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Lying behaviour and individual water intake of suckler cows during out-wintering in Canada

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Traditionally during Canadian winter, suckler cows are kept outside in a specific pen with windbreakers. It has no access to a shelter or building. The objective of this study was to measure the impact of climate conditions on lying behaviour and water intake of suckler cows. Throughout two wintering periods, individual water intake and lying behaviour of two groups of suckler cows were analysed according to partly extreme temperatures down to –40 °C. The results of the two indicators illustrated that suckler cows showed climate induced behavioural changes, whereas water intake was not influenced by increasing cold.

Keywords
Cow-calf operation, suckler cows, out-wintering pens, lying behaviour, water intake

Out-wintering of suckler cows is a traditional way of housing beef cattle in Canada during the winter period. Within the framework of a joined project of the Research and Development Institute for the Agri-environment (IRDA), the Thuenen-Institute of Organic Farming and other contributing partners, environmental as well as welfare aspects of out-wintering of suckler cows were studied. Individual water intake and lying behaviour of suckler cows were recorded using ALT-Pedometer during two winter periods. Simultaneously, climate conditions were measured on-site. The main goal of the study was to identify behavioural changes and response to water intake to evaluate adaptability of suckler cows in extreme climate situations.

State of knowledge

Thermal adaptation

Cattle, as well as other mammals, are homeotherm. Their normal body core temperature is 38.3 °C (Bianca 1968). Bovines try to keep body core temperature constant due to thermal strain through behavioural and physiological adaptation (Bianca 1977). The adaptation is called thermoregulation. In the case of thermal strain, homeothermic animals will try at first to adapt their behaviour and physiological adaption will follow later. Figure 1 illustrates critical ambient temperatures and different zones of thermal comfort of homeothermic animals (Bianca 1968). In principle, threshold values of critical ambient temperatures of behavioural and physiological adaptation will vary due to the age of the animal (Bianca 1977). Ambient temperatures in the thermal comfort zone (A to A') are perceived by bovines neither cold nor hot (Pollmann et al. 2005). According to Bianca (1976), the thermal comfort zone for calves is between 13 and 25 °C, whereas adult cattle feel thermally comfortable within a range of 0 to 16 °C. Within the thermal neutral zone, energy consumption for the maintenance

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of core temperature is the lowest (Pollmann et al. 2005). Between the outlines of thermal comfort zone up to the thermal neutral zone (lower critical temperature (LCT) and upper critical temperature (UCT)), cattle try to protect themselves against cold and heat. In case of cold, they start developing a thicker hair coat or they look for wind protected areas. In hot climates, cattle increase their evaporation in order to maintain body core temperature (Pollmann et al. 2005; Tarr 2007). Cattle being in an environment with ambient temperature outside the thermal neutral zone spend more energy on heat production or dissipation to maintain their body core temperature (NRC 2000). From Figure 1, it can be also concluded that cattle and homeothermic animals in general are more tolerant against cold compared to heat (LCT–B versus UCT–B’) (Bianca 1976). Between the limits B and B’, cattle will be able to keep their body core temperature more or less constant. With ambient temperatures below B or higher than B’, animals are in a hypothermic or hyperthermic phase. These phases can be seen as extremely dangerous for the life of cattle.

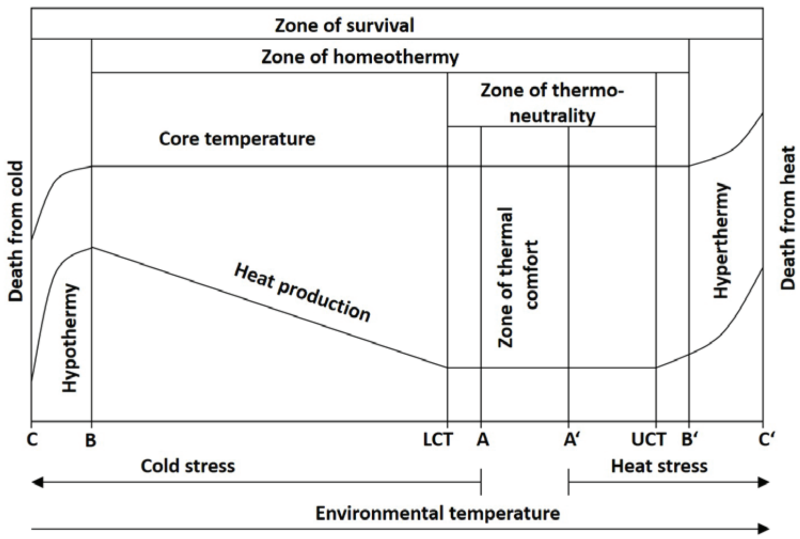

Figure 1: Critical temperatures and zones (Bianca 1968)

Lower critical temperature (LCT)

At ambient temperatures below LCT, metabolic energy produced by the animal from tissue and fermentation is no longer sufficient to maintain body core temperature constant (NRC 2000). This results in a higher metabolic production and thus, a higher energy demand of the animal. Every degree Celsius below LCT increases the energy demand of cattle by approximately 2 % (Tarr 2007). Solar radiation will increase perceived ambient temperature of the animal by 3–5 °C (NRC 1981). According to data of the NRC (1981), LCT for suckler cows with a body weight of 500 kg in medium stage of pregnancy and a dry hair coat is -25 °C on days of low wind speed and without precipitation. Provided that the snow is wet and wind speed is above 16.1 km/h, LCT will increase to –7 °C. As shown by Bianca (1975), LCT of cattle under out-wintering conditions could be –30 °C. LCT of beef cattle can be seen in Table 1, considering type and condition of hair coat with wind chill temperature. LCT for habituated beef cattle with thick hair coat is –8 °C. In contrast, LCT for beef cattle with summer hair coat or wet hair coat will be 15 °C (Tarr 2007).

Table 1: Lower critical temperatures for beef cattle, assuming no wind chill (Tarr 2007)

Coat description	Lower citical temperature (LCT) [°C]
Summer coat or wet coat	15
Fall coat	7
Winter coat	0
Heavy winter coat	-8

Lying behaviour of cattle under different climate situations

Graunke et al. (2010) recorded lying behaviour of more than 4 years old beef cattle on two Swedish farms (A and C) during out-wintering period using pedometers (IceTag3D, IceRobotics, UK). The mean ambient temperature was between –5.3 and 6.5 °C. The sampling interval of pedometers as well as behaviour recording interval was 15 minutes. When analysing behaviour and climate, a significant difference in lying behaviour could be seen on both farms. The lower temperature and precipitation were and the higher humidity was, the higher lying time values were recorded. On farm C, lying time was significantly longer when the wind speed was higher. When analysing climate and behaviour versus daily mean values of climate data, Graunke et al. (2010) could not find significant relations between climate and lying behaviour. With ambient temperatures below 0 °C, an effect of wind speed on lying behaviour could be seen. Mean lying time per animal per day on farm C was 10 h, which was significantly higher than lying time of 9.2 h on farm A. Graunke et al. (2010) concluded that a higher wind speed on farm C might be the reason for longer lying time. Another reason could be the size of the out-wintering area. Cattle were less often searching wind protected areas and thus, tried to protect themselves by a longer lying time. In a study of Mülleder et al. (2003), daily mean lying time of suckler cows housed in a cubicle loose housing system was 10.6 h. Tucker et al. (2007) investigated the effect of body condition and housing system on dry and non gestating dairy cows during winter time. 20 cows, divided in two groups of 10 animals each, were alternately housed one week in a pen without roof and wind protection and one week within the building. Both housing systems had free stalls bedded with sawdust. The outdoor housing had an irrigation system and ventilation to manipulate climate conditions. Average temperature was 4.9 °C for outdoor housing and 5.6 °C for indoor housing. Lowest wind chill-temperature for outdoor housing was –9.9 °C and for indoor housing –3.1 °C. Within outdoor housing period, cows were lying 4 h on average per day. In contrast, cows housed indoor were lying 12 h per day. When comparing standing and lying behaviour of cows having low or high body condition score, it could be demonstrated that cows with a high body condition score showed less standing time per day and had longer lying time per day. The authors concluded that wet bedding in the outdoor housing might be the reason for thermal losses. Even standing on a wet surface could increase thermal losses.

Water intake

Bahr (2007) measured water intake of suckler cows 14 days prior to calving at a precision of 0.5 l. Cows were housed in a moderate climate with free access to pasture and to a building. The water trough was placed in the building with an animal per trough ratio of 15:1. The mean water intake two weeks up to two days before calving was 18.4 to 26.4 l per cow and day. Cows visited the water trough 3 to 5 times a day on day 14 before calving. Water intake of cows with winter calving was significantly higher than that of cows with spring or summer calving. The author concluded that the water content of the roughage might be responsible for it. Hay and silage was fed during winter time and in spring and summer cows were grazing fresh grass. Thus, water intake of grazing cows was higher compared to water intake when feeding silage or hay.

Brew et al. (2011) studied water intake of 146 beef cattle from 7 to 9 months while housed in a naturally ventilated barn. Mean ambient temperature for the beef cattle was 15 °C. The water intake was about 30 l day^{-1} and life weight varied between 200 and 400 kg. Water intake was significantly and positively correlated with feed intake, but was not influenced by ambient temperature. In another research study of pregnant suckler cows housed extensively in moderate climate, Terörde (1997) found that water intake of cows was between 34 and 40 l per animal per day. Terörde (1997) assumed a demand for water of 4 l per kg of dry matter. Arias and Mader (2011) could demonstrate that mean and lowest ambient temperature as well as the temperature humidity index (THI) had an impact on water intake of beef cattle housed in a feedlot during finishing period. During summer temperatures, finishing beef cattle drank 32.4 l per animal per day, whereas in winter, average water intake was 17.3 l per animal per day. Ambient temperatures were –2 °C in winter and 21.4 °C in summer. Hoffman and Self (1972) concluded from the results of their study of beef cattle in feedlots that water intake of one year old beef cattle is depending significantly on seasonal temperatures. During winter, daily water intake of cattle was 19.0 l per day, while water intake in summer was 31.2l per day. According to NRC (2000), water intake will decrease with increasing cold until 4.4 °C and will remain constant for lower temperatures

Animals, Materials and Methods

In our study, two groups of 10 suckler cows each (Simmental × Angus) were housed on almost identical adjacent wintering pens for two wintering periods (end of January until April 2013 and mid December 2013 until March 2014). During the first wintering period (VD1) all cows were pregnant except one cow of group 2. On March 13th 2013 one cow of group 1 was excluded from the experiment following a luxation of the hip. Both cows were excluded from data analysis. In the second wintering period (VD2), 11 pregnant suckler cows of VD1 and 9 pregnant heifers (Hereford x Simmental × Angus) were selected for the study. Animals were randomly assigned to two groups with respect to age and body weight. Group 1 consisted of 5 cows and 5 heifers; group 2 was composed of 6 cows and 4 heifers. Both groups shared a covered and paved feeding area with water trough, divided by a wooden fence and steel feed bunk (figure 2). Within the exercise and lying area of both pens, 2.8 m high wind breaking elements made out of wooden spaced boards were provided. The wind protecting element of group 1 was 19.2 m away from the feeding area and covered 54.2 m² of protected area. The pen of group 2 had a wind breaking element at a distance of 14.1 m from the feeding area and a protected area of 44.2 m². Group 1 had an additional natural wind protection by a hedge of 5 m height. Total space per cow was 50 m². Both groups were fed hay ad libitum without adding concentrates. The covered feeding area was equipped with two video cameras (Panasonic WV BP-102) to identify suckler cows individually at the waterers and associate each cow to recorded water flow data. As a durable identification tag cows were dyed individual numbers in the hair coat. Each group had a double heated constant level water trough. Recording of water intake per cow was realised by two electronic flow meters with a resolution of 0.025 l per pulse (OMEGA engineering, Inc., Stamford, CT, USA, Model FTB-4605), which were calibrated three times per experimental period. ALT-pedometers were attached to the left front leg of every cow. The sampling interval was set to 5 minutes. An antenna for the automatic wireless reading of pedometers was fixed on a pole in 15 m distance to the experimental site.

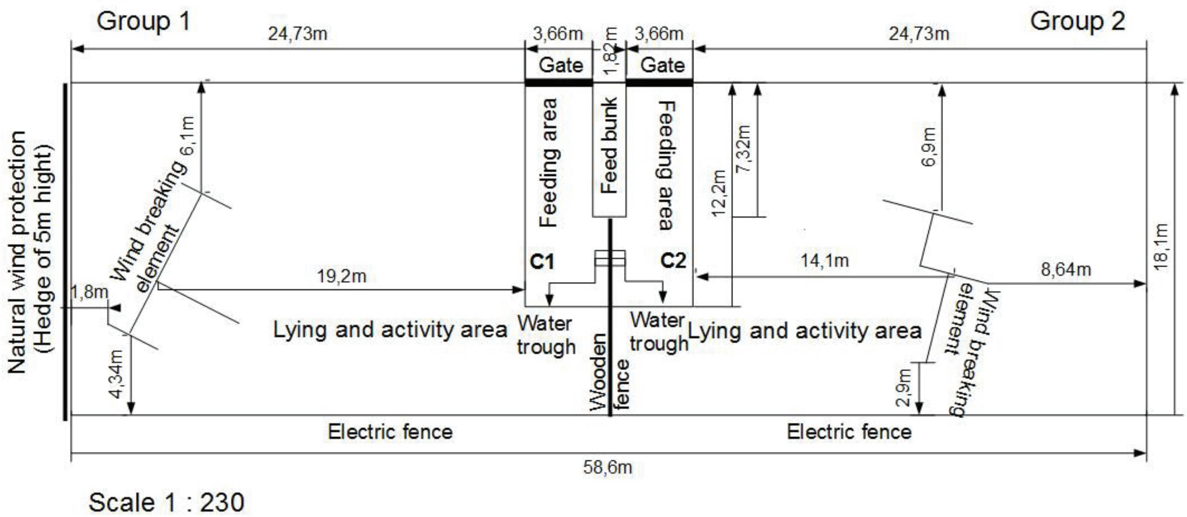

Figure 2: Layout of the experimental set-up

A meteorological station (Reinhardt, MWS9) was set up in 38 m distance to the wintering pens in 3 m height on the roof top of the sampling cabin. All data (video, pedometer, water intake and climate) were recorded by two computers in the sampling cabin. Data recording was time-synchronised using an internet time server. Climate data collected by the meteorological station (solar radiation, temperature, relative humidity and wind speed) were used to calculate the comprehensive climate index (CCI) according to Mader et al. (2010). CCI-Values were aggregated to daily means from hourly means and classified into 6 cold stress thresholds according to Mader et al. (2010) (Table 2). Thus, comparability of climate effects with other studies is given.

Table 2: Arbitrary comprehensive climate index thermal stress thresholds (Mader et al. 2010)

CCI temperature [°C]	Cold stress	CCI cold stress thresholds
> 0	No stress	1
0 to-10	Mild	2
< -10 to -20	Moderate	3
< -20 to -30	Severe	4
< -30 to -40	Extreme	5
< -40	Extreme danger	6

Electronically recorded water intake data were assigned to individual cows in VD1 using videos of 8 (24-hour) days and 14 (24-hour) days in VD2. Analysed days were between 16th of March 2013 and 7th of April 2013 (VD1) and between 19th of December 2013 and 3rd of March 2014 in VD2. Criteria for suitable days to be analysed were an undisturbed daily routine and complete data sets of video and water flow records. In addition, we tried to distribute analysed days evenly within the experimental periods. Table 3 illustrates distribution of analysed days versus CCI cold stress thresholds. Both groups were observed simultaneously, thus one analysed day comprised 19 (VD1) or 20 (VD2) daily mean values. All data of VD1 and VD2 were analysed separately.

Table 3: Number of evaluated days for water intake according to CCI cold stress thresholds, experimental periods and group assignment

Experimental period	Group	CCI cold stress thresholds					Number of analysed days
		1	2	3	4	5	
1	1	1	2	4			7
	2	1	4	3			8
Total VD1		2	6	7			15
2	1		1	6	7		14
	2		1	6	7		14
Total VD2			2	12	14		28

Automatically registered lying behaviour records by ALT-pedometers were stored in a relational database (Access, Microsoft). Raw data from Access-databases were transformed to calculate number of lying periods, total lying time and duration of lying periods using SAS 9.3. In VD1, pedometer data of 1.5 months (1st of March 2013 to 15th of March 2013) were analysed, whereas 3 weeks were used for analysis in VD2 (Table 4). In VD1, 5 days were excluded from the analysis because of the sampling in the pens, and analogue to that, 3 days of VD2 were excluded.

Table 4: Number of evaluated days with lying behaviour according to CCI cold stress thresholds and experimental periods

Experimental period	CCI cold stress thresholds					Number of analysed days
	1	2	3	4	5	
1	9	23	9			41
2		5	7	7	3	22
Total	9	28	16	7	3	63

Distribution of both water flow data and pedometer data was tested regarding normality using procedure univariate (SAS 9.3) and graphically by QQ-plots. Data for a sample size lower than 2000 were tested using Shapiro-Wilks-Test regarding normality. The distribution of the response variable used with procedure Glimmix (SAS 9.3) was adjusted according to the test results. For the response variable “number of lying periods”, Poisson distribution was used as discrete distribution in the model statement. All other behavioural data were analysed using lognormal distribution in the model statement. All values for significance of general effects mentioned in results consider Type-III fixed effects of procedure Glimmix. P-Values of differences between single factor levels of fixed effects were taken from adjusted differences of least-squares means based on Tukey-Kramer test of procedure Glimmix, if fixed effects were significant.

For further analysis of water intake data, all data were related to corresponding climate data. As response variables sum of daily water intake per cow was used, depending on CCI cold stress thresholds, group assignment, heifer/cow as well as interaction between heifer/cow and CCI. Both experimental periods (VD1 and VD2) were analysed separately. Water intake as a response variable was distributed according to normality. Thus, normality (Gauss) distribution was chosen in the model statement together with the link function identity. Least-squares means were calculated for CCI, group (only VD1), heifer/cow as well as interaction between heifer/cow and CCI. The random statement considered repeated measures for individual cows using animal id as subject. Analysis of frequency of drinking bouts per day per cow was done as described already using procedure Glimmix, the only difference was that Poisson distribution was used.

Analysis of pedometer data was performed analogue to water intake data by assigning classified climate data (CCI) in a first step. Total lying time per cow and 24 h, frequency of lying bouts per cow and 24 h as well as mean duration of lying periods were used as response variables for procedure Glimmix. Fixed effects were CCI, group, and in addition for VD2, heifer/cow as well as the interaction between heifer/cow and CCI. All analysis were done separately for VD1 and VD2. Repeated measures were considered by using animal id as subject in the random statement.

Results

Table 5 is a summary of all statistical results regarding water intake and lying behaviour and corresponding data distribution, fixed effects and p-values. Provided that there was a significant fixed effect on one of the response variables, p-values for differences of least-squares means for factor levels were given as well in table 6. P-values mentioned in Table 6 indicate significant differences according to Tukey-Kramer test of procedure Glimmix between single factor levels.

Table 5: Summary for response variables depending on fixed effects (type III) of Glimmix models of VD1 and VD2 regarding significance (n. s. = not significant)

Response variable	**Distribution**	**Fixed effects**	**Factor level**	**Model VD1**	**Model VD2**
Water intake in liter per animal per day	Gauss	CCI	3	n.s. 0.22	n.s. 0.54
		Group assignment	2	n.s. 0.37	n.s. 0.44
		Heifer/Cow	2		$p < 0.0001$
		CCI × Heifer/Cow	3 × 2		n.s. 0.11
Number of drinking bouts per animal per day	Poisson	CCI	3	n.s. 0.33	n.s. 0.29
		Group assignment	2	n.s. 0.16	n.s. 0.23
		Heifer/Cow	2		n.s. 0.08
		CCI × Heifer/Cow	3 × 2		n.s. 0.49
Lying time per animal per day	Lognormal	CCI	3	$p < 0.0001$	
			4		$p < 0.0001$
		Group assignment	2	$p = 0.0457$	n.s. 0.9946
		Heifer/Cow	2		$p < 0.0001$
		CCI × Heifer/Cow	4 × 2		n.s. 0.3198
Number of lying periods per animal per day	Poisson	CCI	3	$p < 0.0001$	
			4		$p = 0.0022$
		Group assignment	2	$p < 0.0001$	n.s. 0.1077
		Heifer/Cow	2		$p < 0.0001$
		CCI × Heifer/Cow	4 × 2		n.s. 0.4101
Duration of lying periods per animal per day	Lognormal	CCI	3	n.s. 0.8223	
			4		$p = 0.0199$
		Group assignment	2	$p < 0.0001$	n.s. 0.2692
		Heifer/Cow	2		n.s. 0.1726
		CCI × Heifer/Cow	4 × 2		n.s. 0.6958

Table 6: Results of p-values according to the Tukey-Kramer test of procedure Glimmix for differences of least square means of fixed effects (n.s. = not significant).

Response variable	Factor	Differences of least squares means		Model VD1 Tukey-Kramer	Model VD2 Tukey-Kramer
		Factor level	Factor level		
Water intake in liter per animal per day	Heifer/Cow	Heifer	Cow		p < 0.0001
Lying time per animal per day	CCI	1	2	p = 0.0253	
		1	3	p < 0.0001	
		2	3	p < 0.0001	p < 0.0001
		2	4		p < 0.0001
		2	5		p < 0.0001
		3	4		p = 0.0008
		3	5		p = 0.0261
		4	5		n.s. 0.9991
	Group assignment	Group 1	Group 2	p = 0.0457	
	Heifer/Cow	Heifer	Cow		p < 0.0001
Number of lying periods per animal per day	CCI	1	2	p = 0.023	
		1	3	p < 0.0001	
		2	3	p < 0.0001	n.s. 0.2886
		2	4		p = 0.0031
		2	5		p = 0.0223
		3	4		n.s. 0.2116
		3	5		n.s. 0.3783
		4	5		n.s. 0.9993
	Group assignment	Group 1	Group 2	p < 0.0001	
	Heifer/Cow	Heifer	Cow		p < 0.0001
Duration of lying periods per animal per day	CCI	2	3		n.s. 0.1698
		2	4		p = 0.0175
		2	5		n.s. 0.0716
		3	4		n.s. 0.7248
		3	5		n.s. 0.8287
		4	5		n.s. 0.9999
	Group assignment	Group 1	Group 2	p < 0.0001	

Water intake

Mean daily water intake per cow per day in VD1 was 46.6 l for group 1 and 37.1 l for group 2 (Figure 3). There was no significant effect of CCI cold stress thresholds and group assignment on water intake in VD1 (p = 0.22 and p = 0.37).

Water intake of cows in VD2 remained almost at the same level as water intake of group 2 in VD1. Group 1 drank 38.2 l per cow per day, as group 2 water consumption was 39.1 l per cow per day. Heifers of both groups consumed on average 24.6 l per cow per day. Regarding fixed effects (Type III) of model statement in VD2, distinction heifer/cow was highly significant for water intake (p < 0.0001). CCI cold stress thresholds and group assignment did not show any significant effect on water intake (p = 0.54 and p = 0.44). In contrast to the model statement of VD1, interaction between heifer/cow × CCI-cold-impact level was added in VD2, but did not show any effect (p = 0.1 l).

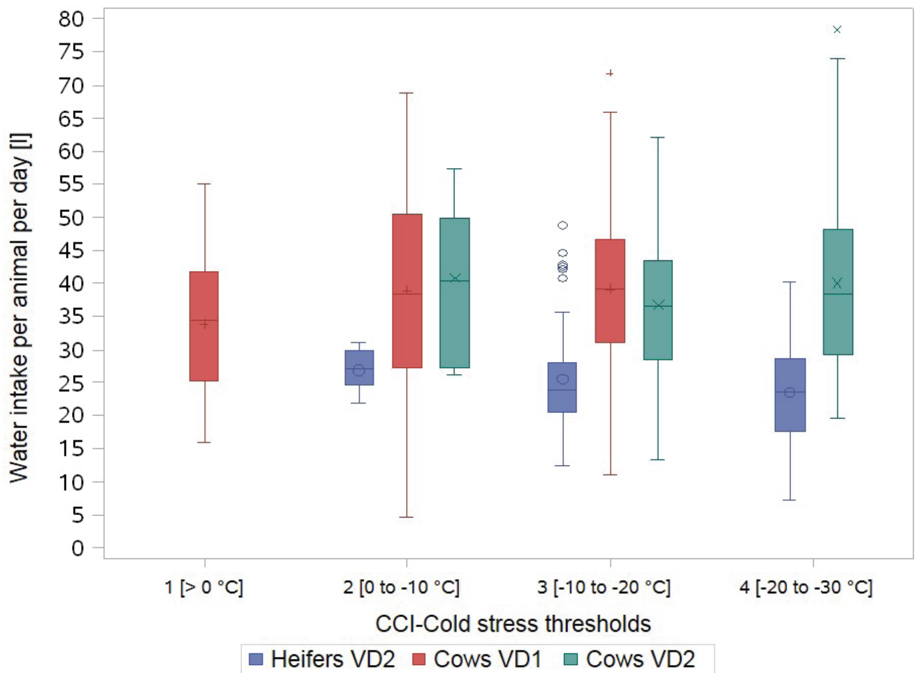

Figure 3: Water intake of cows during VD1 as well as cows and heifers in VD2

Number of drinking bouts

Number of drinking bouts were calculated as mean of single drinking events with water intake per animal per day. Mean values and standard deviations are presented in Table 7.

There was no significant effect of CCI cold stress thresholds and group assignment on the number of drinking bouts in VD1 (Table 5). In contrast, a fixed but not significant effect of distinction heifer/cow could be observed in VD2 (p = 0.08). Interaction between heifer/cow × CCI cold stress thresholds had no significant effect on number of drinking bouts as well as group assignment and CCI cold stress thresholds.

Table 7: Mean values of the number of drinking bouts with water intake per animal per day according to CCI cold stress thresholds in VD1 and VD2

Experimental period	Group	Heifer/Cow	CCI cold stress thresholds	Number of analysed animals	Mean number of drinking bouts per animal per day	Standard deviation
1	1	Cow	1	9	3.7	1.3
			2	18	4.3	1.4
			3	36	4.7	2.0
	2	Cow	1	10	3.6	1.7
			2	40	3.7	1.4
			3	30	3.7	1.5
2	1	Heifer	2	5	4.8	1.5
			3	30	5.5	1.7
			4	35	4.8	1.9
		Cow	2	5	4.8	2.4
			3	30	3.5	1.5
			4	35	3.5	1.3
	2	Heifer	2	4	4.8	0.5
			3	24	3.9	1.1
			4	28	3.8	1.4
		Cow	2	6	4.5	0.8
			3	36	3.7	0.9
			4	40	4.0	1.3

Lying time

The effect of CCI cold stress thresholds as fixed effect on lying time of cows in VD1 was highly significant, whereas group assignment did not show a significant effect (Table 5). Both groups of cows reduced lying time per day from CCI cold stress thresholds 1 and 2 to level 3 significantly (Table 6). Figure 4 shows that cows of group 1 and 2 rested 9 h 41 min and 10 h 31 min, respectively. Within CCI cold stress threshold 2, cows of both groups had a mean lying time of 9 h 14 min and 9 h 43 min, respectively. In the coldest period of VD1 at CCI cold stress threshold 3, a mean lying time of 8 h could be found for both groups (Figure 4).

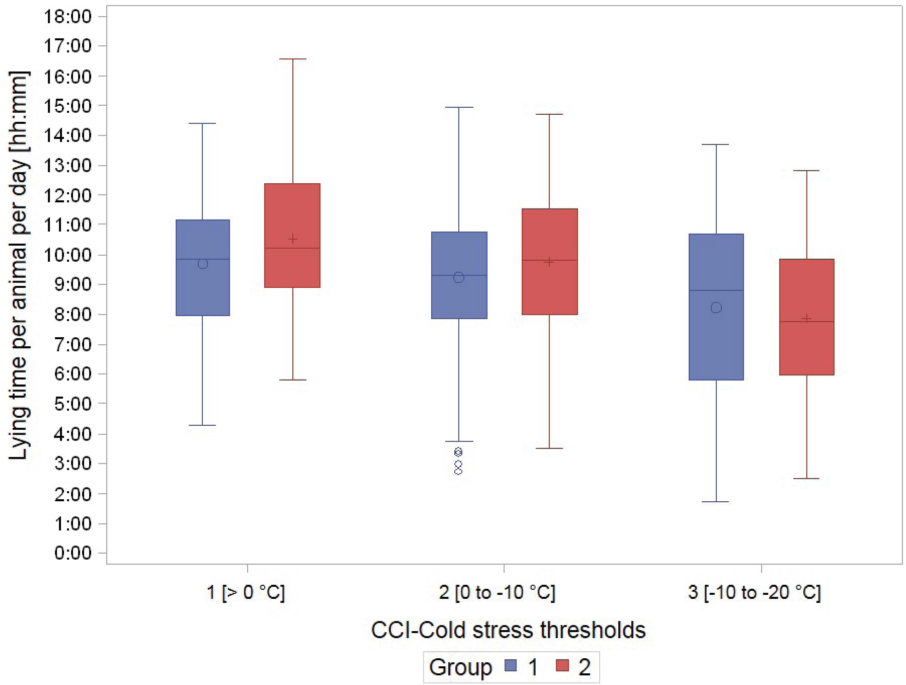

Figure 4: Mean lying time per animal per day according to CCI cold stress thresholds in VD1 and group assignment

In VD2, fixed effects CCI cold climate impact and distinction heifer/cow were highly significant regarding lying time (Table 5), except CCI cold stress thresholds 4 and 5 with no significant difference between them. Between all other CCI cold stress thresholds, a significant difference could be verified (Table 6). Lying time of heifers was significantly different compared to cows. Boxplots in Figure 5 demonstrate that average lying time of both groups in VD2 was 10 h 54 min and 10 h 50 min, respectively. Lying time of both groups declined to 8 h at CCI cold stress threshold 4 (Figure 5). Between CCI cold stress thresholds 4 and 5, lying time of group 1 decreased to 6 h 36 min, whereas lying time of group 2 increased to 8 h 42 min. The trend of lying time for heifers in VD2 was almost parallel to that of cows, but on a lower level. Lying of heifer in group 1 and 2 was 9 h 15 min and 8 h 55 min, respectively. Lying time declined between CCI cold stress thresholds 3 and 4 notably. Within CCI cold stress thresholds 4, lying time of heifer group 1 was 5 h 40 min compared to 5 h 14 min for heifer group 2. Between CCI cold stress thresholds 4 and 5, lying time remained constant on a low level of 5 h 15 min.

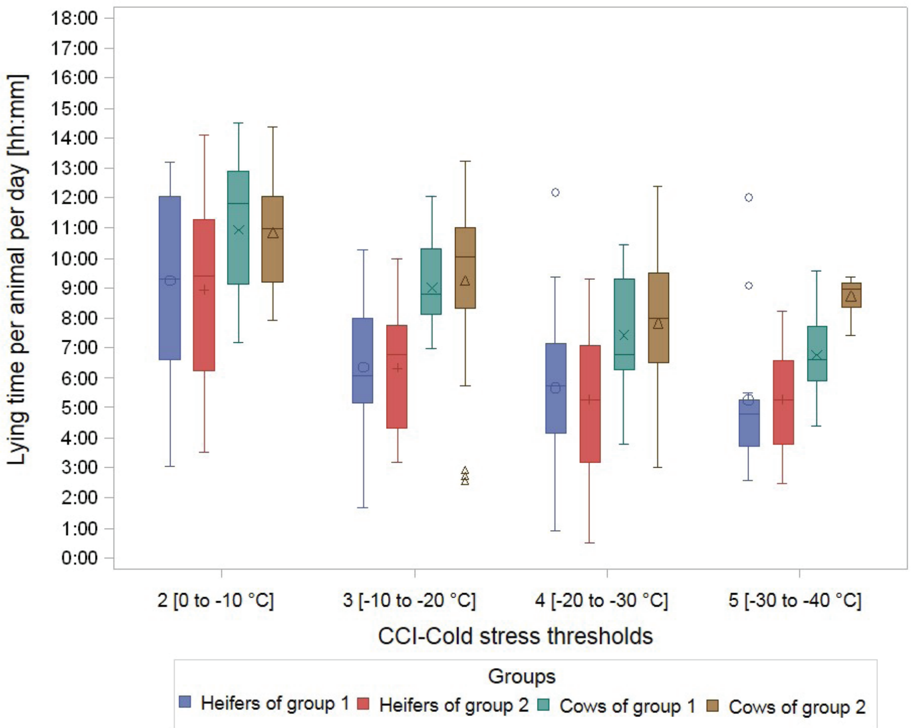

Figure 5: Mean lying time per animal per day within CCI cold stress thresholds of VD2 related to animal groups and distinction heifer/cow

Number of lying bouts

Figure 6 illustrates the number of lying bouts per animal per day as boxplots for VD1. There was a highly significant effect of CCI cold stress thresholds as well as group assignment on the number of lying bouts (Table 5). Differences of least-squares means between CCI cold stress thresholds 1 and 2 were significant, differences between level 1 and 3 as well as 2 and 3 were highly significant (Table 6). Within CCI cold stress threshold 1, cows of group 1 spread their lying time in about 11.6 lying bouts. Cows of group 2 had 10.4 lying bouts at the same CCI cold stress level. Down to CCI cold stress threshold 3, number of lying bouts declined from 9.5 to 8.1 for cows of group 1 and 2, respectively.

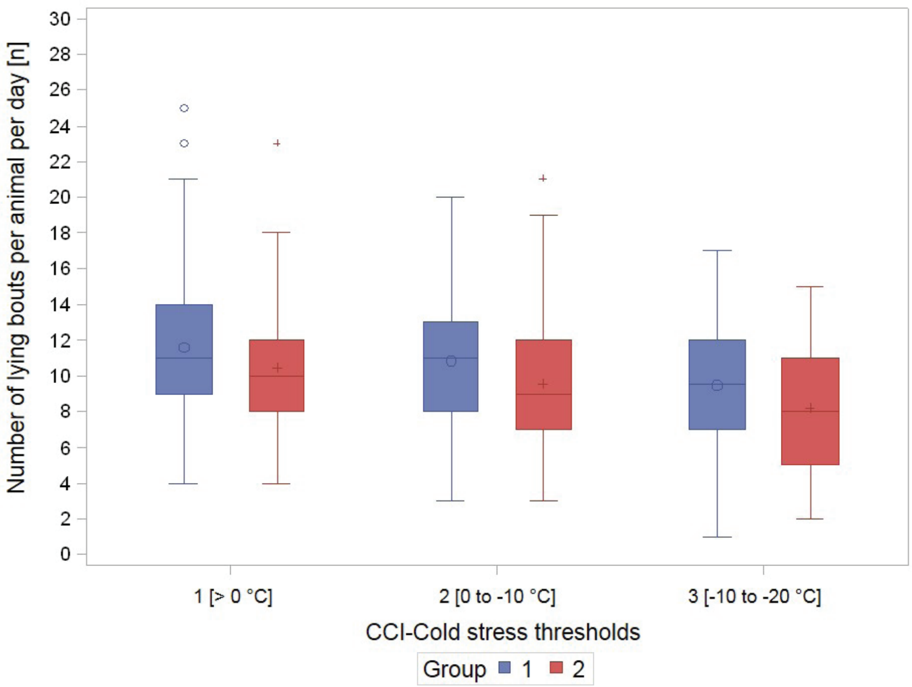

Figure 6: Number of lying bouts per animal per day according to group assignment in VD1

Figure 7 shows the number of lying bouts per animal per day of cows and heifers from VD2 versus CCI cold stress thresholds 2 to 5. The number of lying bouts in VD2 was significantly affected by CCI cold stress thresholds. Distinction heifer/cow showed a highly significant effect on the number of lying bouts (table 5), whereas group assignment and interaction between heifer/cow × CCI cold stress thresholds did not have any fixed (Type III) effect. However, it can be concluded from the graph that cows behave under extreme cold climate (CCI cold stress threshold 5) in the same way as heifers: they lie down less often. Taken as a whole, heifers had fewer lying bouts compared to cows.

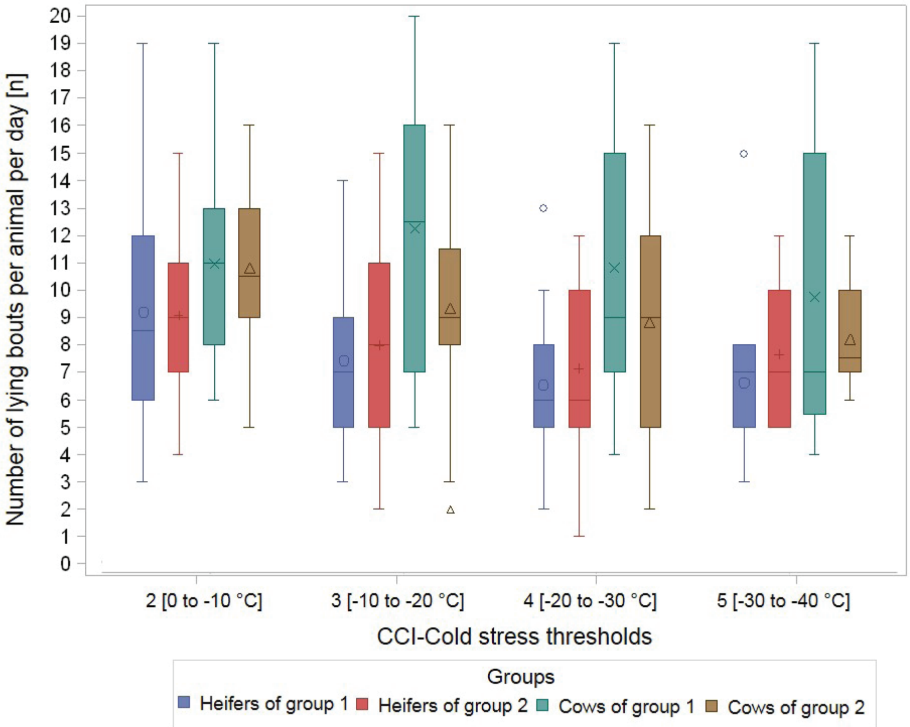

Figure 7: Number of lying bouts per animal per day in VD2 arranged by group assignment and distinction heifer/cow

Referred to differences of least-squares means between CCI cold stress thresholds, number of lying bouts for both heifers and cows decreased from CCI cold stress thresholds 2 to 3, 3 to 4, 3 to 5 and 4 to 5, but not significantly. However, differences between CCI cold stress thresholds 2 and 4 as well as 2 and 5 were significantly different (Table 6).

Duration of lying periods

CCI cold stress thresholds as fixed effect in VD1 were not significant (p = 0.822, Table 5) regarding the duration of lying periods per animal per day, whereas distinction between groups was highly significant (p < 0.0001, Table 5). As illustrated in Figure 8, mean duration of lying periods per animal per day within CCI cold stress thresholds 1 to 3 was almost one hour in group 1 and 1 h 7 min in group 2.

Boxplots (Figure 9) showing the mean duration of lying periods per animal per day for heifers and

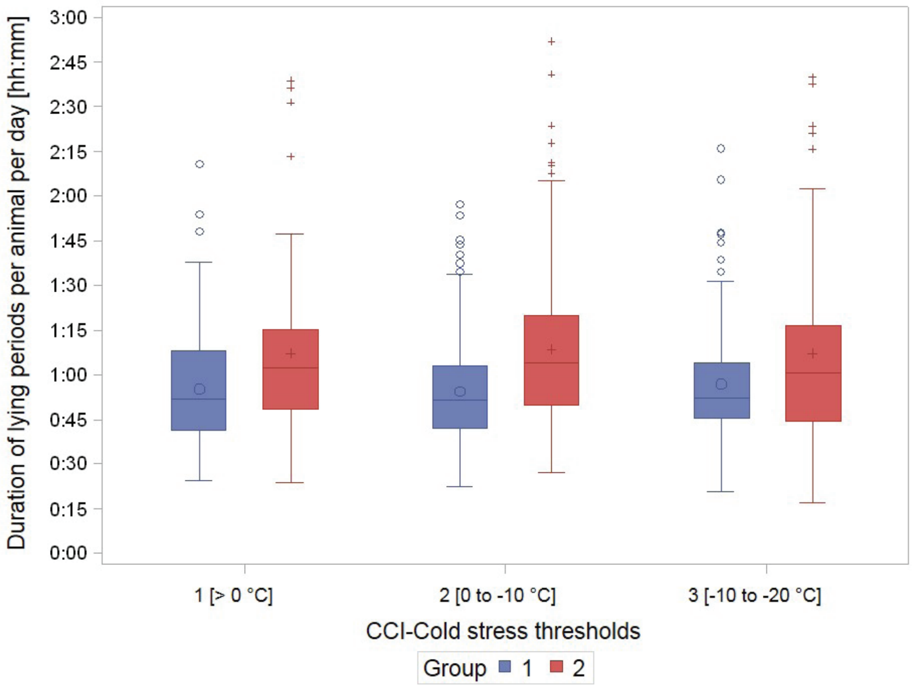

Figure 8: Duration of lying periods per animal per day and group assignment in VD1

cows in VD2 confirmed that the duration of lying periods for all CCI cold stress thresholds ranged from 45 min to 1 h 9 min. Heifers tend to have shorter lying periods with increasing cold. Cows of group 1 reduced mean duration of lying periods from CCI cold stress thresholds 2 (1 h 7 min) to level 4 (49 min). At CCI cold stress thresholds 5, mean duration of lying periods for group 1 increased to 56 min. Cows of group 2 showed for CCI cold stress thresholds 2 to 5 a more or less constant mean duration of lying periods, varying between 1 h 3 min and 1 h 7 min.

There was a significant effect (p = 0.02) of CCI cold stress thresholds on the mean duration of lying periods per animal per day in VD2. Within CCI cold stress thresholds, a significant difference could be found only between level 2 and 4 according to Tukey-Kramer test statistic (Table 6). Fixed effects group assignment, distinction heifer/cow as well as interaction between CCI cold stress thresholds · heifer/cow had no significant effect on the mean duration of lying periods (Table 5).

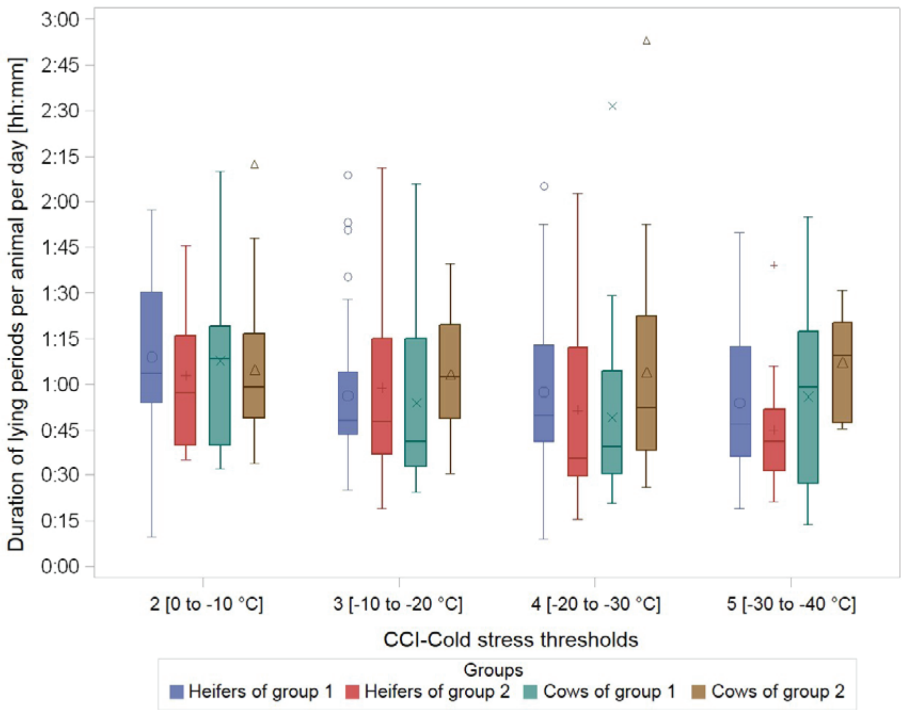

Figure 9: Mean duration of lying periods per animal per day in VD2 arranged by group assignment and distinction heifer/cow

Discussion

Water intake

In this study, no significant effect of CCI cold climate impact on water intake of heifers and cows was found within both experimental periods VD1 and VD2. However, there was a highly significant difference between water intake of heifers and cows. Water intake in our study was in accordance with findings of Terörde et al. (1997), who stated for pregnant cows in moderate climate a daily water intake of 34 up to 40 l. Bahr (2007) measured a daily water intake of 18.4 to 26.4 l, 14 to 2 days prior to calving. This is notably lower than the water intake of suckler cows in this study, which varied between 37 and 47 l per animal per day. However, there is an agreement with the water intake of gestating heifers, consuming on average 24.6 l per animal per day. Bahr (2007) pointed out that the water intake measured in her study was lower as compared to values from the literature, but no obvious sign of thirst could be observed. She explained the low water intake with water content of the feed, which might be a reason for lower water intake, particularly in summer. No separate calculations for winter and summer water intake could be taken from her thesis. One reason for the differences in water intake might be the stage of gestation, which was between the 3rd and 8th month in our study, whereas Bahr (2007) measured water intake 14 days ante partum. In addition, cows in our study had free access to the drinkers, a low animal/drinker ratio of 5 :1 and a short distance to the feed bunk. The number of drinking bouts recorded by Bahr (2007) resulted in mean values between 3 and 5 visits per animal per day, and thus was at a similar level compared to our own results. In a trial of Hoffman and Self (1972), one-year-old beef cattle with an average body weight between 401 and 438 kg drank 19 l per animal per day. Mean ambient temperature was -10 °C. Compared to that, pregnant heifers in our study consumed 6 l more per animal and day and were 100 kg heavier. It can be concluded, that pregnant heifers in a similar thermal condition would consume more water because of the higher body weight and thus, a higher dry matter intake than one-year-old beef cattle in the study of Hoffman and Self (1972). In a study of Arias and Mader (2011) with beef cattle at an ambient temperature of -2 °C, water intake was 7 l lower than water intake of pregnant heifers in our study. Body weights of beef cattle in both studies were at a similar level. The difference in water intake might be due to a higher water content of the feed used by Arias and Mader (2011).

Lying behaviour

Graunke et al. (2010) did not find a significant effect of climate impact on lying time when using daily mean values. In contrast, our results imply a highly significant effect of CCI cold stress thresholds on mean lying time per animal and day as well as a significant difference between CCI-thresholds and differences of lying time. Daily mean temperature in the study of Graunke et al. (2010) varied between +6 and -5.3 °C which is considerably higher compared to the daily mean temperatures in this study. This could be a reason why Graunke et al. (2010) could not find an effect of temperature, humidity, wind speed and precipitation on mean lying time per day. It might be concluded from behavioural changes of suckler cows in our study that body core temperature of cows was close to the lower critical temperature when CCI-temperature declined below 0 °C. As a consequence, animals might have reduced their mean lying time to adapt to the cold and maintain their body core temperature. Tucker et al. (2007) noted that windchill temperature had no effect on lying time of non-lactating dairy cows. Lowest windchill temperatures ranged from -3.1 °C in the barn to -9.9 °C outside the building. Lying time inside the dairy barn averaged to 12 h per animal per day whereas cows outdoors reduced their lying time to 4 h per animal per day. The authors interpreted the extreme difference in lying time with regard to wet bedding areas outside, which might be preventing cows from lying down. Considerably lower lying time of non-lactating dairy cows compared to the lying time of heifers and suckler cows in our study maybe lower due to higher humidity, a thinner adipose tissue and less fat depot fat of non-lactating dairy cows. In the literature, a value for lower critical temperature (LCT) for beef cattle with a compact winter hair coat of -8 °C was found (Tarr 2007). LCT of 500 kg suckler cows in mid third of gestation should be -25 °C, provided that a low wind speed and no precipitation exists (NRC 1981). Statistical differences of lying behaviour between group 1 and group 2 in VD1 might be explained by a non-gestating cow in group 2. This cow was not included in the statistical analysis, but could have interfered with the group behaviour. Contrarily, the number of lying bouts of group 2 is lower and total lying time as well as duration of lying periods is higher. One would have expected that if the behaviour was affected in group 2, the duration of lying periods would be shorter, likewise both total lying time and number of lying bouts would be higher. Individual behaviour of cows was verified according to extreme differences, no abnormality could be identified.

Mean number of lying bouts of suckler cows in our trial is in accordance with results of Mülleder et al. (2003). Suckler cows in the study of Mülleder et al. (2003) showed a mean number of 10.6 lying bouts per animal per day in a cubicle loose housing system. Lower mean number of lying bouts of heifers in this study corresponds to the findings of Mülleder et al. (2003). Besides less insulation of body tissues (NRC 1981), new environment, low rank position within the group and a higher total activity of heifers due to the age might be responsible for a shorter lying time compared to cows.

Conclusions

Suckler cows as well as heifers showed no significant difference in water intake and number of drinker visits regarding to increasing cold. In contrast to that, lying behaviour of cows and heifers showed a clear and significant response to increasing cold. Both cows and heifers reduced their lying time from CCI cold stress threshold > 0 °C (CCI 1) to CCI cold stress threshold 0 to -10 °C (CCI 2). In the same way, lying time decreased significantly from CCI cold stress threshold 0 to -10 °C (CCI 2) to CCI cold stress threshold -20 to -30 °C (CCI 4). It can be concluded that changes of lying behaviour were due to maintain body core temperature higher than LCT. In this context, higher activities of the animals to achieve a higher dry matter intake in order to increase metabolic energy could explain as well shorter lying time. Mean number of lying bouts was reduced as well due to increasing cold, whereas duration of lying periods was only slightly affected by the cold. Behavioural differences demonstrate that suckler cows as well as heifers adapted their behaviour due to increasing cold stress.

From the results of this study, it can be concluded that the water consumption of suckler cows is not modified by the cold stress and the animal adapt their lying behaviour to manage an eventual stress due to extreme winter conditions.

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