Outdoor yards for sheep during winter - Effects of feed location, roof and weather factors on resting and activity

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ABSTRACT

The aim of this experiment was to investigate the effect of roof cover and location of feed on sheep's use of an outdoor yard under different weather conditions. A 2 x 2 factorial experiment was conducted with roof covering of outdoor yard (yes or no) and location of feed (indoors or outdoors) in four different pens, each with one of four possible combinations of these factors. Twenty adult ewes of the Norwegian White breed were randomly allotted to 4 groups with 5 animals. Weather parameters were automatically recorded. The following behavioural parameters were scored using instantaneous sampling every 15 minutes throughout 24 hour video recordings: location (indoors or outdoors), general behaviours (stand/walk, resting, feeding). Weather factors did not seem to have any large influence on sheep behaviour. A roof covering the outdoor yard increased time spent in the yard, had no effect on feeding time, a limited effect on resting time but increased the time spent resting outdoors. Locating the feed outdoors increased time spent in the yard, but also increased the time spent resting indoors, indicating that if a dry and comfortable resting area is offered indoors, the feed should be located in the outdoor yard.

Key words*: environment, housing, Ovis aries, thermoregulation, weather factors, winter.*
Short title*: Jørgensen and Bøe – Outdoor yards for sheep during winter*

INTRODUCTION

In Canada and USA, farmers use shelters or simple buildings to house sheep, utilizing outdoor areas to a large extent, except during lambing (Outhouse 1981). In Britain however, sheep are kept more extensively, spending most of their life outdoors and with only simple shelters or hedges for weather protection during lambing (Robinson 1981). In strong contrast, Norwegian sheep are typically housed 4 to 6 months during winter, in pens with fully slatted floors and a space allowance as low as 0.7-0.9 m^2 per animal (Bøe and Simensen 2003). New regulations for organic sheep farming demand a minimum of 1.5 m^2 total area per animal, and half of this should be a resting area with a solid floor (0.75 m^2 per sheep) (Council Regulation (EC) No. 1804/1999). In order to fulfil these requirements, either the building space has to be increased or the number of sheep must be reduced.

Mean annual snowdepth in Norway is 77cm, but this of course varies considerably throughout the length gradient of the country. The snow usually stays until April and average day temperatures in lambing season may be around 5 °C. This means that pasture is not available before the middle of May and hence additional feeding and housing is imperative during the winter months. One way to reduce the costs of sheep housing is to build simple, non-insulated buildings. Here the sheep will only be exposed to low temperatures and not to radiation, wind or precipitation (e.g. Hahn and Bøe 1985). Unshorn sheep seem to cope well with low temperatures (Lower Critical Temeperature: LCT: -30°C, Webster et al. 1969) and no negative effects of cold housing has been found on sheep performance (Bøe et al. 1991; Vachon et al. 2007; Pouliot et al. 2009). An even cheaper alternative is to use an outdoor yard as activity area and provide only a resting area inside the building. When the sheep are outdoors, they will experience increased heat loss due to radiation, wind and precipitation. These climatic factors will influence the sheep' use of shelter (Curtis 1981; Done-Currie et al. 1984) and shelter is especially important to reduce heat loss in newborn lambs (Alexander et al. 1979; Pollard et al. 1999).

Locating the feed in the outdoor yards will most likely cause animals to spend more time outdoors. Thermally challenged sheep in extensive systems increase their metabolic heat production by increasing their eating rate and thereby their feed intake (Kennedy 1985). However, if the weather is challenging, animals will seek shelter and the time spent feeding will decrease if the feed is located outdoors. A roof that covers the yard and thus protects the sheep from precipitation and partly from wind could therefore be an important feature in areas with inclement weather.

Due to regulations to prevent agricultural runoffs, outdoor areas for animals need to be hardened and drained. A hardened surface will also facilitate frequent cleaning of a relatively small area where the build-up of manure and feed waste will be rather large. The information about amount of manure and hence the necessary frequency of cleaning is however scarce. Melting snow and mud also creates problems in outdoor areas during the Nordic winter/spring period. Canadian recommendations state that soil surface feedlots should only be used in areas with less than 500 mm annual rainfall (Canada Plan Service 2008). For comparison, the southeast region of Norway where the present experiment was performed experience an annual rainfall of 730 mm, while much larger amounts may be expected in coastal areas. Although expensive (e.g. Andersson et al. 2007), concrete seem to be a prerequisite in outdoor yards. However, in larger yards where animal densities are smaller alternative materials could be just as convenient and the intervals between cleanings could be increased.

A measure of behavioural synchrony may give a more sophisticated picture on group cohesion and how well the group can adjust to different housing conditions. Sheep will in general try to synchronize both resting and feeding behaviour since this is important in relation to anti-predator strategies in nature (Michelena et al. 2006; 2008). If the housing conditions do not facilitate this behavioural synchrony, increased frequencies of physical displacements and disturbed resting may be a direct result (e.g. Bøe et al. 2006).

The aim of this experiment was to investigate the effect of roof cover and location of feed on the sheep's use of an outdoor yard under different weather conditions. We hypothesize that the presence of roof over the outdoor yard would affect the use according to weather parameters, and predict that more sheep would be observed to use the outdoor yards

with a roof cover compared to yards without such a roof. We further hypothesize that the location of feed would affect the distribution of sheep between outdoor and indoor areas, and predict that more sheep would be observed standing, walking or resting outdoors in pens where the feed was located outdoors than in pens with feed located indoors.

MATERIALS AND METHODS

Experimental Setup

A 2 x 2 factorial experiment was conducted with roof covering of outdoor yard (yes or no) and location of feed (indoors or in yard). Four groups of five sheep were randomly assigned to the experiment and all groups were exposed to all treatments in a systematic order and rotated between pens every week. Each treatment period lasted for seven days, and average temperatures together with precipitation data was calculated for each 24 hour video recording done at the end of all treatment periods.

The experiment was performed at the Norwegian University of Life Sciences farm in Aas, Norway from November 2009 to March 2010. The experimental site was located approximately 100 m above sea level (latitude: 59° 39′ 49″ N and longitude: 10° 47′ 27″ E). The climate in this region is relatively cold with an annual mean temperature of about 6.2 °C (range 22 °C), 730 mm annual rainfall and 140 days with temperatures below 0 °C (lowest temperatures in January and February) (www.climatetemp.info).

Weather Parameters

A wireless weather station (WMR928NX Oregon Scientific) was used to collect climate data every 20 minutes throughout the experimental period. Using the software (Virtual Weather Station V12.07, Ambient Weather US®) we recorded the following parameters: wind speed and wind direction (sensor a and b, located 1.8 m above the ground at the south-west corner of the experimental barn, Figure 1), outdoor air temperature and air humidity (sensor c and e, located on the wall, 1.8 m above the ground between the outside yards of pen 1 and 2), indoor air temperature and air humidity (sensor d and f located inside the barn 1.8 m above the ground) and precipitation (sensor g, located 2.0 m from the north-west corner of the barn).

Throughout the experiment very little wind was recorded (Table 1), leading to the exclusion of this parameter from our datasets.

Table 1.Weather conditions during the experimental period

	Indoor temperature (°C)		Outdoor temperature (°C)		Wind (m/sec)		Precipitation (mm/day)		Humidity (%)	
	Mean	Range	Mean	Range	Mean	Range	Sum	Range	Mean	Range
November 2009	7.2	1.9 to 11.8	4.9	-1.5 to 16.2	2.9	0 - 9.6	150.7	0 - 22.2	93.2	56 - 98
December 2009	3.0	-8.7 to 13.8	-0.9	-11.7 to 9.3	0.3	0 - 7.8	75.8	0 - 22.3	94.3	45 - 98
January 2010	-6.7	-24.0 to 3.3	-9.9	-27.9 to 10.4	0.2	0 – 6.5	10.7	0 - 2.1	84.7	41 - 98
February 2010	-4.1	-16.0 to 5.0	-6.9	-21.7 to 15.2	0.4	0 - 7.0	36.1	0 - 10.6	83.2	32 - 98
March 2010	-3.7	-13.0 to 6.8	-5.8	-17.8 to 16.1	0.9	0 - 7.6	69.5	0 – 38.0	74.4	22 - 95

In order to test the impact of different weather conditions, the observations were divided into five predefined weather categories:

1) Mild, no rain (average temperatures between + 10 and 0 °C without precipitation)
2) Mild with rain (average temperatures between + 10 and 0 °C with precipitation)
3) Cold, no snow (average temperatures between –1 and –12 °C without snow)
4) Cold, with snow (average temperatures between –1 and –12 °C with snow)
5) Very cold days (average temperatures below –12 °C)

Experimental Pens and Housing

The experiment was performed in an open, non-insulated building with four pens. Two of the pens (pen 2 and 3) had a roof over the outdoor yard, and the two others (pen 1 and 4) had no such covering (Figure 1). Feed was provided inside in two of the pens (pen 1 and 2) while in the other two pens (pen 3 and 4) the feed was provided outdoors in the yard. Feed racks had a continuous horizontal opening (post and rail design) and covered the whole end of the pen (2.4 m long) either indoors or outdoors according to treatment. On top of the roughage a heavy steel ladder was placed to prevent wastage by ewes pulling hay into the yard.

The lower part of the building walls (1.40 m) were solid wood, whereas the upper parts had PVC coated polyester wind breaker (Galebreaker®). The roof over the barn and the outdoor yards consisted of a wooden frame with standard roofing plates to withstand heavy snowfall. Each pen measured 3.76 m x 2.40 m, providing a total area of 1.80 m^2 per ewe. Half of this total area was a dry resting area inside the building on deep straw bedding, and the other half was a yard with concrete surface outdoors.

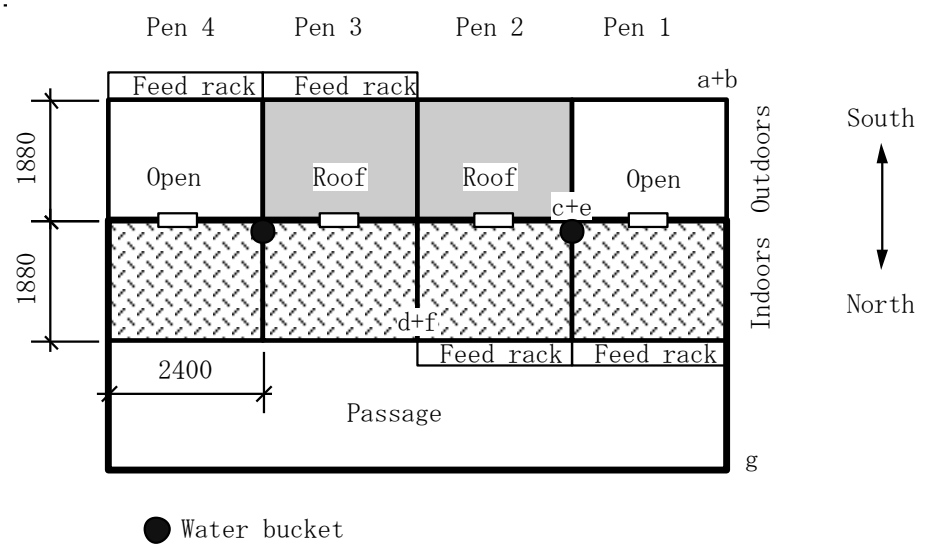

Figure 1. *A schematic presentation of the experimental building with the four pens. A solid roof was present over the whole building, including the inside area of the pens (hatched) and the passageway in front. Only the outdoor yards of pen 3 and 4 were covered with a roof, and pens 3 and 4 were fed outdoors while pens 1 and 2 were fed inside the building. Sensors for climate data were located as indicated on the figure: a = wind speed, b = wind direction, c = outdoor air humidity, d = indoor air humidity, e = outdoor air temperature, f = indoor air temperature, g = precipitation.*

Animals and Feeding

20 adult ewes (aged 1.5-3.5 years) of the Norwegian White breed (mean weight ± STD: 77.1 ± 9.5 kg) were randomly allotted to 4 groups of 5 animals. Good quality hay was provided *ad*

libitum, and drinking water was supplied from frost-proof 65 litre water containers. Throughout the experimental period 0.1 kg/ewe of a standard concentrate feed (Formel sau) was given every morning in the feed racks, before fresh hay was administered. Salt lick stones were mounted in the outdoor yards between pens 1 and 2 and between 3 and 4 for free access.

Prior to the experiment the animals had been on pasture from May to October, and were housed in groups of 12-15 (space: 1.0 m^2/ewe) on expanded metal flooring after the pasture period. All sheep were given a standard treatment against internal parasites and were hoof trimmed a week prior to the start of the experiment. All ewes had a full coat of wool. Mating was performed naturally or by artificial insemination during November and December as the ewes came into oestrus.

The outdoor yard was cleaned out daily (around noon), and the water containers were emptied, cleaned and refilled at the same time.

Behavioural Observations

The ewes were individually marked with numbers across their backs, using a standard marking spray for animals (Felleskjøpet). Twenty-four hour video recordings were performed at the last day of each experimental period using the digital video surveillance system MSH video from M. Shafro & Co (www.guard.lv). From the video recordings we scored the following parameters per individual ewe, using instantaneous sampling every 15 minutes throughout the 24 hours:

1. Location (inside on deep straw bedding or outside in yard)
2. General behaviours
   - Standing/walking (also when drinking)
   - Resting (the sheep is lying down resting)
   - Feeding (head through feed barrier)

In order to quantify the need for cleaning of the outdoor yard, we weighed (on a digital scale) the daily amount of manure and also hay wastage that the sheep had dragged from the feed rack into each yard, once every week. When cleaning of the yards or mating was performed behavioural observations were postponed until the animals had settled down and people had left the experimental barn.

Ethical note

Animals in this experiment were cared for under the guidelines of the National Research Authority (www.FDU.no). These guidelines correspond very well to the guidelines laid down by the Canadian Council on Animal Care and no ethical concerns were indicated by our university FDU representative vet. Animals were used to people and handling and were kept in pens with lower animal density compared to their normal housing conditions. As soon as the experimental period was over, all ewes were returned to their home environment (commercial farming).

Statistical Analysis

In order to test the effect of roof cover and feed location on activity and synchrony of general behaviours we applied a mixed model of analysis of variance with roof cover over outdoor yard (yes, no), feed location (indoors, in outdoor yard), group (1-4) and the interaction

between the two as class variables. Group was specified as a random effect (Hatcher and Stepanski 1994). A very similar mixed model was used to test the effect of weather on activity and synchrony of general behaviours with weather categories (1-5), roof cover, feed location, group (1-4) and the interaction between roof cover and weather category or feed location and weather category as class variables. Group and rotation (1-4) nested within repetition (1-4) was specified as random effects (

The data on manure and feed waste were not normally distributed and we therefore investigated the effect of pen and weather using a non-parametric chi square test with weather category, pen, feed placement and roof cover of yard as class variables. Spearman correlations were used to test the relationship between weather category and the amount of manure and feed waste in yards.

Differences between means were investigated using LS-means that were adjusted for multiple comparisons with the Tukey-Kramer approximation, and all analysis was performed in SAS 9.1®.

RESULTS

General Activity

Irrespective of weather conditions, the sheep were observed more often in the outdoor yards when this was covered with a roof (a 20.6 % increase relative to in the yards without a roof) and when the feed was located outdoors (a 30.0 % increase relative to when feed was located indoors) (Table 2).

Feeding made up approximately 25 % of total observations, but even so ewes were observed only 10.4 % more outdoors in pens with the feed located outdoors. Time spent feeding was not affected by roof over outdoor yard or location of feed (Table 2) and neither was synchrony of feeding. Time spent standing/walking was just the opposite of the time spent resting. In pens with no roof over outdoor yard, ewes spent more time standing/walking than in pens with covered yards, and ewes in pens with feed located indoors also spent longer time standing/walking (Table 2). Furthermore, the total resting time was longer when the outdoor yard was covered and also when feed was located outdoors (Table 2).

The proportion of resting time in the outdoor yard was higher in pens with roof-covered yards (39.9 %) than in the yards without roof (26.7 %) (Table 2). Interestingly, resting in outdoor yard was actually much higher when the ewes were fed inside (41.6 %) than when the feed was offered in the yard (22.2 %) (Table 2). Synchrony of resting (all ewes in a group resting simultaneously) was higher in pens with roof-covered yards, whereas location of feed had no effect on this parameter (Table 2).

Table 2. Effect of roof over outdoor yard and feed location on general activity and behavioural synchrony

Mean % of tot. obs	Effect of roof over outdoor yard				Effect of feed location			
	Roof	No roof	$F_{1,10}$	*P*-value	Indoors	Outdoor yard	$F_{1,10}$	*P*-value
Resting	60.6 ± 1.7	58.1 ± 1.7	41.1	<0.0001	57.7 ± 1.7	60.9 ± 1.7	42.5	<0.0001
- inside barn	36.3 ± 1.6	42.6 ± 1.8	4.9	NS	31.6 ± 1.5	47.4 ± 1.5	46.2	<0.0001
- outdoor yard	24.2 ± 1.4	15.5 ± 1.2	12.9	<0.01	26.2 ± 1.4	13.5 ± 0.7	32.0	<0.001
Feeding	26.0 ± 1.2	24.7 ± 1.3	2.7	NS	25.3 ± 1.2	25.5 ± 1.3	0.11	NS
Stand /walk	13.4 ± 0.8	17.1 ± 0.8	25.5	<0.001	16.9 ± 0.9	13.6 ± 0.7	17.5	<0.01
- inside barn	6.8 ± 0.5	8.7 ± 0.5	10.7	<0.01	8.2 ± 0.45	7.4 ± 0.5	1.4	NS
- outdoor yard	6.5 ± 0.4	8.4 ± 0.6	13.0	<0.01	8.7 ± 0.6	6.2 ± 0.4	21.8	<0.001
In outdoor yard	43.8 ± 1.3	36.3 ± 1.4	7.1	<0.05	34.8 ± 1.4	45.2 ± 1.2	15.7	<0.01
All sheep resting simultaneously	34.0 ± 1.2	29.1 ± 1.3	10.7	<0.01	31.4 ± 1.3	31.7 ± 1.3	0.02	NS

Some individual sheep seemed to prefer resting indoors rather than in the outdoor yards, while other sheep seemed to divide their total resting time equally between the outdoor yard and the deep straw bedding indoors (Figure 2). Six ewes spent on average > 70 % of their resting time indoors while four ewes spent 50 – 55 % of their resting time in the outdoor yard regardless of weather, roof or feed location. Of these four ewes, three weighed approximately 14 kg more than the overall mean weight and were also the heaviest individual in each of their groups. The body weight of the six ewes preferring to rest indoors did not differ much from the mean weight.

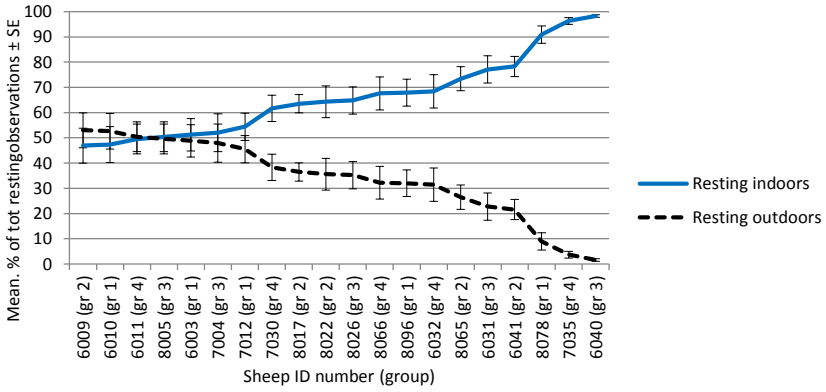

Figure 2. *Individual sheep's choice of resting area throughout the experimental period (group affiliation was indicated by numbers behind the sheep ID numbers).*

Weather conditions did not affect the proportion of time sheep were observed in the outdoor yards, feeding or standing/walking. Resting time was shortest during weather category 2 (mild and rain) and category 3 (cold, no snow) and longest during weather category 4 (cold, no snow) and category 5 (very cold) (Figure 3). Days with mild temperatures and no rain were intermediate. Resting in the outdoor area was observed significantly less on days with mild temperatures and rain compared to on days with mild temperatures without rain (Figure 3).

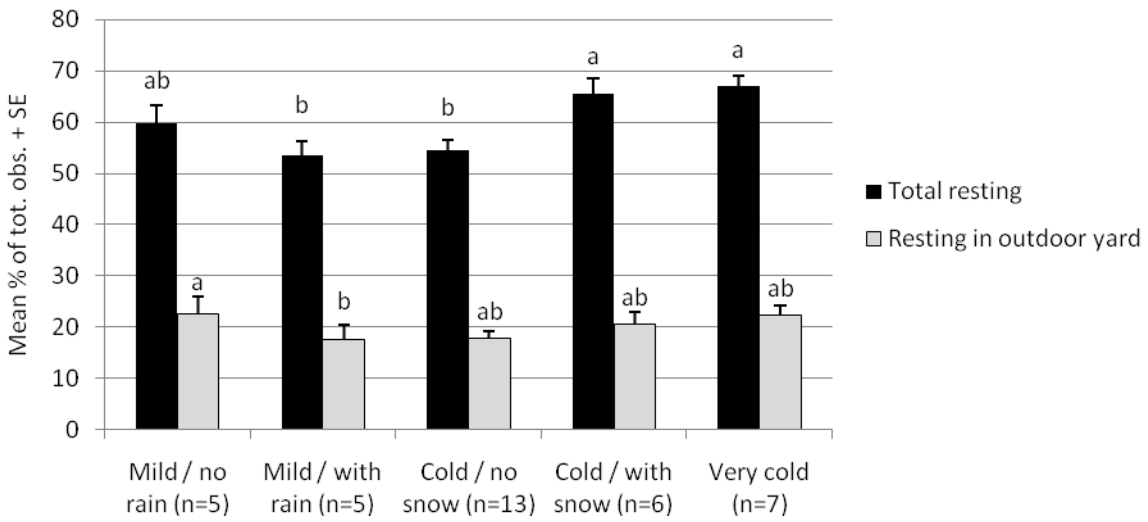

Figure 3. *The effect weather on the proportion of sheep resting in total and in the outdoor yard. Different letters above bars depict significant differences between weather categories (P<0.05).*

Within weather category 2 (mild, with rain), significantly more sheep were observed resting in the outdoor yards that were covered with a roof (24.5 ± 3.9 %), compared to when yards were not covered (10.9 ± 3.2 %) (Interaction effect weather category and roof cover: $F_{4,114}$=2.5, P<0.05).

A higher degree of resting synchrony was found on cold days with snow (weather category 4: 34.6 ± 2.3 % of tot obs.), compared to days with mild temperatures and rain (category 2: 23.8 ± 2.0 %) ($F_{4,114}$=5.4, P<0.01). Resting synchrony on days with weather categories 1, 3 and 5 was 31.4 ± 2.2 %, 30.1 ± 1.4 % and 34.6 ± 2.3 % respectively.

No effect of group was found for any of the behaviours tested in the model.

Amount of Manure in Outdoor Yard

The presence of roof over the outdoor yard did not affect the amount of manure and feed waste, but there was a strong tendency indicating that the amount of manure and feed waste was higher in pens where feed was offered in the outdoor yards (mean ± SE pen 3: 11.1 ± 0.8 kg; pen 4: 14.0 ± 1.3 kg) compared to in pens where the feed was offered inside the barn (pen 1: 5.2 ± 0.4 kg; pen 2: 5.2 ± 0.3 kg) (X^2_{55}=71.3, P=0.068).

The weather did not affect the amount of manure and feed waste in the outdoor yards, but a correlation was found between the two variables, indicating that as weather moves towards lower temperatures the amount of manure and feed waste decreased (Figure 4) (R=-0.27, P<0.05). On days with rain the manure and feed waste were of course heavier, especially in the yards without roof cover (Figure 4).

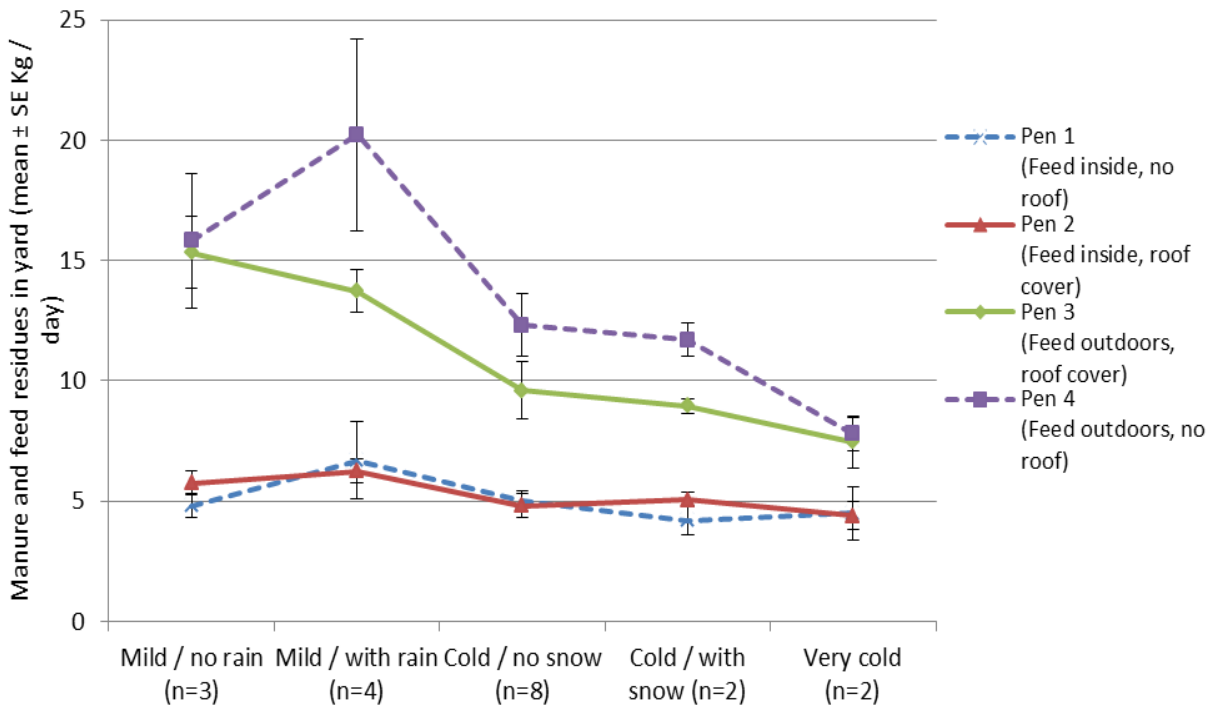

Figure 4. *Effect of weather, roof cover and feed location on daily build-up of manure and feed residues in the outdoor yards.*

DISCUSSION

In agreement with our first prediction, the sheep spent more time in the outdoor yards that were covered with a roof. Previous studies have shown that rain increases heat loss and thus the lower critical temperature also increases markedly (Curtis 1981; Mount and Brown 1982). Hence, we would expect a larger reduction in overall use of the yards without roof during rainfall and snow, but we could not find any interaction between roof cover and weather condition for this measure. Sheep reduce heat loss by limiting their lying time (Færevik et al. 2005) and the importance of a dry surface in the resting area has been demonstrated both for cattle (Gonyou et al. 1979; Redbo et al. 2001; Webster et al. 2008), horses (Mejdell and Bøe 2005) and goats (Bøe et al. 2007). Looking at each activity separately, we found that more sheep rested in the outdoor yards with a roof cover on days with mild temperatures and rain compared to in yards without such a roof. The presence of a roof will make the surface of the outdoor yard drier, but the effect of roof covering on total resting time and synchrony of resting was actually quite moderate compared to results from experiments with reduced lying space for ewes (Bøe et al. 2006). This suggests that the precipitation affects ewe's resting behaviour to a larger degree than temperature per se.

Another factor contributing to heat loss is wind and the combination of wind and precipitation has the potential of challenging the ewe's thermoregulatory behaviour to a large extent (Webster et al. 1969; Bennett 1972; Curtis 1981). The ewes in the present experiment did not experience much wind during the period (maximum wind speed registered:,9.6 m/second) and this factor was therefore omitted from the weather categories. The rather modest effect of weather on sheep behaviour in the present study can be explained by their

full coat of fleece, *ad libitum* access to feed and the provision of a dry and sheltered resting area indoors.

Weather or roof cover did not affect the time spent feeding in our experiment, and neither did the location of feed. Several animals increase their feed intake when exposed to cold conditions in order to boost the metabolic heat production (e.g. sheep: Kennedy 1985, cattle: Young 1981; Schwartzkopf et al. 2002). Our results on the other hand indicate that the sheep were not thermally challenged enough to use this strategy.

Supporting our second prediction, the sheep spent longer time in the outdoor yard when feed was located in the yard, but, the increased time spent in the yard (ca. 10 %) was far less than time spent feeding (ca. 25 %). Total time spent resting was actually somewhat higher when feed was located in the yard, but more important was the large increase in time spent resting in the indoor area. When feed was located indoors, the sheep were also found to be standing and walking more. This suggests that when all feeding activity is in the yard, the area indoors will emerge as a preferred and undisturbed resting area. According to Bøe et al. (2006) 0.75 m^2/ewe is minimum space allowance for resting ewes. In addition to this, locating the feed outdoors will reduce the requirements for indoor space and thus facilitate the change from conventional to organic sheep production. Nevertheless, some of the ewes chose to rest in the yard even when feed was located there. This means that the sheep did not consider the yard to be an especially unfavourable resting area. The fact that all of these ewes were considerably heavier than the overall mean of the group, furthermore suggests that they were not displaced from the indoor area (Hass 1991).

More manure and feed waste was found in the outdoor yards when feed was offered outdoors. Some of this could of course be attributed to more hay waste in these pens compared to in the pens that were fed indoors and it indicates a potential for improvement of the hayfeeder design. Feed waste will however also create a drier and softer flooring and thus improve the quality of the floor in the yard for resting. The rather large daily build-up of manure and feed waste in our experiment (Figure 4) shows that frequent cleaning is imperative. . In conclusion, a roof covering the outdoor yard increased time spent in the yard, it had no effect of feeding time, a limited effect on total resting time, but increased the time spent resting in the yard. Locating the feed outdoors increased time spent in yard, but it also increased the time spent resting indoors, indicating that if a dry and comfortable resting area is offered indoors the feed should be located in the outdoor yard. Utilizing an outdoor yard as part of the total area may be both a cheap and animal friendly way of meeting new space regulations for sheep production. A roof covering the outdoor yard may be beneficial in areas with large amounts of rain and snow in order to preserve surface properties and reduce runoff problems.

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