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Does shelter design matter? A note on the effect of two shelter types on shelter use by cattle during winter

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ABSTRACT

Little is known about the effect of shelter design on sheltering behavior in out-wintered cattle. In this pilot study, we explored the effects of two different shelter designs (rectangular: 50 m^2 vs. hexagonal 53 m^2 with three separate compartments) on shelter use by cattle. Two shelters of each type were included in the study, and shelter use by 67 Aberdeen Angus cattle in four groups was recorded in a crossover study, ensuring that all groups were tested with both shelter types. Shelter use (i.e., number of cattle standing or lying inside each shelter) was recorded by use of infrared trail cameras. Rectangular shelters were used significantly more than hexagonal shelters ($P < 0.001$). The proportion of animals in the shelters that were lying down did not differ between the shelter types. Cold, windy, and wet conditions increased sheltering behavior. In this study, cattle preferred rectangular shelters over hexagonal shelters possibly because they prefer to shelter together as a group. Further studies on optimal shelter design are required.

Introduction

Slow-growing and robust cattle breeds such as Scottish Highlander, Galloway, Hereford, and Aberdeen Angus are often used for year-round grazing. Outdoor keeping of cattle has benefits relating to animal health and welfare, such as reduced claw and leg problems (Haskell et al., 2006), opportunity to perform natural behavior (Bracke and Hopster, 2005), and greater space allowances, which reduce aggression (Kondo et al., 1989). However, exposure to adverse weather conditions can decrease welfare and health of cattle kept outside during winter (Tucker et al., 2007; Webster et al., 2008; Young, 1981). Cold resistance depends on the combined effect of the individuals' own heat production and its insulation by fat tissue and fur coat. However, wind and rain lower the insulating effect of the fur coat (Schütz et al., 2010). Accordingly, outdoor-wintered animals increase their use of protected areas during times with precipitation, lower ambient temperatures, and increased wind speed (Graunke et al., 2011; Van laer et al., 2015). Thus, animals kept in areas with limited natural protection against wind and precipitation may benefit from a well-designed shelter to mitigate the risk of cold stress. Responses to cold stress can include reduced lying time, increased adrenocortical activity, and decreased white blood cell numbers, which may indicate impaired welfare (Tucker et al., 2007; Van laer et al., 2014; Webster et al., 2008). In some countries, including Denmark, shelter is required for cattle kept 24 h outside during winter, but there is a lack of knowledge on optimal shelter design.

It has been recommended that shelters are designed to allow the animals an overview of their environment (Kluever et al., 2008). This can be achieved by leaving one full side of the shelter open, although this also decreases the degree of protection offered by the shelter. It should further be ensured that dominant cows do not prevent other cows from entering, so that all animals in the group have access to the shelter. This pilot study aimed to investigate the effect of two different shelter designs (A: rectangular with one open side, and B: hexagonal with three compartments) on shelter use by cattle during winter and the effect of weather on the overall use of shelters. We hypothesized that cattle would show preference for the hexagonally shaped shelters because the three compartments offer protection against the wind regardless of wind direction and allow lower-ranking cows to enter another compartment than that occupied by higher-ranking cows. We further hypothesized that shelter use increase with decreasing ambient temperatures, increased wind speed, or rain.

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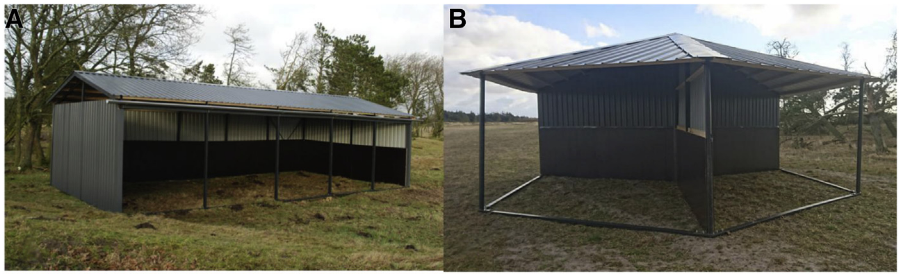

Figure 1. The two types of shelter used to investigate effects on shelter use by Angus cattle during winter. (A) Rectangular (50 m^2). (B) Hexagonal (53 m^2) with three identical compartments. During the experiment, the ground in both types was covered with straw.

Materials and methods

Four shelters were used in the study; two were rectangular shelters (5 m × 10 m) with one long side open (Figure 1A) and the other two were hexagonal shelters (53 m^2) with an inner Y-shaped wall, splitting the shelter into three identical compartments (Figure 1B). Both types of shelters were made of the same metal for sides and roof.

The data collection took place in February and March 2017 in one Angus herd located in Jutland, Denmark. A total of 67 adult Aberdeen Angus cattle were included in the study. They were separated into four groups (15-18 animals/group) pastured on four paddocks (2-3 ha/paddock) with access to one shelter in each paddock—either design rectangular or design hexagonal (Figure 2). Each group had access to ad lib hay and water, and forest areas were barred with electric fence to ensure that shelter was only provided by the artificial shelters.

The use of the shelters was tested in a crossover design, ensuring that all groups had access to both designs of shelters (Table 1). Each experimental period lasted 24 days. The cattle groups switched paddock between the experimental periods, and a habituation period of one week was included before each period.

Shelter use was recorded by infrared trail cameras (Black IR Trail Camera; ScoutGuard, USA) taking a picture every 15 minutes (Rectangular shelters: two cameras, one placed under the roof in each end; Hexagonal shelters: three cameras, one camera per compartment). The use of the shelters was estimated by scan sampling every full hour during each 24-day period (i.e., 24 scans × 48 days per group). For each scan, the number of animals in the shelter was counted, and their activity (lying/standing) was noted. The number of animals in the shelter was based on pictures from both cameras in the rectangular shelters where a mid-line was used to avoid double counting of animals. In the hexagonal shelters, the number of animals in the shelter was based on a count of animals in all three compartments.

Ambient temperatures (°C) were collected every hour using loggers (iButton DS1923; Resolution: 0.6% RH; ±0.5°C; Maxim Integrated, San Jose, CA). One logger was placed in each of the rectangular shelters, whereas for the hexagonal shelters, one logger was placed in each compartment. The temperature inside the hexagonal shelters was calculated as the mean of the logger data from the three compartments. To obtain the local outside temperature, one logger was also placed outside. All loggers were placed at a height of approx. 2 m. Furthermore, daily meteorological data consisting of temperature (°C), average wind (m/s), and precipitation (mm) were collected from the nearest meteorological station (Aalborg airport, 60 km from the location). A chill factor index (CFI) was calculated based on the equitation of Environment Canada (Webster et al., 2008): $CFI = 13.12 + 0.62 * T - 11.37 * V^{0.16} + 0.40 * T * V^{0.16}$, where T = temperature (°C) and V = average wind speed (converted into km/h). Daily (24 h) averages of all meteorological data were calculated and used in the analysis.

Statistical analysis

Based on the data obtained from the hourly scans, two variables were calculated: Percentage of animals in the shelter (number of animals in the shelter/total group size × 100; GROUP%) and the percentage of animals in the shelter that were lying down (number of animals lying/number of animals in the shelter × 100; LYING%). For the analysis examining the effect of shelter design, a daily average for each group for these two variables was calculated. For the hexagonal shelters, the daily average was calculated based on data from all three compartments. The daily mean of GROUP% and LYING% were analyzed in a mixed model (PROC MIXED; SAS Institute Inc., Cary, NC), taking the effect of repeated measures on group (1-4) within period and the random effect of period (1,2) into account. Treatment (rectangular or hexagonal) was included as fixed effect, and daily ambient temperature, CFI, and precipitation as covariates. Measurements on different days for the same group

Figure 2. Two locations on a private farm were used for the experiment. The paddocks (marked by thin black lines) contained either a rectangular or a hexagonally shaped shelter. The arrows indicate the open side of the rectangular shelters. The cattle groups changed paddock between the experimental periods, ensuring that the groups were tested with both shelter types.

Table 1
Experimental design

Experimental period	Design rectangular	Design hexagonal
Period 1 (24 days)	Group 1 and 3	Group 2 and 4
Period 2 (24 days)	Group 2 and 4	Group 1 and 3

Using a crossover design in two experimental periods, four groups of cattle were tested with both types of shelter design (rectangular and hexagonal, Figure 1A and B).

were assumed correlated, leading to the use of a first-order autoregressive covariance structure [AR(1)]. Throughout, *P*-values were based on the Satterthwaite approximation for the denominator degrees of freedom.

In the hexagonal shelters, the Wilcoxon test was used to investigate if the three compartments were equally used by the cattle. To compare the overall use of shelters across shelter design during night (22-05 h) and day (9-16 h), the Mann-Whitney U test (MWU) was conducted using data only from the night and day periods.

The data were analyzed in SAS Enterprise Guide 7.1 (SAS Institute, Inc., Cary, NC). Statistical significance was accepted at $P < 0.05$.

Results

Effect of shelter design

An overview of the weather conditions in the two experimental periods is presented in Table 2. The two shelter types did not differ in inside temperature ($P > 0.05$).

A higher percentage of the groups was inside when the animals had access to rectangular shelters compared with hexagonal shelters (Figure 3). Shed use was increased by low ambient temperature ($F_{1,155} = 37.6$, $P < 0.001$), low wind chill factor ($F_{1,186} = 21.3$, $P < 0.001$), and increased precipitation ($F_{1,152} = 4.7$, $P = 0.032$). There was no difference between the shelter types in terms of the proportion of the cows in the shelters that were lying (LYING%; rectangular: 82.4% ±1.5 vs. hexagonal: 82.8% ± 1.2, $F_{1,38.5} = 0.0$, $P = 0.94$). There was no difference in the use of the three different compartments in the two hexagonal shelters.

The shelters were used less during the light hours (9-16) compared with dark hours (22-05) (GROUP%, median [25; 75%]; 9-16 h: 5.9 [5; 19] vs. 22-05: 19.9 [6; 35], MWU, $P = 0.008$). In addition, a larger percentage of the animals in the shelters were lying during the night, compared with during the day (LYING%; 9-16 h: 80.0 [73; 83] vs. 22-05: 83.6 [81; 90], MWU, $P = 0.011$).

Discussion

The study showed that the cattle used both types of artificial shelters. However, based on the hourly scans where the number of animals in the shelters were counted, we found that a higher percentage of the groups was inside when the animals had access to the rectangular compared with the hexagonally shaped shelters. Thus, in contrast to our hypothesis, the cattle preferred the rectangular shelters. The hexagonally shaped shelters were designed to prevent that higher-ranking animals would keep lower-ranking animals from sheltering and to ensure that the shelter would provide protection against the wind, regardless of wind direction. The two shelter types were approximately the same size (50 and 53 m^2), and with 15-18 cattle per group, the available space was only 2.8-3.5 m^2/individual, which is below the recommended shelter space (Fogsgaard and Christensen, 2018). Thus, there was likely competition for space and lower-ranking individuals may have been reluctant to enter shelters/compartments with higher-ranking cows. Interestingly, this did not lead to increased use of the hexagonally shaped shelters, suggesting that cattle may be more motivated to remain within sight of their herd mates rather than sheltering, within the range of weather conditions prevalent in this study. Thus, the preference for the rectangular shelters may relate to cattle being gregarious herd animals, and they would have to split up and lose sight of each other to make use of the different compartments of the hexagonally shaped shelters. Indeed, the highest recorded number of animals in one compartment was 10 animals. Cattle are known to synchronize behavior and stay close together (e.g., Stoye et al., 2012), ensuring the benefit of the group for detection of danger.

The lower use of the hexagonally shaped shelters could also be related to a compartment preference, for example, if only compartments opposite the wind direct was used. However, we found no overall difference in the use of the three compartments. Thus, although the experimental farm was located close to the west coast with occasional strong winds, usually coming from the west, the cattle did not make greater use of the compartments on the east side.

Our results also suggest that sheltering behavior in cattle is related to weather conditions. The cattle increased their use of the shelters with lower ambient temperatures and CFI, across both shelter types and experimental periods. Other studies have also reported that cattle seek shelter behind windbreaks, in natural vegetation, or stay closer together with increased wind speeds and decreased ambient temperatures (Graunke et al., 2011; Olson and Wallander, 2002). In contrast, Schütz et al. (2010) investigated responses to short-term exposure to simulated rain and wind in dairy

Table 2
Overview of meteorological data during the experimental periods

Meteorological variable	Mean ± SE	Median [25; 75 %]	Minimum	Maximum
Period 1				
Temperature, in shelters (°C)	2.1 ± 0.3	2.6 [−0.5; 4.5]	−3.8	7.1
Temperature, outside (°C)	1.8 ± 0.3	2.2 [−0.9; 4.2]	−4.0	6.6
Precipitation (mm/24 h)	0.9 ± 0.2	0.1 [0; 1.8]	0	6.1
Wind speed (m/s)	19.7 ± 0.9	19 [13; 26]	3	39
Chill factor index	−9.4 ± 0.3	−9.8 [−8; −10]	−14	−3.6
Period 2				
Temperature, in shelters (°C)	4.7 ± 0.2	4.9 [3.7; 6.4]	−1.1	8.3
Temperature, outside (°C)	4.4 ± 0.3	4.6 [3.3; 6.3]	−1.7	7.9
Precipitation (mm/24 h)	1.2 ± 0.2	1.0 [0; 2.0]	0	7.1
Wind speed (m/s)	19.9 ± 0.9	16 [13; 28]	6	37
Chill factor index	−9.9 ± 0.2	−9.6 [−8; −12]	−14	−5.6

Ambient temperatures were measured hourly by loggers on the experimental farm. Daily averages were calculated for the analysis, and averages across all days are shown in the table. Other data are from the nearest weather station, Aalborg Airport, 60 km from the location.

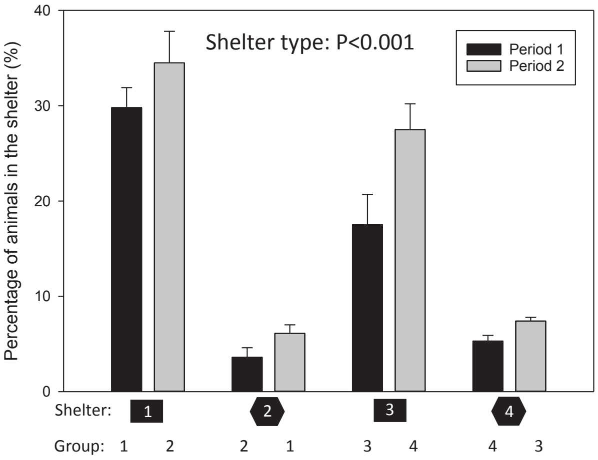

Figure 3. The percentage (mean ± SE) of cattle in the four groups (n = 15-18/group) that were inside the shelter was affected by shelter type. In both study periods, the hexagonally shaped shelters were used less than the rectangular shelters ($F_{1,26.8} = 87.2$, $P < 0.001$).

cattle and found no effect on the use of the shelters. However, the authors reported decreased lying and eating time when wind and rain were combined. Decreased lying behavior, higher plasma cortisol concentrations, and fecal cortisol metabolites were also reported for cattle kept in continuous, simulated rain and wind (Tucker et al., 2007). Indeed, lying is a highly prioritized need in cattle, and limited access to proper lying areas can have negative effects on animal welfare (Ekesbo, 2011; Munksgaard et al., 2005). In this study, a higher proportion of cattle were lying in the shelters during night, and the shelters were generally used more at night than during the day. A similar pattern was reported in Fogsgaard and Christensen (2018) and for horses in Christensen et al. (2018). In this pilot study, it was unfortunately not possible to mark the cattle individually. In future studies, it would be highly relevant to investigate individual use of shelters to explore whether some individuals are less likely to shelter in relation to social status and other lifetime factors. Also, our study did not include welfare measures including whether animals that shelter less also have decreased total lying time. Both types of shelters were used predominantly and equally for lying, suggesting that cattle entered the shelters when motivated to lie down or that being inside the shelter induced lying behavior. Recordings of total lying time, that is both inside shelters and outside, are necessary to further explore the effect of shelter access on lying behavior.

There is generally a lack of studies on optimal shelter design for animals kept outside during winter. Christensen et al. (2018) reported that horses used shelters with two entrances more than shelters with only one entrance (measuring 1.5 m), suggesting that entrance conditions and visibility of the surroundings are important for sheltering behavior in horses. Visibility of the surroundings is likely also important for cattle, and it has been suggested that cattle show preference for natural shelter compared with artificial shelters (Van laer et al., 2015). In our study, the natural vegetation was fenced off and further studies are required to investigate preferences for natural vs. artificial shelter.

Conclusion

In this pilot study, cattle groups without access to shelter from natural vegetation used artificial shelters to a varying degree, depending on shelter design. In contrast to our hypothesis, rectangular shelters were used more than hexagonally shaped shelters with three separate compartments. Low ambient temperatures and CFI led to increased shelter use, and shelters were used mainly at night.

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Authors' contributions: The idea for the paper was conceived by K.K.F. and J.W.C. The experiments were designed by K.K.F. and J.W.C. The experiments were performed by K.K.F. and J.W.C. The data were analyzed by all authors. The paper was written by all authors.

Ethical considerations

The study conformed to the "Guidelines for ethical treatment of animals in applied animal behavior and welfare research" suggested by the ethics board of the International Society of Applied Ethology (www.applied-ethology.org). According to national legislation, no ethical permission was required for the experiments.

Conflict of interest

The authors declare no conflicts of interest.

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