
Body mass (kg)	Snow	488.8	479.0	490.0	489.0	501.0	520.5	428.3	427.5	±1.97	NS	**
	Water	481.3	471.5	490.8	492.0	505.0	522.5	436.3	428.8			
TOH space (kg)	Snow	355.1	347.0	354.3	359.4	374.3	391.4	323.4	322.3	±2.08	NS	**
	Water	355.3	341.9	353.4	366.3	381.3	397.6	329.8	324.6			
TOH space (% body mass)	Snow	72.3	72.2	72.1	73.6	74.7	75.2	75.5	75.4	±1.18	NS	*
	Water	74.4	72.6	72.2	74.6	75.5	76.1	75.6	75.7			

†Water denied to snow group from 21 Dec.
‡Water occasionally available from melting snow after 13 Mar.
§Level of significance between treatment groups.
¶Level of significance among periods.
*, **, $P < 0.05$ and $P < 0.01$, respectively; NS, not significant

Table 3. Water influx, snow and water intakes and urine omolality of pregnant and lactating cows ($n = 8$) having access to water (water) or only snow (snow) as a water source during winter

		Starting period										
	Treatment	29 Nov.	21 Dec †	18 Jan.	14 Feb.	13 Mar.‡	10 Apr.	8 May	5 June	SEM	*T*§	*P*¶
Water influx ($kg\ d^{-1}$)	Snow	26.9	20.8	16.9	22.4	23.3	40.7	47.7	51.2	± 0.65	NS	**
	Water	24.3	23.1	17.0	22.9	21.5	37.1	45.4	47.9			
Water influx ($g\ kg^{-1}\ d^{-1}$)	Snow	55.1	43.6	34.5	45.8	46.5	77.6	111.1	118.5	± 1.63	NS	**
	Water	51.2	49.8	35.2	46.8	42.5	71.3	104.7	113.5			
Water drunk ($kg\ d^{-1}$)	Snow	15.6	NO//	NO	NO	NO	NM††	NM	NM	± 0.27	**	**
	Water	14.7	11.0	7.4	8.1	8.5	NM	NM	NM			
Snow intake ($kg\ d^{-1}$)	Snow	8.3	17.8	13.7	19.4	20.3	-	-	-	± 0.35	**	**
	Water	6.6	9.1	6.7	11.8	10.0	-	-	-			
Snow & water intake ($kg\ d^{-1}$)	Snow	23.9	17.8	13.7	19.4	20.3	37.7	44.7	48.2	± 0.75	NS	**
	Water	21.3	20.1	14.0	19.9	18.5	34.1	42.4	45.0			
Snow & water intake ($g\ kg^{-1}\ d^{-1}$)	Snow	48.9	37.3	28.3	39.6	40.5	71.8	104.0	111.9	± 1.61	NS	**
	Water	44.9	43.4	29.0	40.6	36.6	65.5	97.7	106.4			
Urine osmolality ($mOsm\ kg^{-1}$)	Snow	1062.5	950.3	870.3	995.5	943.0	NM	NM	NM	± 18.65	NS	**
	Water	1003.5	965.3	828.5	904.0	982.0	NM	NM	NM			

†Water denied to snow group from 21 Dec.
‡Water occasionally available from melting snow after 13 Mar.
§Level of significance between treatment groups.
¶Level of significance among periods.
//Not offered.
††Not measured.
$^{**}P < 0.01$, NS = not significant.

DISCUSSION

Pregnant cows were able to rely on snow as their primary water source for 3 mo. Their overall performance, as judged by body mass changes, water influxes and metabolic heat production were similar to cows which had access to water. However, closer examination of the data did reveal a small difference between the groups. During the first 2 wk that water was denied the snow cows, their water influxes decreased by 22.7%, whereas the water cows decreased their water influxes by 4.9% (Table 3). This difference in water influx was also related to differences in body mass changes between the two treatment groups. The snow cows increased their body masses by only 2.2% (11.0 kg) over the first month that liquid water was denied whereas the cows with access to water increased their body masses by 4.1% (19.3 kg). Most of the difference in body mass was due to a difference in absolute tritiated water space. Other ruminants such as sheep (Degen and Young 1980a) and goats (Thomson et. al. 1980) reduced their water intakes when first exposed to cold conditions and this resulted, at least in sheep, in mainly a reduced rumen volume. This may have also occurred in the cows used in the present study.

The differences in water flux and body mass occurred because of an adjustment period to eating snow over the first few days following the denial of water. When novel to consuming snow, penned steers required a day or so to start eating snow (Young and Degen 1980) and free-ranging cows required 3–5 d (Young et al. 1980). The pregnant cows in the present study had consumed snow as a water source one year before the present experiment, yet a short period of adjustment was still required. Thereafter, the water influx was similar to that measured in cows offered water and was adequate to satisfy their needs. This was supported by the observation that the urine osmolalities were similar in the two treatment groups and that once water was

Table 4. The metabolic heat production and rectal temperature of pregnant and lactating cows ($n = 8$) denied water (snow) and cows offered water (water) when measured outdoors (variable ambient temperature) and indoors (ambient temperature 0°C)

		Starting period													
		29 Nov.	21 Dec.†	18 Jan.	14 Feb.	13 Mar.‡	10 Apr.	8 May	5 June	3 July	31 July	SEM	S§	T¶	P‖
Metabolic heat (kJ $kg^{-0.75}$)															
Outdoor	Snow	432.5	455.3	460.6	438.9	500.0	–	517.5	404.2	364.6	392.4	5.67 5.67	NS	NS	*
	Water	446.1	464.0	466.5	420.9	510.4	–	499.5	449.0	417.7	391.4				
Indoor	Snow	475.3	496.8	432.9	491.4	515.3	-	533.6	508.2	401.4	468.0				
	Water	473.1	474.0	444.0	485.7	468.2	-	539.7	528.8	409.2	442.6				
Rectal temperature (°C)															
Outdoor	Snow	38.4	37.8	37.5	37.9	38.0	–	38.3	38.4	38.3	–	0.5 0.54	NS	NS	NS
	Water	38.0	38.2	37.6	38.2	38.2	–	38.3	38.3	38.0	–				
Indoor	Snow	–	38.4	38.2	38.4	38.4	–	38.3	38.7	38.3	-				
	Water	–	38.6	37.8	38.2	38.2	-	38.3	38.8	38.3	–				

†Water denied to snow cows from 1 Dec.
‡Water occasionally available from melting snow after 13 Mar.
§Level of significance between sites (outdoor vs. indoor).
¶Level of significance between treatments.
‖Level of significance among periods.
*$P < 0.05$; NS = not significant.

Table 5. Milk production and its composition from cows ($n = 8$) that received only snow (snow) or cows that had access to water (water) as a water source during the winter

	Treatment	Weeks of lactation						SEM	T†	P‡
		2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	14 - 16			
Milk yield	Snow	8.86	8.03	8.49	8.56	6.53	4.93	±0.09	NS	*
(kg d^{-1})	Water	7.55	7.46	7.07	6.49	5.25	4.30			
Fat	Snow	3.99	4.07	3.93	3.86	3.61	3.57	±0.12	NS	NS
(%)	Water	4.43	3.76	3.50	4 09	3.73	3.20			
Protein	Snow	3.48	3.11	2.88	2.94	2 95	3.13	±0.04	NS	**
(%)	Water	3.77	3.09	3.15	3.19	3.13	3.07			
Lactose	Snow	5.09	5 51	5.32	5.32	5.33	5.08	±0.04	NS	*
(%)	Water	4.96	5.30	5 38	5.30	5.35	5.05			
Dry matter	Snow	13.50	13.58	13.05	13.00	12.65	12.52	±0.13	NS	NS
(%)	Water	13.93	13.05	12.95	13.50	13.10	12.25			
Energy	Snow	3.23	3.24	3.07	3.33	2.99	2.92	±0.06	NS	*
(MJ kg^{-1})	Water	3.40	3.08	2.97	3.23	3.09	2.76			
Total energy	Snow	28.70	26.02	26.18	26.53	18.37	14.38	±1.09	NS	*
(MJ d^{-1})	Water	25.81	22.96	21.09	21.03	16.48	12.30			

†Level of significance between treatment groups.
‡Level of significance among periods.
*,** $P < 0.05$ and $P < 0.01$, respectively; NS, not significant.

made available to the snow cows, they did not drink more water than the water cows. That is they did not compensate for any body water deficit that could have occurred while they were consuming snow. Both groups of cows increased their water influxes when they were lactating and the air temparature rose, as has been previously reported (Degen and Young 1980b). Furthermore, the water cows consumed snow during winter in addition to the water they drank.

Both groups of cows increased their body masses over the pregnancy. Their tritiated water spaces also increased in absolute terms and as a fraction of body mass. We have reported previously on this occurrence in pregnant cows during the winter in which the increase in body mass was due to fetal growth, fetal fluids and fetal membranes and maternal body solids actually decreased (Degen and Young 1980b).

The amount of snow consumed by the snow cows ranged between 14.01 kg and 20.11 kg d^{-1}. For these cows to raise the snow temperature to 0°C, melt it and bring the water to body temperature required 7.22 MJ to 10.36 MJ d^{-1}. These estimates are based on an initial snow temperature of −10°C, specific heat of snow and water of 2.09 and 4.18 kJ kg^{-1}. $°C^{-1}$, respectively, and latent heat of melting snow of 334.7 kJ kg^{-1}. The estimated heat required was equivalent to 10.7–15.3% of the daily metabolizable energy intake of the cows. This increased heat demand should theoretically result in an increased metabolic heat production and/or decreased rectal temperature. If the former were true, there should have been substantial loss of body energy reserves and presumably body mass. Measurements of metabolic heat production, rectal temperature and body mass changes provided no evidence of any difference between the snow and water cows in the present study.

There does not seem to be a common consensus as to whether heat produced by digestion and activity can be substituted for thermoregulatory purposes. On the one hand, Cameron and Luick (1972) suggested that a reduction in snow intake would help conserve body energy reserves as less metabolic heat would be required to melt the snow and raise the water to body temperature. Indeed, these authors reported that reindeer in Alaska reduced their water turnovers and presumably their snow intakes during the winter months.

On the other hand, Butcher (1973) has suggested that the heat produced from the digestion of feed and the heat increment of feeding, at least in sheep, is more than adequate to offset the energy required to melt the snow and raise the water to body temperature. The latter suggestion was supported by the present study and by a study on horses by Dieterich and Holleman (1973), who found no difference in metabolic parameters or energy requirements between horses consuming snow and those consuming water.

The pattern of snow intake is important in determining the thermal stress of the cow. When water was continuously available, cows drank once or twice a day, whereas cows with continuous access to snow consumed small amounts throughout the day, interspersed with a number of feeding bouts (Young et al. 1980). Rapid ingestion of large volumes of snow resulted in decreased rumen and rectal temperatures and increased metabolic heat production (Degen and Young 1984). Consumption of cold water also resulted in decreased rumen temperatures (Bailey et. al. 1962; Sims and Butcher 1966; Brod et al. 1982). When large amounts of snow were ingested by cattle, the decrease in rumen temperature was greater than that caused by cold water (Degen and Young 1984); however, in sheep which ate snow at a slow rate, the drop in rumen temperature was actually less than that measured in sheep drinking cold water (Sims and Butcher 1966).

Milk yield and its composition for the two groups of cows and the growth rate of their calves were similar indicating that there was no carryover effect of withholding water during the winter. The milk yield and calf growth rate were similar to values obtained earlier in the same cows (Degen and Young 1980b) and also similar to cross-bred cows of the same breeding in which the cows had access to water throughout winter (Jeffery et. al. 1971; Butson and Berg 1984).

In conclusion, the present study showed that pregnant beef cows can be denied water for lengthy periods of time when there is adequate snow available. Over the winter months there were no detrimental effects on body mass change, water influx or energy requirements of the cows. In addition there was no difference in their milk production or in the growth rate of their calves when compared to cows that had access to liquid water throughout winter. There, however, may be a short adjustment period when the cows are first denied water until they start consuming snow.

ACKNOWLEDGMENTS

We thank Jack Francis, Ken Plumb and Craig Breakey for technical assistance and Gavin Godby and Robert Hardin for help with statistics. Financial support was provided by the Agriculture Research Council of Alberta and the Natural Sciences and Engineering Research Council of Canada.

Association of Official Analytical Chemists. 1984. Official methods of analysis. 14th ed. AOAC, Inc. Arlington, VA.

Bailey, B. C., Hironaka, R. and Slen, S. B. 1962. Effects of the temperature of the environment and the drinking water on the body temperature and water consumption of sheep. Can. J. Anim. Sci. **42**: 1–8.

Brod, D. L., Bolsen, K. K. and Brent, B. E. 1982. Effect of water temperature, digestion and rumen fermentation in sheep. J. Anim. Sci. **54**: 179–182.

Butcher, J. E., 1973. Snow as the only source of water for sheep. Pages 205–209 *in* H. F. Mayland, ed. Proceedings of Symposium on Water-Animal Relations. University of Idaho Press, Kimberly, Idaho.

Butson, S. and Berg, R. T. 1984. Lactation performance of range beef and dairy-beef cows. Can. J. Anim. Sci. **64**: 253–265.

Cameron, R. D. and Luick, J. R. 1972. Seasonal changes in total body water, extracellular fluid and blood volume in grazing reindeer. Can. J. Zool. **50**: 107–116.

Degen, A. A. and Young, B. A. 1980a. Effect of cold exposure on liveweight and body fluid compartments in sheep. Can. J. Anim. Sci. **60**: 33–41.

Degen, A. A. and Young, B. A. 1980b. Liveweight, total body-water and maternal body-solid changes in pregnant and lactating beef cows. J. Agric. Sci. (Camb.) **95**: 1–5.

Degen, A. A. and Young, B. A., 1981. Response of lactating ewes to snow as a source of water. Can. J. Anim. Sci. **61**: 73–79.

Degen, A. A. and Young, B. A. 1984. Effects of ingestion of warm, cold and frozen water on heat balance in cattle. Can. J. Anim. Sci. **64**: 73–80.

Dieterich, R. A. and Holleman, D. F. 1973. Hematology, biochemistry and physiology of environmentally stressed horses. Can. J. Zool. **51**. 867–873.

Greenhouse, S. W. and Geisser, S. 1959. On methods in the analysis of profile data. Psychometrika **24**: 95–112.

Jeffery, H. B., Berg, R. T. and Hardin, R. T. 1971. Factors influencing milk yield of beef cattle. Can. J. Anim. Sci. **51**: 551–560.

Kleiber, M., 1975. The fire of life. R. E. Krieger Publishing Co., Huntington, N.Y.

Milliken, G. A. and Johnson, D. E. 1984. Analysis of messy data. Volume 1: Designed experiments. Lifetime Learning Publications, Belmont, Calif.

National Research Council. 1984. Nutrient requirements of beef cattle. 6th Revised ed., National Academy of Science, Washington, D. C.

Sims, P. L. and Butcher, J. E. 1966. Water source effects on rumen temperature. J. Anim. Sci. **26**: 590 (Abstr.).

Thomson, E. M., Forshing, M. L. and Thompson, D. W. 1980. The effect of cold exposure on fluid balance, circulating arginine vasopressin concentration and milk secretion in the goat. Pflugers Arch. **383**: 241–244.

van Es, A. J. H. 1967. Constants and factors regarding metabolic water. Pages 513–517 *in* K. L. Blaxter, J. Kielanowski, and G. Thorbeck, eds. Energy metabolism of farm animals. Oriel Press, Newcastle-Upon-Tyne, U.K.

Young, B. A. and Degen, A. A. 1980. Ingestion of snow by cattle. J. Anim. Sci. **51**: 811–815.

Young, B. A., Kerrigan, B. and Christopherson, R. J. 1975. A versatile respiratory pattern analyzer for studies of energy metabolism of livestock. Can. J. Anim. Sci. **55**: 17–22.

Young, B. A., Tennessen, T. and Degen, A. A. 1980. Liveweight and behavioural responses in cattle ingesting snow as their water source. 59th Annual Feeders' Day Report. Pages 60–61, Department of Animal Science, University of Alberta, Edmonton, Alta.