



Physical and social environment for sheep

- Effects on spacing behaviour, social interactions and activity budgets in housed ewes

(Fysisk og sosialt miljø for sau)

- Effekter på fordelingsadferd, sosiale interaksjoner og aktivitetsbudsjett hos søyer i inneførringsperioden)

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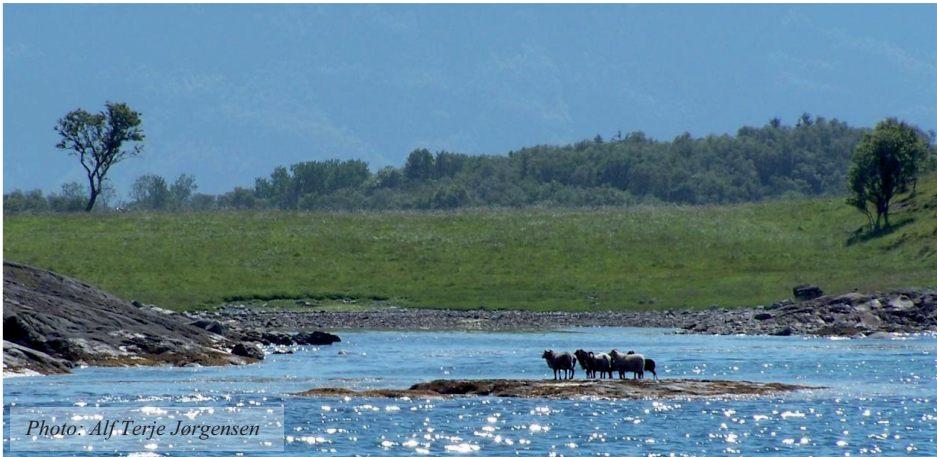


Photo: Alf Terje Jørgensen

"Adapt or perish, now as ever, is nature's inexorable imperative".

H. G. Wells

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SAMMENDRAG

Jørgensen, G.H. M., 2010. Fysisk og sosialt miljø for sau – Effekter på fordelingsadferd, sosiale interaksjoner og aktivitetsbudsjett hos søyer i inneføeringsperioden. Philosophiae Doctor Thesis 2010:49, Universitetet for miljø og biovitenskap, Institutt for husdyr- og akvakulturvitenskap.

I inneføeringsperioden blir sauen ofte holdt i et stimulusfattig miljø med høy dyretetthet og fullspaltegulv, noe som medfører begrenset tilgang til ressurser, hyppig håndtering og lite plass til å trekke seg unna eller unngå sosiale interaksjoner. Dette kan vise seg å påvirke fôroptak, vekst, reproduksjon og generell helse. Gjennom de fem artiklene inkludert i denne avhandlingen har vi undersøkt hvordan det fysiske og sosiale miljøet påvirker fordelingsadferd, sosiale interaksjoner og aktivitetsbudsjettet hos søyer i inneføeringsperioden. Våre resultater er av både teoretisk og praktisk betydning. Nor-x og Spæl sau rasene fordeler seg ulikt i samme miljø og dette kan tenkes å være en effekt av forskjellig seleksjon for produksjonsegenskaper. Sauer foretrekker å ligge inntil en vegg og de konkurrerer om liggeplasser. Å være i store grupper medførte ikke en reduksjon i aggresjonsnivå hos søyer, men synkronitet av både ete- og liggeadferd gikk ned og færre søyer ble observert å stå i kø ved eteplassen. Det er mulig at den begrensede perimeterlengden i de store gruppene kan ha resultert i en økt konkurranse om de beste liggeplassene, noe som understreker hvor viktig det er å tilby nok liggeplasser. Å installere liggeplattformer i fullspaltegulvsbinger kan imidlertid bidra til å øke liggekomforten hos søyer, og slike bør plasseres inntil vegger, være 0.5-0.6 m brede og ha en liten helning slik at urin lettere renner av. Ekstra vegger på liggeplasser medførte ikke en økning i liggetid eller synkronitet av liggeadferd, men søyer utnyttet et uteareal som en del av totalarealet gjennom vinteren og ingen negative effekter av været ble identifisert. Et tak som dekker uteområdet bidrar til å holde underlaget tørt mens fôret bør plasseres vekk fra liggeområdet.

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ABSTRACT

Jørgensen, G.H. M., 2010. Physical and social environment for sheep – Effects on spacing behaviour, social interactions and activity budgets in housed ewes. Philosophiae Doctor Thesis 2010:49, Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences.

Keeping sheep indoors in stimulus poor environments with high densities and fully slatted floors, often involve limited resources, frequent handling and little space to retreat or avoid social interactions. This may in turn affect feed intake, growth, reproduction and overall health. Through the five papers presented in this thesis we have aimed to investigate how the physical environment affects spacing, social interactions and activity budgets in housed ewes. Our findings are of both theoretical and practical importance. The Nor-x and the Spæl sheep breeds display different spacing behaviour in the same environment and this might be an effect of different selection pressures on production traits. Sheep prefer to rest against a wall and they compete for these preferred resting places. Being in larger groups did not decrease the aggression level among ewes, but synchrony of both feeding and resting behaviour declined and fewer sheep were observed to stand in queue for access to feed. It is possible that the limited wall perimeter in larger groups might have resulted in an increase in aggressive interactions for preferred resting space, underlining the importance of providing a sufficient number of resting places. Installing solid resting platforms on top of the slatted floors may increase resting comfort for ewes, these should however be placed in relation to walls, be 0.5-0.6 m wide and have a small slope in order to drain off urine. Installing additional walls on a solid resting area did not increase total resting or resting synchrony. Sheep do utilize an outdoor area as part of the total area throughout winter and no detrimental effects of weather factors were identified. A roof covering the outdoor area helps keeping the surface dry and the feed should be located away from the resting area in order to ensure undisturbed resting.

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LIST OF PAPERS

This thesis is based on the following papers referred to by their roman numerals in the text:

Paper I

Jørgensen, G.H.M., Andersen, I.L., Holand, Ø., Bøe, K.E. Differences in the spacing behaviour of two breeds of domestic sheep (*Ovis aries*) – influence of artificial selection?
Submitted to Ethology

Paper II

Jørgensen, G.H.M., Andersen, I.L., Berg, S., Bøe, K.E., (2009). Feeding, resting and social behaviour in ewes housed in two different group sizes. Applied Animal Behaviour Science 116, 198-203

Paper III

Jørgensen, G.H.M., Bøe, K.E., (2009). The effect of shape, width and slope of a resting platform on resting behaviour of and floor cleanliness for housed sheep. Small Ruminant Research 87, 57-63

Paper IV

Jørgensen, G.H.M., Andersen, I.L., Bøe, K.E., (2009). The effect of different pen partition configurations on the behaviour of sheep. Applied Animal Behaviour Science 119, 66-70

Paper V

Jørgensen, G.H.M., Bøe, K.E. Outdoor yards for sheep during winter – Effect of feed location, roof and weather factors on resting behaviour and activity.
Submitted to the Canadian Journal of Animal Science

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INTRODUCTION

General introduction

Norway produces considerable amounts of lamb meat every year (23 000 tons) compared to neighbouring countries (Finland: 700 tons; Denmark: 2 000 tons; Sweden: 4 100 tons) (Vatn, 2009). This production is largely based on extensive grazing of mountainous pastures during the summer months. During 4 to 6 months of winter however, approximately 1 million Norwegian ewes (SSB, 2010) are normally housed in small groups (6-20 animals) on fully slatted floors and with a relatively high animal density (0.7-0.9 m² per animal) (Bøe and Simensen, 2003). Similar management is found in Sweden, Finland and Iceland (Dýrmundsson, 2006). This intensive housing is practical, firstly due to the large amounts of snow and the need for shelter and additional feeding, and secondly due to the fact that lambing occurs in most regions before spring pasture is fully grown. In the winter feeding period, very few sheep are offered access to an outdoor area. In contrast, some of the sheep production in the United Kingdom is largely based on extensive grazing and little to no housing, with only simple shelters or hedges to protect the ewes against the weather during lambing (Robinson, 1981). Sheep farmers in the USA and Canada provide shelters or simple buildings during lambing, but utilize outdoor areas to a large extent throughout the year (Canadian plan service, 1981; Outhouse, 1981). The new EU regulations for organic sheep farming (Council Regulation (EC) No. 1804/1999) that demand at least 1.5 m² total area per animal, are thus more difficult to introduce in some Nordic countries than in the rest of Europe.

Social behaviour and living environment

Wild sheep are highly gregarious, living in groups between 7 (Soay sheep) and 61 individuals (Bighorn sheep), with an average group size of approximately 8 animals (Grubb and Jewell,

1966; Woolf et al, 1970). Group size and use of space vary according to breed, season, topography and gender (Grubb & Jewell 1974; Lynch et al. 1992; Meldrum & Ruckstuhl 2009) and can to a large extent be explained by resource availability or distribution. Group size and flocking behaviour also change according to predator pressure in the given environment, with larger groups observed in periods with higher predation risk (Hopewell et al., 2005). Wild and feral ewes form groups together with their offspring in one home area, while males form bachelor groups in other home areas (Geist, 1966). The home area is not defended (Hunter and Milner, 1963) and may overlap between different groups. Except for breeds that have evolved around the equator with little differences between seasons, most sheep display seasonal mating and during the rut, groups break up and the males join different female groups (Lynch et al., 1992; Rowell and Rowell, 1993).

Sheep often display a daily pattern of movement within this home area. They camp in high and medium areas during dusk and travel to the lowland areas to graze in the morning (Grubb and Jewell, 1974; Lynch et al., 1992). Daily movements, resting areas and time spent resting is affected by temperature and weather factors (Mysterud et al., 2007) and up to 10 hours per day can be spent resting in the shade in a hot climate (Lynch et al., 1992). Even so, free ranging sheep spend the majority of their 24 hours grazing, up to 13 hours per day when the feed is limited or most commonly in bouts of 20 to 90 minutes followed by bouts of 45 to 90 minutes with rumination and resting (Lynch et al., 1992). Utilization of and movement within the home areas is typically smaller during winter and larger during summer (Grubb and Jewell, 1974; Lawrence and Wood-Gush, 1987, 1988) and wild sheep may have different home ranges according to season (Geist & Petocz, 1977). Synchronization of activities is common in sheep (Rook and Penning, 1991) but it is also used in many gregarious species in order to increase predator avoidance, by swamping predators with vulnerable offspring

through synchronized reproduction (Ims, 1990; Adams and Dale, 1998), sharing the responsibility of vigilance (Roberts, 1996) and thus making more time available for feeding and resting (Penning et al., 1993). Synchrony of resting and activity is also important in order to maintain group cohesion and -stability (Conradt and Roper, 2000).

The social organisation of group living animals into dominance hierarchies is a well known feature that probably has evolved in order to reduce conflicts over limited resources (Lindberg, 2001). Sheep have a sophisticated social organisation (Rowell and Rowell, 1993) where dominance is linked to reproductive success, at least for rams (Pelletier and Festa-Bianchet, 2006). Among female sheep, hierarchies are also evident (Bennett, 1986) but often non-linear (e.g. Eccles and Shackleton, 1986; Hass, 1991), and the direct function of these are somewhat diffuse compared to in the ram groups. While rams compete for access to females in oestrus, females have little resources to compete for as grass is more or less evenly distributed over their home area. This may explain why adult ewes display few aggressive interactions towards each other compared other female ungulates (Fournier and Festa-Bianchet, 1995). When feed becomes limited in space however, i.e. in winter, the competition intensifies also among females, in most domestic species (goats: Masteller and Bailey, 1988; pigs: Brouns and Edwards, 1994; reindeer: Holand et al. 2004). Mouflon sheep affiliate more closely to some individuals than others, and this could be explained by kinship, age or gender (Le Pendu et al., 1995; Guilhem et al., 2000).

Within groups, individuals move towards and away from each other in a dynamic manner (e.g. Matthiopoulos, 2003) and it is imperative that sheep are able to keep a functional space between them; enhancing communication, foraging efficiency and escape response when being attacked by an opponent or predator (Krause and Ruxton, 2002). Individual distance can

be defined as ‘the minimal distance that an animal normally keeps between itself and other members of the same species (Drickamer et al., 2002). This distance has been reported to increase with age in female ungulates (red deer: Hall, 1983; sheep: Guilhem et al., 2000). Different breeds of sheep show different preferences for spatial distribution (Dudzinski and Arnold, 1979; Dwyer and Lawrence, 1999) and both sex (Michelena et al., 2008) and familiarity (Boissy and Dumont, 2002) affects individual distance and the use of space. Merino sheep for example, maintain a mean individual distance when grazing of 1.5 m while Blackface sheep keep 7.5 m between themselves and their nearest neighbours on pasture (Lynch et al. 1992). Furthermore, Crofton (1958) found a range of 13 – 27 m between nearest neighbours of Corriedale sheep at pasture, whereas Sibbald et al. (2008) reported a mean nearest neighbour distance between grazing Scottish Blackface sheep of around 5 meters. When sheep are resting, the individual distance is much smaller; most nearest neighbours were found less than 2 m apart in free ranging Blackface sheep that rested in a shelter (Lynch et al., 1985). This phenomenon of smaller distances when resting than when grazing have been explained by the relatively higher risk of predation and increased escape time when animals are lying down. Similar results have been reported in poultry (Keeling and Duncan, 1991) but little data on differences in spacing according to activity have been gathered in ungulates (Petherick, 2007).

Norwegian sheep breeds

Early archaeological findings suggest that sheep and goats were among the first animals to be domesticated by humans around 11 000 years ago (Lynch et al., 1992; Fisher and Matthews, 2001), most likely arriving Scandinavia during the Stone Age (Chessa et al., 2009). Descending from the European wild sheep; these early sheep were small, had short tails, horns and a variety of coat colours (Chessa et al., 2009). The human management was probably

limited at first, but developed into daytime herding and fencing during night in order to protect the sheep against predators (Drabløs, 1997). Flocking ability and ease of herding were thus probably important early selection criteria. In order to improve meat production, Norwegian farmers started to import sheep from the United Kingdom during the 17- and 1800's (Drabløs, 1997). As the large predators became scarce in the Norwegian fauna, human selection criteria for production traits like fast growth and wool quality became more important than flocking abilities (Zohary et al., 1998), and mainly British breeds were used to create crossbreds in the 1800's (Drabløs, 1997). Some herds of the Norwegian Spæl sheep (Nordic short tail breed group) were however saved by enthusiasts after 1900 with some crossing with similar sheep from the Faroe and Gotland islands and from Iceland, but with minimal influence from other breeds. To this day, the majority of sheep in meat and wool production in Norway are from either the heavy, long tailed composite breed group (mostly Norwegian white) or the from the lighter, short tailed breed group (mostly Spæl sheep).

Extensive and intensive management

A few Norwegian farmers keep their sheep outdoors all year around, but regulations demand that additional feed and shelter is provided (FOR 2005-02-18-160). Many of these farmers usually keep old Norwegian Wild sheep (LMD, 2003), a breed that traditionally has been kept extensively in coastal areas, with little influence from humans. Nowadays, this type of management must be approved by the Norwegian Food safety Authority and farmers are required to keep the herd in a fenced area to make sure that supervision can be maintained, especially during lambing (FOR 2005-02-18-160).

In contrast to common extensive management in Great Britain, USA and Australia, the majority of sheep production in the Nordic countries is based on intensive housing during

winter. Most sheep are kept in groups according to age, the number of foetuses they are carrying and the level of feeding they require. Lambing season is supervised indoors where ewes are separated in individual pens from shortly before to a few days after lambing. Ewes and lambs are then introduced to supervised spring pasture before release on extensive mountain pastures for approximately five months. Lamb survival is quite high, only 4.2 % of Norwegian lambs that are born alive, die in the period from birth to the end of spring pasture (an additional 4.2 % of lambs are stillborn) (Sauekontrollen, 2008). On mountain pasture the losses vary substantially according to the presence of predators (e.g. Warren and Mysterud, 1995; Warren et al., 2001; May et al., 2008) and the average loss at summer pasture in 2008 was 9.9 % of live lambs released (Sauekontrollen, 2008). After the extensive grazing period during summer, female lambs are selected to replace old ewes. Only a few males are kept for breeding, the rest are slaughtered before they reach sexual maturity. The relative cold Norwegian climate is not optimal for the blowfly (e.g. *Lucilia sericata*) and invasive routines like castration or tail docking are thus not needed. Even so, there are several other factors that may affect animal welfare in this form of sheep production.

Challenges in intensive sheep production

Intensive housing and confinement of sheep during the winter months involve handling (Rushen et al., 1986) the risk of heat stress, bad air quality, noise and restricted space to move (Horton, 1991), that in turn may result in serious health problems (Caroprese, 2008). High animal densities and a stimulus poor environment on fully slatted floors may also increase the risk of behavioural problems like wool pulling (Done-Currie et al., 1984). Even though the herds in Norway are still relatively small (20-49 sheep in average), the trend is moving towards fewer and larger herds (Sauekontrollen, 2008). This change in management structure often involve larger groups of animals. Together with a loss of individual control, large

groups are often rationalized so that farmers install fewer feeding and resting places than there are animals, in order to reduce total costs. Animals are hence expected to share the resources effectively and fairly.

In the same way as documented for other production animals (e.g. Fraser, 1983), the common behavioural problems in sheep are indeed aggressive social interactions like displacements from feed and resting areas (Marsden and Wood-Gush, 1986; Bøe et al., 2006; Bøe and Andersen, 2010). Despite the fact that most individuals perform acceptably in intensive systems, the social hierarchy will favour animals with high competition ability. Unless animals are packed too closely to inflict any behaviour at all towards group members (like the case on transports) the amount of aggressive interactions will often increase proportionally with increasing density (Horton, 1991). Another effect of restricted space and high density is the submissive animals' loss of space to retreat far enough from the aggressor, which means that the subordinate animal might experience high levels of agonistic interactions over long periods of time (Lindberg, 2001). It has been shown in many species that this results in a limited feed intake and impaired growth (pigs: Stookey and Gonyou, 1994; goats: Jørgensen et al., 2007; sheep: Bøe and Andersen, 2010; Bøe et al., submitted). Ultimately, a reduced reproductive success (e.g. fur foxes: Bakken, 1993a, b), lower milk yield (sheep: Sevi et al., 2001) and a lower immune response (poultry: Fahey and Cheng, 2008; sheep: Caroprese et al., 2010) could be the outcome. Other studies have found that restricted space allowances reduced milk yield in cattle (Næss et al., submitted) and reduced both milk yield and udder health in sheep (Sevi et al., 1999 a).

New regulations and the search for practical solutions

New regulations for organic sheep farming (Council Regulation (EC) No. 1804/1999) demand a total area of minimum 1.5 m² per animal, and half of this should be a resting area with a solid floor. Since most of the sheep barns in Norway have pens with fully slatted floors and a high animal density, these regulations have large economic implications for the farmer. Either barns must be extended, or the total number of animals must be reduced in order to comply with the demands. Also, half of the total area must be converted from slatted floors to a solid resting area. From this, several questions arise, one of which is of both theoretical and practical interest; how much space do sheep really need? The spatial requirements of an animal consist of the static space + the dynamic space + the social space + some residual space (Baxter, 1984). The static space is the actual space that the animal's body occupy while the dynamic space refers to the extra space needed for posture changes, turning around or movement. The residual space occurs due to the fact that animals are irregularly shaped. The knowledge of the physical size of sheep from different breeds is scarce and mainly related to live evaluations of carcass yields (e.g. Wolf et al., 2001). Nevertheless, it is the social space that is the most difficult to determine, as it is defined as "the space needed to satisfy the behaviour of an animal resulting from the proximity of other animals" (Baxter, 1984). A pen environment will of course limit the individual's ability to retreat or leave the group all together, and the fixed space available will therefore also limit the individual distances that animals can achieve. Nevertheless, very few studies have documented how sheep space themselves in intensive housing situations (e.g. Horton et al., 1991) while there are several examples of differences between breeds in spacing behaviour on pasture (e.g. Lynch et al., 1992; Sibbald et al., 2008).

In many farm animal species kept in intensive housing systems there are records of aggressive interactions decreasing as group sizes increases (fowl: Lindberg and Nicol, 1996; Hughes et

al., 1997; Estevez et al., 2003, 2007; pigs: Nielsen et al., 1995; Turner et al., 2001; Andersen et al., 2004; calves: Færevik et al., 2007; and goats: Andersen et al., submitted). No studies have previously dealt with the effects of group size on aggressive behaviour in housed sheep. This leads us to the following question: can the organisation of sheep in larger groups reduce aggressive interactions during the winter feeding period? One theory explains this effect with the finding that a larger proportion of animals will change towards more defensive strategies in increasing group sizes (Andersen et al., 2004). At the same time, a few individuals with a high competition capacity appear to engage in fights that last longer and are more intensive (Andersen et al., 2004), so increasing group sizes will probably not eliminate the presence of aggressive interactions altogether. The importance of keeping the animal density and access to resources constant when investigating the effects of group size should however be emphasized (Estevez et al., 2007).

Next after feed, a limited space for resting causes most of the displacements in sheep (Marsden and Wood-Gush, 1986). This indicates that a comfortable resting area is a preferred resource worth competing for (Færevik et al., 2005). Sheep prefer to rest against walls when housed indoors (Marsden and Wood-Gush, 1986; Færevik et al., 2005), so wall perimeter is also an important component when sheep are looking for resting areas. Physical partitions have successfully reduced aggressive interactions and displacements for both pigs and cattle at the feed barrier (Andersen et al., 1999; DeVries and von Keyserlingk, 2006), but could perhaps also ensure an effective use of the whole solid floored area as high and low ranked individuals become “out of sight” from each other behind walls. Small lambs will benefit from solid floors that decrease heat loss by conductivity and prevent drafts, in the same way as newly shorn sheep prefer straw covered resting surfaces or floors made of wood rather than expanded metal (Færevik et al., 2005). As an alternative to fully slatted floors, the farmers

may choose deep straw bedding but the availability of bedding material is often scarce, especially in the northern regions, and the litter needs considerable composting before it can be used as a natural fertilizer. If one should install solid resting platforms on top of the slatted floors instead, how should these platforms be designed? Sheep do not seem to have specific dunging areas in a pen environment, so a built-in slope might help to keep the platform drier. How large this slope should be and whether it will affect resting behaviour has not been tested previously. When the total space is small, the space for placing resting platforms is accordingly limited.

Providing only simple non-insulated buildings will reduce the building costs to a large degree. An outdoor area together with an existing building may also help to increase the total area in order to satisfy the new regulations. In regions with cold winters and snow, some kind of housing is needed; especially to protect newborn lambs from severe heat loss (Alexander et al., 1979; Pollard et al., 1999). Nevertheless, unshorn adult sheep seem to have little physical need for insulated buildings (Berge, 1997) as their lower critical temperature is below -30°C (Webster et al., 1969). No negative effects of cold housing have been found on growth, carcass traits or milk yield in sheep (Bøe et al., 1991; Vachon et al., 2007; Caroprese et al., 2009; Pouliot et al., 2009). Various climatic factors will however influence heat loss and the sheep's use of shelter (Curtis, 1981; Done-Currie et al., 1984), while a roof over the outdoor yard might significantly protect the sheep and surface from precipitation. The location of feed will be another important feature affecting the time sheep spend outdoors, as they are probably drawn towards the food. The various effects of feed location, weather factors and the presence of a roof need further investigation before good recommendations can be made for Nordic regions.

AIM OF THESIS

The aim of the thesis is to study effects of the physical and social environment on spacing behaviour, social interactions and activity budgets in housed ewes.

A series of experiments were conducted in order to fulfil the following subgoals:

1. A) To investigate individual distance between sheep during resting and feeding activities
1. B) To check if there are any breed-differences in spacing behaviour within a pen environment
2. To look at the group size and explore if this affects resting pattern and aggressive interactions in ewes
3. To test how different designs of a solid resting platform affect ewes resting behaviour
4. To study if additional pen walls can facilitate an effective use of a solid resting area
5. To investigate if design of outdoor yards and climate factors will affect sheep activity and resting behaviour during winter

METHODS

The methods used in the papers included in this thesis are common and acknowledged in behavioural sciences. These involve direct observations in live time (Paper III), instantaneous sampling from still pictures (Papers I, II, IV and V), and continuous observations (Paper II and IV) from video. All experiments were done with groups of sheep, rather than individuals. The experiments often reflect common practise in Norwegian sheep husbandry and no aversive interventions like blood samples or feed deprivation were employed. The feeding and housing conditions were kept very similar within experiments, and animals were provided with experimental conditions that gave more space (a minimum of 1.5 m² per animal) than in their home pen (Papers I, II, IV and V). Animals were also given free access to good quality roughage (Papers I, II, IV and V). Even though the sheep came from the same herd, and were familiar with each other, the division of animals into smaller groups may disrupt the social dynamics so that new hierarchies have to be established before the group can settle down. We therefore gave them at least a week to habituate to the experimental pens, feeding routines and their new environment before any behavioural recordings were performed (Papers I-V).

Paper I

Eight groups of four pregnant ewes from the Nor-X breed (a heavy, composite breed mainly selected for growth and meat quality) and eight groups of four pregnant ewes of coloured Spæl sheep (a light breed, mainly selected for wool quality) were placed in oblong experimental pens (12 x 2 m) for 7 days. Pens had a solid resting area of wood (12 x 0.6 m) and an open horizontal feed barrier running along the 12 m long side opposite to the resting area. Black stripes for every 0.5 m were painted on the resting area and on top of the feed barrier in order to measure distance between pairs (6 possible pairs per group) from instantaneous sampling pictures drawn from 24 hour digital video recordings. Distance and

body orientation (Head to Head; Head to Back; Back to Back) during resting was recorded every 15 minutes from 1800 to 0600 hours while distance during feeding was recorded every 2 minutes for two hours immediately after morning (08:00) and evening (15:00) refill of hay.

We chose to measure the distance between every possible pair in the group to be able to compare individual distance, body orientation and weight differences. This way we in fact investigated the group cohesion rather than only the nearest neighbour distances, as the distance between the two ewes resting or feeding the furthest apart also was measured. The two breeds compared were different in mean body weight, the Nor-X breed weighing in average 22 kg more than the Spæl ewes, but this did not affect how much space each breed occupied on the resting area. Both Spæl sheep and Nor-X seemed to fit within three stripes or approximately one meter when resting on the platform (Figure 1).



Figure 1. Pictures from video showing space occupied by Nor-X sheep (left) and Spæl sheep (right) during resting. The lower pictures also demonstrate the breed difference in spacing behaviour.

Studies have in fact documented that the body length change little according to increased body weight (e.g. Janssens and Vandepitte, 2004).

An alternative way of exploring individual distances and spacing behaviour might be to observe animals in a larger pen without feed or other resources that they might be drawn towards. The advantages of this set-up are many; the ability to track each individual's movement in relation to group mates in a more dynamic way, for one, is very exiting. Secondly, the spacing behaviour and individual distance could be measured in two dimensions without being confounded by resource location. Since we, in the present experiment, forced the animals to rest and feed in given areas, we could however measure the distance between them more accurately. Furthermore, both feed and resting areas are found in commercial sheep barns, emphasizing the relevance of our results for future space recommendations.

Paper II

During an initial period of 14 days, 36 adult (2-6 years old) ewes of the domestic Norwegian Dala breed were divided into four groups of 9. In the second period (14 days), these ewes were merged into one group of 36 ewes. This experiment was repeated with a second batch of ewes, but this time starting with a group of 36 individuals in the first period, then splitting them up into four groups of 9 ewes in the second period. Space allowance per ewe (1.5 m^2) and number of feed openings (3 ewes per feeding place) was kept constant regardless of group size. Good quality hay was fed *ad libitum*. From 24 hour video recordings we scored the following activity behaviours using instantaneous sampling every 10 minutes: feeding, resting, queuing, standing/walking and other behaviours.

Our experimental set-up gave eight small groups and only two large groups which of course is unfortunate. The reason for this was limited resources, facilities and number of sheep available at the time. I would however argue that since we measured behaviour on individuals and followed the same individuals from large to small group sizes or vice versa, there were few alternative design options. Keeping the same management and level of resources, we assumed that any differences between groups were related to the treatments, and group was treated as a random effect in our statistical model.

Paper III

The experiment was conducted in three different commercial farms in Norway, within each herd, two of the factors; shape (U-shaped, L-shaped or platform both in front and back (FB-shaped) of the pen), width (0.5 or 0.6 m) or slope (0; 5 or 10%) of a solid wooden resting platform were tested in a 2 x 2 factorial design using four experimental pens per herd. The effect of cleaning frequency (daily or every other day) was replicated within herd using four additional experimental pens (eight experimental pens in total within each herd). Eight groups of ewes were systematically rotated between pens within herds, and the ewes' use of the resting platforms (resting on the platform, resting on the slatted floors, standing) was scored the last six days of each experimental period. The manure on the solid resting platforms was collected and weighed while moisture on the surface of the resting platforms was scored using four predefined categories, the two last days of each experimental period.

The farmer went into the barn at a quiet time of the day and scored the number of sheep resting and there is always a chance that the animals are affected by the presence of the observer when choosing this method of observation. The sheep should however habituate to the observer quite rapidly, and one of the strengths of this experiment was the many replicates

per farm, where eight different groups were rotated through the treatments. The results were also applicable for practical recommendations and valuable comments from the farmers were included in the study.

Paper IV

A total of 24 adult pregnant ewes of the Nor-x breed were rotated between five treatment pens and one control pen (each with four ewes) in a Latin Square design. In five treatment pens solid walls were mounted on the resting area in different configurations (parallel wall: PAR; cross wall: CRO; perpendicular wall, PER; resting cubicles: CUB and three walls: THR) (Figure 2), while one pen was kept without additional walls (control: CON). From 24 hour video recordings the general activity (feeding, resting in contact with original pen wall, resting in contact with additional wall, resting in the activity area, blocking access to resting area etc.) was scored using instantaneous sampling every 10 minutes during the entire 24 hours. Social interactions (displacements, unsuccessful displacement attempt and head butting) were scored continuously for six hours during daytime (from 1000 to 1600 hours).

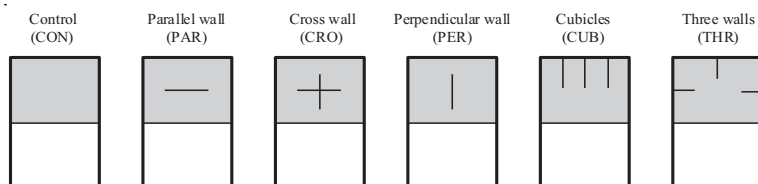


Figure 2. The six experimental pens and the different configurations of additional walls.

The pen dimensions were chosen according to the new regulations for organic farmed sheep that demand a total area of 1.5 m² per animal and 0.75 m²/ewe solid resting area. One could of course speculate how the sheep would utilize the additional walls if they had been given more space or a resting area of a different shape, but providing a larger total area than this is

probably not realistic for most commercial farmers. These wall configurations will of course decide the resting pattern and guide the direction that sheep are able to keep according to each other. This was however an effect we wanted to take advantage of and hypothesized that the “out of sight, out of mind” effect of the solid walls would help to make more sheep utilize the limited resting area simultaneously.

Paper V

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 (Figure 3).

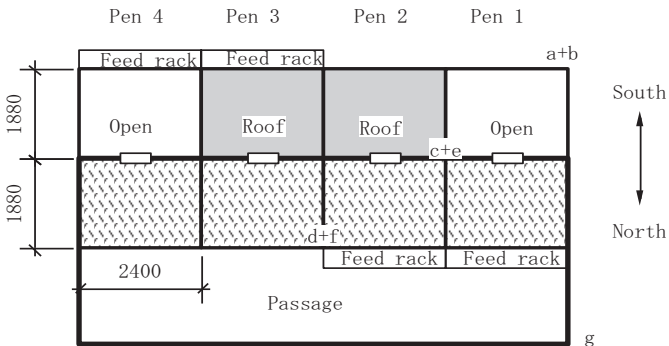


Figure 3. Experimental building with the four pens, feed location and presence of roof over the outdoor yard. The building was non-insulated and had a passage indoors.

Twenty adult ewes of the Norwegian White breed were randomly allotted to 4 groups with 5 animals. Good quality hay and water was provided *ad libitum* and groups were kept in each pen for one week before being systematically rotated to another pen. Weather factors were divided into five exclusive categories: 1: mild (more than 0°C), no rain; 2: mild, with rain; 3: cold (-1 to -12°C), no snow; 4: cold, with snow; 5: very cold days (average temp below -12

°C). The following behavioural parameters were scored per individual using instantaneous sampling every 15 minutes throughout 24 hour video recordings: location (indoors or outdoors), general behaviours (stand/walk, resting, feeding).

Again, the space allowance was chosen according to the new regulations for organic farmed sheep, but a much larger outdoor area than the one tested in this experiment could very well be prepared. The costs of mud-proofing an outdoor surface will nevertheless be smaller than the costs of extending the building. Alternative solutions for solid floors indoors could also be investigated and the floor properties under different temperatures are of major importance for time spent resting (Færevik et al., 2005) and the practicality of utilizing this building also during lambing season.



Photo: Kleo Delaveris

SUMMARY OF RESULTS

Paper I

Regardless of breed, the mean individual distance between group members was 2.2 m during resting and 2.7 m when animals were feeding. The Nor-X ewes kept a significantly larger individual distance to their pen mates both during resting and feeding, compared to the Spæl ewes. Spæl ewes also kept a significantly smaller individual distance during resting than during feeding, but this difference according to activity was not found in Nor-X ewes (Figure 4). More than 50 % of all resting observations were registered as sheep resting in a “Head to Back” orientation and the Nor-X breed kept larger individual distances when resting in a “Head to Head” orientation than when orientated “Back to Back”. Looking at the selection history of these two breeds we discovered differences in how long they had coexisted with large carnivores. Our results indicate that selection for growth and meat quality might influence spacing behaviour and recommend that similar anti-predator strategies are further investigated in other breeds and species.

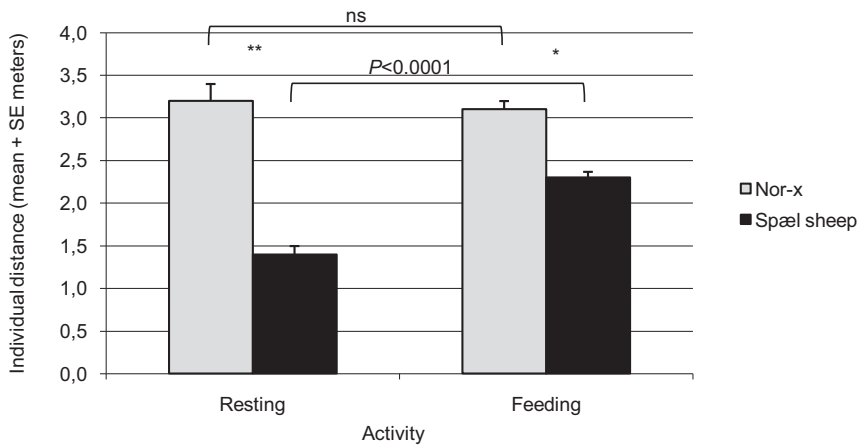


Figure 4. Breed difference in individual distance when feeding and resting.

Paper II

Ewes in large groups (36) had a larger variation in resting time at day one, less synchronized resting (Figure 5) and eating behaviour, and spent less time queuing at the feed barrier compared to in the small group size (9). There were no effects of group size on aggressive interactions or feed intake. In conclusion, a larger group size decreased synchrony in resting and feeding behaviour and reduced the time spent queuing in front of the feed barrier. It is possible that the aggression level in sheep is more sensitive to changes in space allowance than to changes in group size per se.

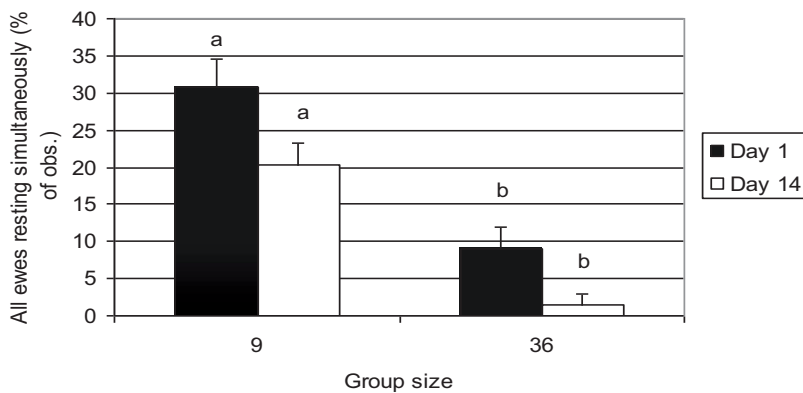


Figure 5. Resting synchrony in ewes according to group size and time spent in the group.

Paper III

In all herds, significantly more sheep were observed resting in pens with FB-shaped resting platforms than in pens with U- or L-shaped platforms. A reduced time on resting platforms was mainly compensated for by an increase in number of sheep resting on the slatted floor and partly by an increase in the number of sheep standing. An effective perimeter length (EPL) of minimum 0.9 m/ewe was necessary to enable all sheep to rest simultaneously on the resting platform. Increasing the slope of the resting platform had no effect on the resting

behaviour, but decreasing the width of the platforms resulted in more ewes resting on the slatted floor. A slope of 5 % resulted in a significantly lower amount of manure and a lower moisture score. In two of the herds, cleaning out every second day increased the amount of manure, but not the moisture score. In conclusion, resting platforms of solid wood may be a relatively cheap and convenient way of increasing the resting time and comfort of sheep housed in fully slatted floor pens, as long as there is sufficient effective perimeter length available.

Paper IV

No significant differences were found between the different configurations of additional walls in total resting time, resting synchrony or displacement behaviour. However, when housed in the CUB configuration, the ewes performed more blocking behaviour, consequently resulting in more ewes resting in the activity area. More head butting was observed in the THR treatment than in the CRO treatment. In conclusion, additional walls did not increase the resting time, reduce aggressive social interactions or increase the synchrony of resting behaviour in ewes. It is probably more important for sheep to have enough resting space to lie simultaneously and the ability to keep within visual contact with group mates, than to avoid physical contact.

Paper V

Weather factors did not seem to have any large influence on sheep behaviour (Figure 6) but on days with mild weather and rain more sheep were resting in the outdoor yards that were covered with a roof compared to in yards without such a roof. A roof covering the outdoor yard also increased the time spent in the yard, but had no effect on time spent feeding. Locating the feed outdoors increased the time spent in the yard, but also increased the time

spent resting indoors, indicating that if a dry and comfortable resting area is provided indoors, the feed should be located in the outdoor yard. In conclusion, precipitation affects sheep use of outdoor yard more than low temperatures per se. The presence of a roof over outdoor yards may be beneficial in areas with a lot of precipitation. Sheep seemed to choose a resting place away from the feed location.

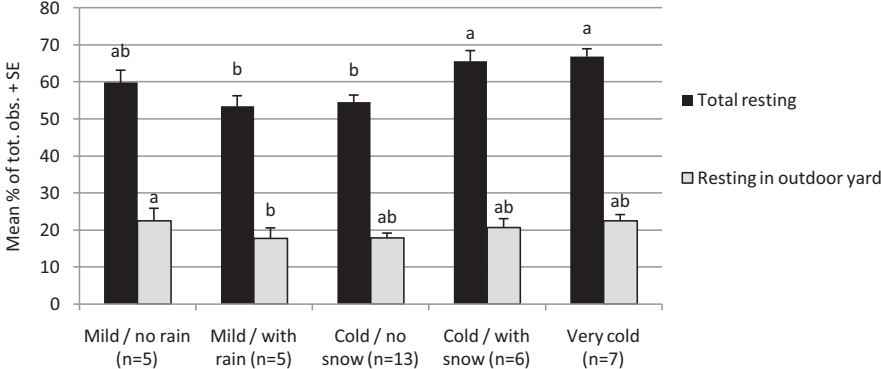


Figure 6. Effect of weather on resting behaviour in sheep during winter.



Norwegian Wild sheep. Photo: Kleo Delaveris

GENERAL DISCUSSION

Individual distance

Maintaining some individual distance is not only important to ensure an effective fleeing response under a sudden predator attack (Krause and Ruxton, 2002), but it is also necessary in housed situations in order to give the animal time to redirect its movements if it comes too close to another individual within the social group. In Paper I we investigated the spacing behaviour of sheep in a pen environment and found a mean individual distance between pairs of sheep of 2.2 m when resting and 2.7 m when animals were feeding. In theory, one could expect group living animals to distribute themselves over an available area in a manner maximizing the individual distance between them, but there is always a limit of how far apart they will disperse. This is linked to the need for maintaining group cohesion and thereby the protective benefits of living in groups (Michelena et al., 2008). Our methods of measuring the mean individual distance between all possible pairs in each group did in fact consider the group cohesion (Paper I) rather than the nearest neighbour distances as opposed to most studies reporting the spacing of grazing sheep. These studies also report very different distances, from 1.5 m in Merino sheep (Lynch et al., 1992) up to 27 m in Corriedale sheep (Crofton, 1958). It might however be argued that providing only a 12 meter long pen was limited in order to investigate spacing behaviour in Paper I, and that sheep on pasture will keep much larger individual distances. Keeping the gender and age constant, we only changed between the breeds, using the same stable environment (Paper I). The pen also reflects the actual housing conditions to a larger extent than observing spacing at pasture, we had fixed reference points for distance measurement and the results could prove helpful when evaluating minimum spatial requirements in the new regulations for housed sheep.

Interestingly, the Nor-x sheep kept larger individual distances between themselves and their pen mates compared to the coloured Spæl sheep (Paper I). Studies comparing farmed fish and their wild counterparts suggest that artificial selection for growth might unintentionally have decreased the threshold for performing agonistic behaviour (Ruzzante, 1994; review: Huntingford and Adams, 2005). The two breeds of sheep compared in Paper I have indeed experienced different levels of artificial selection for growth (Eikje, 1979; Kvame, 2005). In captive environments, resources are often limited in space and individuals that assume offensive strategies and show more agonistic behaviours will gain access to more food and resting space (Dumont and Boissy, 2000; Boissy and Dumont, 2002). If this natural selection within the domestic environment is combined with a strong artificial selection for growth, larger individual distances might also be expected as animals try to keep out of each others way to avoid costly aggressive contact (Ruzzante, 1994). Contrary to this theory, most articles comparing behaviour in breeds that have been more, and breeds that have been less selected for production traits reveal a common trend; high yielding breeds are more docile and they spend more time feeding and less time in social interactions (poultry: Vaisanen and Jensen, 2004; cattle: Sæther et al., 2006). This is explained by the theory of resource allocation (Schütz and Jensen, 2001). If an offensive behaviour strategy gives more food than a defensive one, this might however not contradict the findings of larger individual distances and more aggressive interactions among highly selected breeds compared to their wild ancestors (Ruzzante, 1994).

Tight flocking behaviour and small individual distances have been recognized as an efficient anti-predator behaviour (review: Lima and Dill, 1990) and many ungulates display smaller individual distances in situations where animals are more vulnerable to attack (e.g. cattle: Shiyomi and Tsuiki, 1999; Sheep: Michelena et al., 2008). Free ranging sheep also keep

closer to their nearest neighbours when resting than when grazing (Lynch et al. 1985; Le Pendu et al., 1996; Blanc et al., 1999). In Paper I we discovered the same effect in the Spæl sheep, but no such difference in the Nor-x sheep. This might indicate that the coloured Spæl sheep display a stronger anti-predator behaviour than Nor-x sheep. Animals isolated on islands without predator pressure can very well lose or modify some of their anti-predator strategies (Blumstein and Daniel, 2005), and the British Isles have been devoid of large carnivores like bears since the 11th century and wolves since the 17th century (Schwartz et al., 2003). In contrast, sheep in Norway have lived together with bears and wolves until the early 1900's (Swenson et al., 1994) and now the carnivore populations are increasing. If the differences in spacing behaviour were large enough between the early Norwegian Spæl and the British ancestors of the Nor-x sheep, then these behavioural mechanisms might still be visible today, after a rather limited time under similar intensive husbandry. The results from Paper I fit very well with this hypothesis and our findings are supported by Hansen et al. (2001) who found that the Old Norwegian Wild sheep keeps closer together than the Norwegian White composite breed when exposed to predator-related stimuli at pasture. Furthermore, Sibbald and colleagues (2009) discovered that sheep assigned to a 'shy' personality category maintained smaller nearest-neighbour distances than sheep that were categorized as having a 'bold' personality. Although highly anecdotal, it is still a common view among sheep farmers that sheep from the short tailed breed group are more shy and easier to gather down from mountain pasture than the heavier, long tailed breeds.

Social interactions

The common agreement that sheep display few aggressive interactions towards group members (Fournier and Festa-Bianchet, 1995) might easily create a false security that it never happens (Done-Currie et al., 1984) and that it is therefore not likely a source of stress. Both in

Papers II and IV, the most common aggressive interaction was pushing and kicking in order to displace other ewes from the resting and feeding area. Although not as extreme as in experiments with limited resting space (in average 16.2 displacements per ewe / day: Bøe et al., 2006), the number of displacements in total were considerable (mean 7.2 incidents per ewe in Paper II and 4.7 in Paper IV). One might for instance expect that a subordinate ewe would try to maximize her distance to a dominant ewe, especially if they are oriented “Head to Head”. This relates to the notion that the personal sphere, that is, “the area around an individual which it tries to keep free from conspecifics” (Keeling, 1995), is larger around the head of the animal (McBride, 1971). In paper I, over 50 percent of resting observations were scored as pairs lying in a “Head to Back” orientation, and Nor-x pairs lying in the intimate “Head to Head” orientation did so with larger individual distances than pairs lying “Back to Back”. Lynch and colleagues (1985) also described sheep trying to manoeuvre so that they did not face another sheep when resting in a shelter.

Another important phenomenon is synchrony of maintenance behaviours as described in several species (cattle: Fregonesi and Leaver, 2001; horses: Boyd and Bandi, 2002; Rifa, 1990; sheep: Michelena et al., 2006). In all but one paper (Paper III) included in this thesis, the synchrony of resting behaviour was measured, revealing a strong motivation for all members of small groups to rest simultaneously. About 60-70 % of all resting observations were scored in complete synchrony in Paper I and although the mean resting synchrony was smaller in Paper II, it declined significantly when groups increased from 9 to 36 animals. This has also been found in grazing sheep where large groups have become less synchronous (Boissy and Dumont, 2002) and an increased individual variation in resting time in the largest group indicate that some individuals show a substantial decrease in time spent resting (Paper II). As previously mentioned, many sheep farmers make the animals share a limited number

of feed barrels, water bowls and resting space, and limited resting space has been documented to cause a significant reduction in resting time for lower ranked dairy goats (Andersen and Bøe, 2007). Correspondingly, a reduction in the number of feeding places might not reduce the time spent feeding or the actual feed intake to a great extent at group level, but the major increase in displacements more than suggest that subordinate individuals also reduce their feed intake substantially (dairy goats: Jørgensen et al., 2007; sheep: Bøe and Andersen, 2010; Bøe et al., submitted).

Group size

Several experiments have shown that animals display fewer aggressive interactions when kept in large groups than in smaller groups (fowl: Lindberg and Nicol, 1996; Estevez et al., 2003; pigs: Nielsen et al., 1995; goats: Andersen et al., unpublished), and in pigs for instance, more individuals will change towards defensive strategies as group size increase while only a few animals will succeed when competing for resources (Andersen et al., 2004). In Paper II we tested the hypothesis that also ewes in large groups would show fewer agonistic interactions than ewes in smaller groups, but the results did not reveal a difference between group sizes. This may be explained by the relatively low level of aggressive interactions recorded, combined with the fact that ewes were given ample space (1.5 m², Paper II). On the other hand, sheep have been reported to visually recognize at least 50 other individuals (Kendrick et al., 2001), but when group sizes increase above this limit of recognition, each individual might not be able to claim and maintain social dominance. It is thus possible that marked reductions in the amount of aggressive interactions could only be found in groups of more than 50 ewes. One should however keep in mind that sheep have evolved to live in large groups that are divided into subgroups during migration and grazing (Festa-Bianchet, 1988; Boissy and Dumont, 2002). Perhaps this dynamic change in group size makes sheep more

tolerant towards new group members compared to pigs, cattle and goats, and thus the basis for comparison of aggression between group sizes disappears.

Care was taken to keep the number of ewes per feeding place and the space allowance constant between group sizes (Paper II), since limitations in these factors have previously confounded and maybe also concealed group size effects in several experiments (review: Estevez et al., 2007). Stricklin et al. (1995) found that the ratio of perimeter to area decreases as group size increases, when the space allowance is kept constant in a square pen, and the same effect emerged in our experiment (Paper II). It is possible that the decrease in perimeter length per ewe in the largest group size (0.6 m / ewe vs. 1.4 m /ewe in small groups) may have contributed to an increase in competition for attractive resting places (Bøe et al., 2006), and thus outweighed the predicted reduction in aggression in larger groups (Paper II). It should however be mentioned that previous results suggest that high animal densities probably impose a greater threat to animal welfare (Horton, 1991; Sevi et al., 1999 a) than group size *per se* (Sevi et al., 1999 b), supporting our findings in Paper II.

Resting behaviour, platforms and pen partitions

Resting is for ruminants especially important in order to fulfil their digestion process, and a study using operant conditioning show that cattle have a highly prioritized and inelastic behavioural need for resting (Jensen et al., 2005). Also sheep compete and displace each other quite frequently when resting space becomes limited (Bøe et al., 2006). The general activity was scored day and night in three of the papers, revealing a mean proportion of time spent resting of 59.3 % (Paper V), 63.6 % (Paper II) and 70.2 % (Paper IV). These results underline the importance of a comfortable resting area (Færevik et al., 2005), and one way to provide this in fully slatted floor pens is to install resting platforms of solid wood.

We found that the ewes used the resting platforms actively, but the number of sheep resting on solid resting platforms was closely related to the effective perimeter length (EPL) available in each pen (Paper III). This is again an expression of the sheep's preference of resting against a wall (Marsden and Wood-Gush, 1986; Færevik et al., 2005; Paper II) and only when the EPL was as long as 0.9 m/ewe could all sheep be observed to rest simultaneously (Paper III). Body measurements of ewes weighing 80 kg (similar to the Norwegian white breed) show that they have a body length of around 0.8 m from the point of the shoulder to the pin bone (e.g. Riva et al., 2004), further supporting our estimate. Introducing solid floors are always challenging in order to maintain hygiene and health, but we found that a built-in slope of 5 % resulted in less manure on the resting platform and also a reduced moisture score (Paper III). The slope did however not affect resting behaviour to a large degree (Paper III), but our narrow resting platforms also restricted the ewe's freedom to choose other resting patterns or positions. In earlier experiments with loose-housed dairy cows given moderate slopes (8-10 %) on the resting area, Keck et al. (1992) found that slopes modified the resting pattern but not the time spent resting, whereas another study with fattening bulls reported more incidents of slipping and falling when resting areas sloped more than 5 % (Schulze Westerath et al., 2006). A width of 0.50 m is probably sufficient for ewes of smaller breeds and a wider resting platform not only accumulated more manure but also took up more of the total space in the pen (Paper III). Larger animals on the other hand might need wider platforms, and towards the end of the pregnancy ewes become substantially wider over their backs. During this period it is also increasingly important to provide a comfortable resting area.

In an attempt to increase the effective perimeter length and thus maybe ensure that all individuals could utilize a limited resting area, we installed additional walls that the ewes

could lean against when resting. The provision of such additional walls did not decrease the number of displacements; neither did it affect total resting time or the synchrony of resting (Paper IV). To my knowledge there have been few studies looking at the effects of additional walls on the resting pattern of farm animals (cattle: Aland et al., 2009; goats: Ehrlenbruch et al., 2010), and none could be found for housed sheep. In paper IV we therefore had to provide first-hand designs of the additional walls. When placing additional walls in the middle of this rectangular resting area we expected the sheep to take advantage of the whole area, included the space behind walls. Instead, we witnessed multiple incidents of ewes lying down and effectively blocking the access to the resting area from other ewes, as they were very reluctant to step or jump over each other. Access to the resting area was thus blocked, but the resting synchrony in the group was maintained by ewes lying down in the uncomfortable activity area instead (Paper IV). In the cubicle treatment especially, the sheep rested more in the activity area (Paper IV) and this was due to blocking, the strong need for maintaining behavioural synchrony (Rook and Penning, 1991) and a preference for maintaining visual contact with group mates (Crofton, 1958). Since the additional walls were solid, they did not facilitate vigilance to the sides, and in the cubicle treatment some ewes even backed into the cubicles before lying down.

The continuous finding that sheep prefer to rest against walls when kept in a pen environment (Marsden and Wood-Gush, 1986; Færevik et al., 2005; Paper II) is rather intriguing. It might simply be a feature of resting comfort, facilitating rumination and helping to keep their heads in a better position for periodic vigilance. On the other hand, it may only be a result of the high density environment where seeking out the perimeters of the pen for resting is necessary to avoid being stepped on. Interestingly, free ranging Soay Sheep also display a preference for resting “to the leeward of banks, rocks or tussocks of grass” (Grubb and Jewell, 1966), and

this might in turn be an anti-predator strategy where vigilance is reduced to fewer directions. Furthermore, Blackface sheep on pasture have also been reported to gather within a shelter and rest with a space of less than 2 m between individuals (Lynch et al., 1985). This strengthens the theory that sheep do not have the same need for physical separation that dairy goats display (Bøe et al., 2006; Andersen and Bøe, 2007). Interestingly, deep pens of the same size as the ones used in Paper IV gave similar resting times as pens with a wide shape (Bøe et al., 2006), but the narrower resting platforms tested in Paper III were promising as sheep seemed to prefer resting on these than on the slatted floors.

Utilization of outdoor areas

Making use of an outdoor area as part of the total area for housed sheep could be a cost effective solution to increase space allowance. Weather factors on the other hand, have the potential of challenging the ewe's thermoregulatory behaviour to a large extent (Webster et al., 1969; Bennett, 1972; Curtis, 1981), especially in the northern regions of Scandinavia. In Paper V the weather factors did not affect the proportion of time sheep were observed in the outdoor yards, feeding or standing/walking but on days with mild temperatures and rain, the ewes reduced both total resting and resting in the outdoor yards (Paper V). Precipitation in the form of rain increases both heat loss and the lower critical temperature markedly (Curtis, 1981; Mount and Brown, 1982). The main strategy for reducing heat loss in sheep seems to be a reduction of resting time (Færevik et al., 2005). Thus, the finding that more sheep chose to rest in the outdoor yards that were covered with a roof is perhaps not surprising (Paper V). The importance of a dry surface in the resting area has also been demonstrated for cattle (Gonyou et al., 1979; Redbo et al., 2001; Webster et al., 2008), horses (Mejdell and Bøe, 2005) and dairy goats (Bøe, 2007) in earlier experiments. The presence of a roof over the outdoor yard also resulted in ewes spending more time outdoors and they performed more

synchronous resting. Interestingly, weather factors, feed location or roof cover did not affect the time spent feeding (Paper V), indicating that although the resting pattern was changed the feeding behaviour neither declined nor increased according to treatments. One could expect an increase in the *ad libitum* feed intake in order to boost the metabolic heat production if the environment threatened their ability to maintain body temperature (e.g. Kennedy, 1985).

When the feed was located in the outdoor yard, time spent resting in the indoor area increased (Paper V). Ewes were also standing and walking more in pens where the feed was located indoors (Paper V), suggesting that sheep prefer a spatial separation between the feeding and the resting area so that resting ewes are not disturbed by traffic. This is supported by a study from the eighties that described ewes using different parts of their pen for different activities, most of the ruminating sheep were found close to areas with solid boundaries that sheep could rest against, while most standing sheep were found in open areas with much traffic (Marsden and Wood-Gush, 1986). Utilizing an outdoor area can bring about challenges related to the management of mud, manure and waste water. The relatively large build-up of manure and feed residues in our outdoor yards revealed the need for cleaning on a daily basis (Paper V). This build-up is of course smaller and more distributed if a larger outdoor area is used, but costs of surface preparations will increase proportionally with the size of the outdoor area (Andersson, et al., 2007). The presence of a roof over the outdoor area will however contribute to a drier surface and drier manure that could be regularly gathered by tractor.

CONCLUDING REMARKS

The mean individual distance between sheep, regardless of breed was 2.2 m when resting and 2.7 m when ewes were feeding. Different breeds of sheep display a different spacing behaviour in the same housing situation. Ewes from the large composite Nor-x breed kept larger individual distances between themselves and group mates compared to the smaller coloured Spæl sheep, both during resting and feeding. Only the Spæl sheep kept significantly closer together during resting than when feeding, a proposed anti-predatory strategy not found in the Nor-x breed (Paper I). Sheep prefer to rest against a wall, a notion that was supported in all papers included in this thesis. Although the reason for this might be unclear, sheep regard wall space at their resting area as preferable and a resource worth fighting for (Paper II). The social behaviour of adult ewes is complex and appears to be less dependent upon group size than space allowance and the organisation of limited resources within the space (Paper II). When building solid resting platforms, a length of at least 0.9 m per ewe should thus be provided in connection with a wall (Paper III). Installing additional walls on the resting platform did however not increase the total resting time and synchrony of resting. This was probably due to the walls restricting visual contact with group members and the ability for some individuals to block access to the resting area from others (Paper IV). In order to increase the total space for housed sheep, the utilization of an outdoor area could be a cost effective solution, also during winter. The weather factors had minor influence on resting behaviour and no effect on time spent feeding. A roof covering the outdoor yard is practical in areas with a lot of precipitation but more important is the division between functional areas, so that resting ewes are not disturbed by ewes that are feeding (Paper V).

Practical applications

Keeping sheep in large groups does not seem to be a problem as long as they can all get access to feed and a comfortable resting place. Care must be taken if resources are limited as some lower ranked individuals might experience serious food deprivation if they are constantly displaced from the feed barrier. Installing a narrow resting platform on top of the slatted floors is an easy and convenient way of increasing the resting comfort of housed ewes, but the platforms should be located along walls and give at least 0.9 m wall length per animal. A built-in slope of around 5 % helps keeping the platforms dry and the width of the platform should be adjusted to the sheep breed. These solid platforms could also be hinged to the walls so that they are used only in periods where they are required. Utilizing an outdoor area as part of the total area seems to be an effective way of increasing the total space per ewe.

Preparation of the surface outdoors is however of major importance as it improves hygiene and facilitate regular removal of manure and feed residues. The feed should be located away from the resting area and even though the whole outdoor area is not covered with a roof; the feed itself should be covered in order to maintain the quality.

Suggestions for further research

During winter, our sheep are expected to thrive in large animal densities; they are regularly handled by humans, they should grow fast and produce many lambs while sharing limited resources. When the summer comes the same sheep are released on extensive rangeland and mountain pastures. Here, the environment is quite different and the sheep are expected to show optimal anti-predator behaviour with a tight flocking ability, to look after their lambs and to have the knowledge to seek shelter from weather and avoid poisonous plants. In my

opinion, this is very difficult to obtain without a major research effort on interaction effects between genotypes and environments (e.g. Dwyer and Lawrence, 1999).

The phenomenon that experience from being in a large group appear to reduce the competition level in later group situations (e.g. Buchwalder and Huber-Eicher, 2005; Andersen et al., submitted) should be further investigated in sheep, especially since the farm structure is changing towards bigger farms and groups. Also the utilization of an outdoor area as part of the total area should be tested in areas with a lot of precipitation combined with wind. Especially important are the practicalities around lambing and lamb survival in such systems. Knowledge on the lamb's preference for different surface properties is also lacking. Local variations in climate and the availability of straw to create deep straw bedding indoors should be taken into consideration and alternative litters like peat or wood chips must be investigated, especially in relation to the later utilization of the manure as fertilizer that is of major importance in organic farming systems.



Sheep at the Norwegian University of Life Sciences. Photo: GHM Jørgensen

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Norwegian Wild Sheep caught by the tide. Photo: Alf Terje Jørgensen



Mouflon sheep at Langedrag. Photo: GHM Jørgensen

*“An education isn't how much you have committed to memory, or even how much you know.
It's being able to differentiate between what you know and what you don't”*

Anatole France

Differences in the spacing behaviour of two breeds of domestic sheep (*Ovis aries*) – influence of artificial selection?

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ABSTRACT

The aim of this experiment was to investigate differences in spacing behaviour, measured by the individual distance when resting and feeding, between two breeds of sheep with a different selection history. Eight groups of four pregnant ewes from the Nor-X breed (a heavy, composite breed mainly selected for growth and meat quality) and eight groups of four pregnant ewes of coloured Spæl sheep (a light breed, mainly selected for wool quality) were placed in oblong experimental pens (12 x 2 m) for 7 days. Pens had a solid resting area of wood (12 x 0.6 m) and an open horizontal feed barrier running along the 12 m long side opposite to the resting area. Black stripes for every 0.5 m were painted on the resting area and on top of the feed barrier in order to measure distance between pairs (6 possible pairs per group) from instantaneous sampling pictures drawn from digital video recordings. The heavy Nor-X ewes kept a significant larger individual distance to their pen mates both during resting and feeding compared to the lighter Spæl ewes. Spæl ewes also kept a significant smaller individual distance during resting than during feeding, but this difference according to activity was not found in Nor-X ewes. Looking at the selection history of these two breeds we discovered differences in how long these breeds had coexisted with large carnivores. Our

results indicate that selection for growth and meat quality might influence spacing behaviour in sheep. The role of domestication on this phenomenon is also discussed.

INTRODUCTION

Animals' flocking behaviour is primarily influenced by resource availability and distribution (Gills & Kramer 1987; Matthiopoulos 2003), or predator pressure (Hamilton 1971). In groups of free-ranging sheep, the use of space vary according to breed, season, topography, forage availability and gender (Grubb & Jewell 1966; Lynch et al. 1992; Meldrum & Ruckstuhl 2009) and can to a large extent be explained by resource availability or distribution as well as the breeds' domestication history. Animals that have undergone domestication can be recognized by rapid changes in phenotypic traits (Jensen 2006), the most important behavioural changes being reduced fear and anti-predator responses coupled with increased sociability and longer sensitive periods for socialisation (e.g. Belyaev et al. 1985). Domestic animals still display strong social motivation and they are willing to work for access to conspecifics (e.g. Adeymo & Heath 1982; Holm 2002; Hovland et al. 2008). Another interesting effect of domestication is a heightened threshold for agonistic behaviours – as reported in studies on Norway rats (Price 1984). More recent experiments on captive fish indicate the opposite, that aggression may increase with artificial selection for fast growth due to a correlation between aggressive behaviour and a prioritized access to resources (larger animals) (Ruzzante 1994). The latter seems to be a more likely effect in fast growing production animals as well, and if so, this may work to increase individual distance between individuals.

Individual distance can be defined as 'the minimal distance that an animal normally keeps between itself and other members of the same species' (Drickamer et al. 2002) and such

distances has been observed in several taxonomic groups from insects (Dicke 1986) to fish (Partridge 1980), birds (Keeling & Duncan 1991) and mammals (Rosenblum et al. 1964). Other authors have used different terms, for instance 'social distance' (Lynch et al. 1992) which is defined as the maximum distance of dispersal (group cohesion), or 'personal field' (McBride 1971) which is a radius around each animal that is greater in front of the head, and animals actively avoid entering these fields of others. Most avoidance behaviours in groups are linked to reducing the cost of the social lifestyle (Warburton & Lazarus 1991), just as attraction between individuals is regulated by the benefits of group living. Indeed, it is imperative that individuals are able to maintain some space between them; enhancing communication transmission, foraging efficiency and escape response when being attacked by an opponent or predator (Krause & Ruxton 2002). A form of activity synchrony is also important in order to maintain group cohesion and stability (Conradt & Roper 2000).

One important question that arises is whether individual distance should be regarded as a static or a dynamic entity? If static, one would expect animals to distribute themselves with a fixed individual distance between each other, like often observed in birds sitting on an electric cable or the distance between nests in a colony of birds (Drickamer et al. 2002). In other species however, the individual distance seems much more dynamic, dependent upon space allowance (cattle: Kondo et al. 1989), familiarity, reproductive state or age difference (e.g. van Dierendonck et al. 2004). The activity also seem to modify the individual distance between animals as free ranging sheep have been observed in closer proximity to their nearest neighbours at rest than during grazing (Lynch et al. 1985; Michelena et al. 2008). This phenomenon was explained by the relatively higher risk of predation and increased time to escape when animals were resting. Similar results have been reported in poultry (Keeling & Duncan 1991) but little data on differences in spacing according to activity have been gathered in other ungulates (Petherick 2007).

Individual distance and flocking behaviour differ between breeds of sheep. For instance, Mediterranean types of sheep (e.g. Merino) maintain a closer individual distance than English lowland and Scottish hill types of sheep (Dwyer & Lawrence 1999; Fisher & Matthews 2001), which could be related to differences in predation pressure where these breeds have evolved. In predator rich pastoral systems, artificial selection will focus on flocking behaviour to ease herding and decrease predator success. Sheep in Norway have lived together with predators like wolves and bears until the early 1900s (Swenson et al. 1994), and human selection was mostly based on ability to flock and ease of herding. During the 17- and 1800s however, Norwegian farmers started to import sheep from Great Britain (Drabløs 1997). These British breeds had evolved without the influence of large carnivores for some time, since bears were exterminated during the 10th century and wolves since the 17th century in Britain (Schwartz et al. 2003). As the large predators became more and more scarce also in Norwegian fauna, human selection criteria for production traits like fast growth and wool quality got more important than flocking abilities, and mainly British breeds were used to create crossbreeds (Drabløs 1997) in the 1800's. Some herds of the Norwegian Spæl sheep (Nordic short tail breed group) were however saved by enthusiasts after 1900 with some crossing with similar sheep from the Faroe and Gotland islands and from Iceland, but with minimal influence from other breeds. A previous study indicates that there is behavioural differences between the native short tail sheep and the composite Norwegian White breed today, since the former flocked closer together than the latter, when exposed to predator-related stimuli (Hansen et al. 2001). Such breed differences has never been documented concerning the requirement for social space. Summarizing other data on spacing behaviour in sheep, the same trend occur; breeds which have been heavily selected by man display less gregarious behaviour than breed that may have been less influenced by humans (Fisher & Matthews 2001). Also differences in flocking behaviour between two breeds of poultry have

been explained by adaptations to different predator pressures in the two environments that these poultry breeds have evolved (Keeling & Duncan 1991). Few studies have investigated spacing behaviour in sheep (e.g. Crofton 1958; review: Lynch et al. 1992; Sibbald et al., 2000) and none of these were performed in a controlled environment for breed comparisons.

The aim of this experiment was to investigate differences in spacing behaviour, measured by the individual distance when resting and feeding, between two breeds of sheep with a different selection history. We hypothesized that the native Norwegian breed (Spæl) would maintain a smaller distance to its pen mates when resting and feeding than ewes from the composite breed (Nor-X). Furthermore, we hypothesized that the ewes would maintain a larger individual distance when feeding than when resting. Finally, we hypothesized that the light breed (Spæl) would have a higher degree of behavioural synchrony than the heavy composite breed (Nor-x).

METHODS

Eight groups of four ewes from the Nor-X breed were tested during four weeks in February/March 2007, and eight groups of four ewes of Spæl sheep were tested during four weeks in January/February 2008. The two breeds were tested in separate years due to restrictions in facilities and the fact that the experimental pens had to be thoroughly cleaned and disinfected before bringing in animals from another farm. Each group was transferred to one of two identical experimental pens for a period of 7 days.

Animals

The 32 ewes from the Nor-X breed, a large, white sheep selected for meat quality (meat line: Kvame 2005; Kvame & Vangen 2007) had a mean body weight of (mean \pm STD) 79.6 ± 5.2 kg. It is based on several Norwegian crossbred breeds: Dala, Rygja and others, now grouped

as Norwegian White, and has been crossed with imported Texel sheep on several occasions. All the ewes were pregnant in second to third trimester and were selected at random from a population of ewes that were more than 2 years old in order to make sure that they were fertile and had completed at least one pregnancy. Prior to the experiment, the ewes were housed in groups of 20-30 animals with a space of 2.3 –3.4 m² per animal on deep straw bedding. Sheep were given *ad libitum* access to silage and fresh water.

The 32 ewes from the coloured Spæl breed, a lighter Norwegian breed (Steinheim et al. 2008), mainly selected for wool quality (Eikje 1979; Drabløs 1997) had a mean body weight of (mean ± STD) 56.9 ± 7.7 kg. All the ewes were pregnant in their second to third trimester, and some of them had horns. Prior to the experiment the ewes were kept outdoors in groups with free access to shelter, silage and water. In December, the ewes where moved into a sheep barn, on deep straw bedding and kept in groups of 20-25 individuals with a space of 2.4 – 3.0 m² per animal. Also indoors the sheep were given *ad libitum* access to grass silage and water.

The mean weight difference between pairs within groups, regardless of breed was (mean ± STD) 6.1 ± 0.08 kg with a range from 0 up to 20 kg. For more information on the Norwegian sheep breeding scheme and genetic differences between the two breeds, we refer to Eikje (1979) and Eikje et al. (2008).

Experimental pens

Two identical pens measuring 2.0 m x 12.0 m (24.0 m² in total and 6.0 m² per animal) were constructed (Fig 1) inside an insulated and mechanically ventilated building at the University campus Aas. The lying area, a raised platform with solid wooden floor running along the whole length of the pen and was 0.6 m wide. The platform was marked with black stripes every 0.5 m so that distance between individuals could be measured from video recordings.

Every morning at 09:00 the platform was cleaned and a thin layer of saw dust was provided to insure a dry and non-slippery surface. In order to prevent the sheep from lying in the activity area, grids made of wooden beams (5.0 x 5.0 cm) were placed on the concrete floor between the feed barrier and the resting platform. A continuous horizontal feed opening was running along the other side of the pen, in the entire 12 length of the pen. On top of the feed barrier we painted black stripes for every 0.5 m (Fig 1).

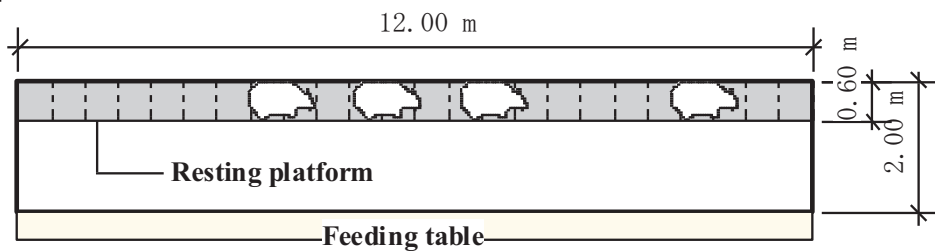


Figure 1. The experimental pen with a wooden platform for resting area (grey), activity area covered with grids and a feeding table

Feeding

The ewes had free access to good quality hay that was evenly distributed along the 12.0 m feed barrier. Every morning the hay residues were removed and a standard concentrate feed for sheep (0.3 kg/day per ewe) was evenly distributed along the feed barrier, before fresh hay was administered. Water was provided *ad libitum* from two buckets, one in each short end of the pen.

Behavioural observations

The white Nor-X ewes were individually marked with numbers from 1 to 4 across their backs, with a standard marking spray for animals. Most of the Spæl sheep had coloured wool and

was therefore identified by their different markings on the heads, legs or wool colour (brown, black, grey or mixed colour). If two sheep in the same group were hard to tell apart, they were marked using strips of white textile that was tied into their coat of wool (Fig 2b). Four colour cameras were mounted above each pen and connected to a digital video recording system (MSH video system®). The ewes were video recorded for 24 hours at the 7th day of each experimental period.

The distance between the ewes and their positions towards other ewes when lying (“Head to Head”, “Head to Back” or “Back to Back”, Fig 2a) was scored for each of the six possible pairs per group (96 different pairs in total), using instantaneous sampling every 15 minutes from 6 p.m. to 6 a.m. (a quiet period of the 24 hours), giving 60 observations per pair and group.

The distance between the ewes when feeding (Fig 2b) was scored using instantaneous sampling every second minute for four hours (two hours immediately after morning feeding (08:00), and two hours immediately after evening feeding (15:00), giving 120 observations per pair and group.

The same person performed all observations and the mean distance between the two individuals in each pair was calculated and used as statistical unit in the datasets.

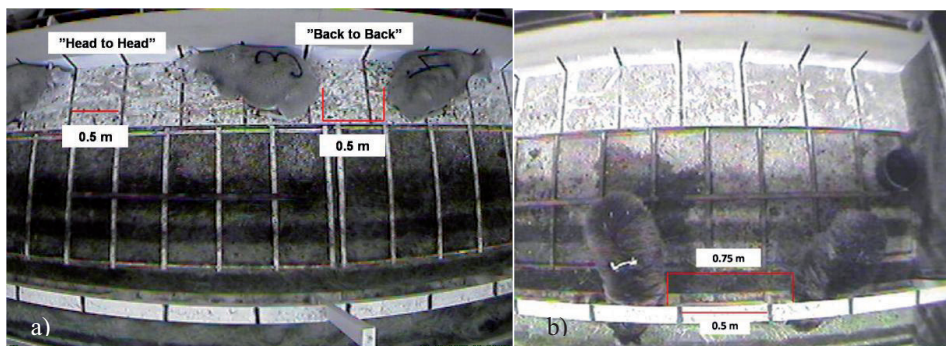


Figure 2a) and b). Experimental pens and examples of measures done between pairs of resting sheep a) and feeding sheep b).

Ethical note

A university representative of the National Research Authority (www.FDU.no) approved this experiment, and no ethical concerns were indicated. Animals were minimally handled and kept in pens with lower animal density compared to their normal housing conditions. As soon as each group had spent 7 days in the experimental pens they were returned to their home environment (commercial farming).

Statistical analysis

To test the effects of breed or weight differences on individual distance and CV of individual distance we used a mixed model of analysis of variance, with breed (Nor-X, Spæl sheep), group (1-16), type of activity (resting or feeding) and the interaction between breed and type of activity as class variables. Group nested within breed was specified as a random effect, while weight difference between pairs was included as a continuous variable (SAS Institute Inc. 1989).

The effect of breed on body orientation (“Head to Head”, “Back to Back” or “Head to Back”) was tested using the same mixed model of analysis of variance with breed and group as class variables, again group nested within breed was specified as a random effect. A separate dataset was calculated on the basis of mean individual distance between each pair (n=96) in the three different resting positions. Then the effects of body orientation on individual distance during resting was tested using a similar mixed model of analysis of variances with breed, body orientation, group and the interaction between breed and body orientation as class variables. Group was specified as a random effect.

Resting and feeding synchrony was calculated from the number of observations where all group members were resting or feeding simultaneously, giving one percentage value for each group (8) within breed (2) and activity (2). Breed effects on synchrony of resting and

feeding behaviours was tested in a similar mixed model, with group, breed, type of activity and the interaction between breed and type of activity as class variables. Group was specified as a random effect.

Correlations between the mean individual distance during resting and feeding were tested using Pearson's correlations, and least square means was used to verify the differences between means. All analysis were done using the SAS® 9.1 software.

RESULTS

Individual distance

The mean individual distance between group members was 2.2 m during resting and 2.7 m when animals were feeding. The more selected Nor-X sheep kept a significant larger individual distance to their pen mates during both resting and feeding, compared to the less selected Spæl sheep ($F_{1,12}=52.2$, $P<0.0001$, Figure 3). Spæl sheep kept a larger distance to their group mates when feeding than when resting, but this difference related to activity was not found in the Nor-X sheep (significant interaction effect between breed and activity: $F_{1,150}=13.7$, $P<0.001$, Fig 3). Even though the two breeds differed in body weight, the heavy Nor-X sheep did not occupy more space at the resting area than the lighter Spæl sheep. Individuals from both breeds seemed to take up the space of approximately 1 meter (three painted stripes) when lying on the resting platform, and previous studies on body measurements show that body length change little according to increased body weight (e.g. Janssens & Vandepitte 2004).

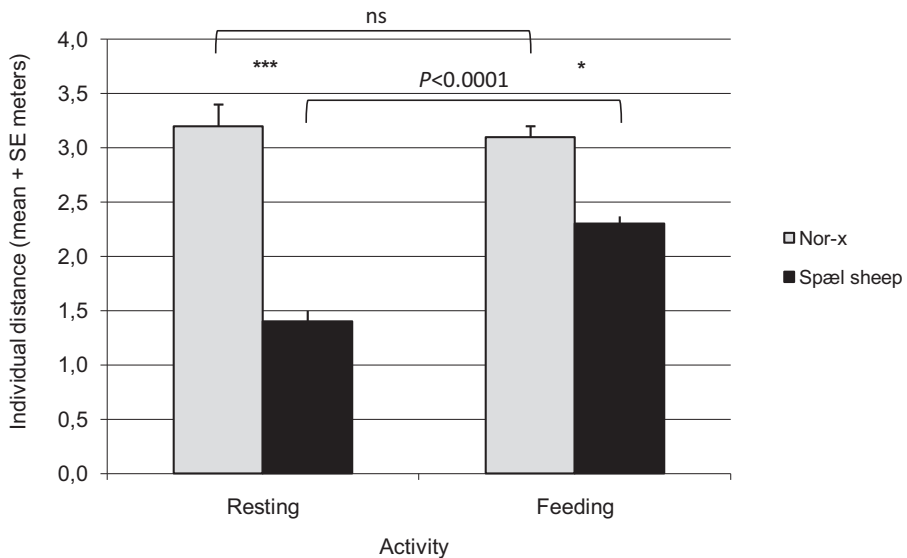


Figure 3. Mean individual distance according to type of activity and breed. Differences between breeds within activity $*=P<0.01$; $***=P<0.0001$.

Spæl sheep showed a significant larger variation in individual distance when feeding and resting than Nor-X sheep ($F_{1,12}=16.5$, $P<0.01$, Fig 4). Regardless of breed, the variation of individual distance when feeding was larger than when resting (Figure 4), indicating that the individual distance during feeding was less consistent since sheep changed places more frequently. No significant interaction effect between breed and individual distance or group effect was found concerning variation in individual distance during feeding or resting.

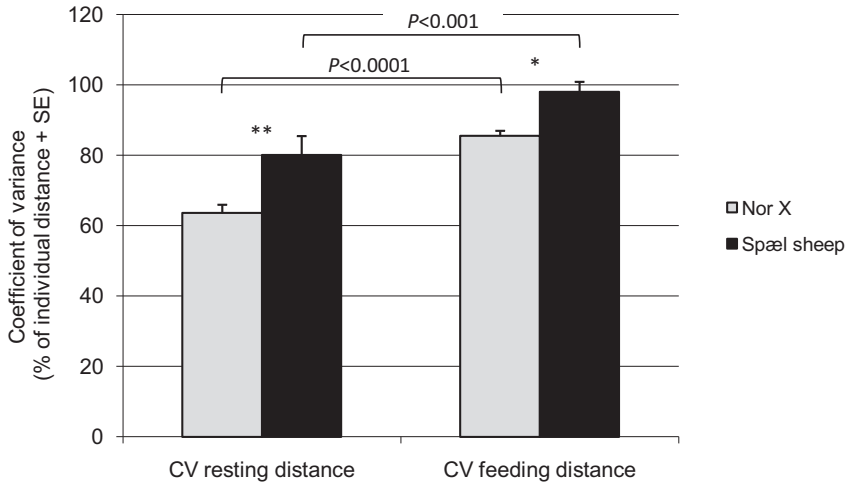


Figure 4. The coefficient of variance according to type of activity and breed. Differences between breeds within activity $*=P<0.05$; $**=P<0.0001$.

Pairs of sheep that kept within close proximity to each other during feeding also kept within shorter individual distances during resting (Fig 5). Individual distance during resting or feeding was not affected by intra-pair weight differences.

Body orientation

More than 50 % of all resting observations were registered as sheep lying “Head to Back”, but the breeds did not differ significantly regarding resting positions. However, the Nor-X breed ($26.9 \pm 2.3\%$) tended to spend more time resting “Head to Head” compared to Spæl sheep ($25.3 \pm 1.3\%$, $F_{1,14}=3.9$, $P=0.06$). The “Parallel” orientation where ewes were lying in full body contact side to side (Nor-X: $0.09 \pm 0.09\%$, Spæl sheep: $0.5 \pm 0.3\%$), was rarely observed and thus excluded from further analysis.

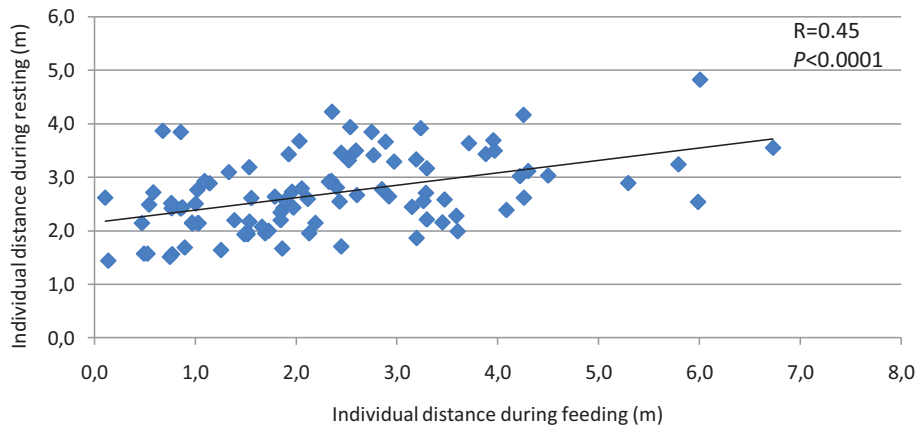


Figure 5. Regression between mean individual distance during feeding and resting activities for the 96 pairs of sheep.

The mean individual distance between pairs of resting sheep was larger when orientated “Head to Head” than when orientated “Back to Back” ($F_{2,271}=4.5$, $P<0.05$), but this difference was only significant in Nor-X sheep (Fig 6). No interaction effect between breed and body orientation was found, and group did not affect the body orientation significantly.

Synchrony of behaviours

In general, all four group members were resting or feeding simultaneously in more than 60 % of observations (mean \pm SE resting: 66.1 ± 3.2 %, feeding: 67.3 ± 2.4 %). In Spæl sheep 70.9 ± 4.7 % of all resting observations were registered in complete synchrony where all four group members rested at the same time, while the corresponding value for the Nor-X sheep was 61.4 ± 3.7 %. When feeding, complete synchrony was scored in 67.7 ± 4.2 % of feeding observations in the Spæl sheep while this was 66.9 ± 2.7 % in the Nor-X sheep, however none of these synchrony measures were significantly different between breeds. There were no

significant interactions between breed and type of activity on behavioural synchrony, or group within breed.

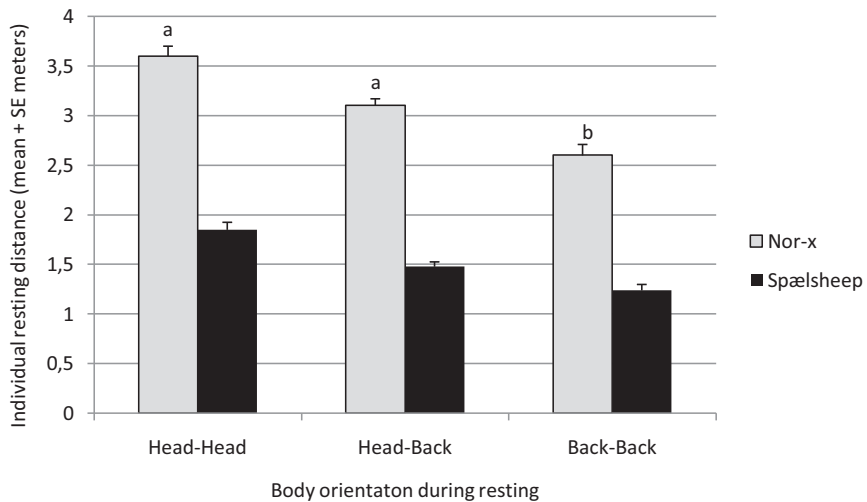


Figure 6. Mean individual distance according to body orientation (position) and breed. Different letters above bars indicate significant differences between body orientation categories, $P < 0.05$.

DISCUSSION

As predicted, the Spæl sheep maintained smaller individual distances to their pen mates, both when resting and feeding, compared to ewes from the Nor-X breed. Furthermore, Spæl sheep kept a significant smaller individual distance during resting compared to when feeding, while no such difference could be found for Nor-X ewes.

Free ranging sheep keep closer to their nearest neighbours when resting than when grazing (Lynch et al. 1985; Micheleneva et al. 2008), a behaviour that could be related to anti-predatory strategies. Interestingly, Dwyer & Lawrence (1999) found that light and extensively kept sheep like Blackface were less gregarious than heavy, more intensively kept Suffolk

sheep. Grubb & Jewell (1966) in fact suggested that domestication created animals that tolerated crowding to a larger degree and should therefore be more gregarious than animals subjected to natural selection only. One recent experiment on breed differences in anti-predator behaviour however, shows opposite results that correspond well with our findings (Hansen et al. 2001). We also found that individual sheep actively adjusted their distance to certain other individuals in the group, maintaining closer proximity to some ewes than others.

Maintaining some individual distance is not only important to facilitate an effective fleeing response under predator attack, but it is also necessary to give the animal time to redirect its movement if it comes too close to another individual within the social group (Krause & Ruxton 2002). If animals would distribute themselves over an available area, one could expect that they would all try to maximize the individual distance between them, up to some limit for group cohesion. In sheep, individual distance is influenced by biological states, social relationships, resource distribution and crowding (e.g. Hutson 1984; Gills & Kramer 1987; Sibbald et al. 2000; Matthiopoulos 2003). In the present experiment we found a mean distance between individuals when resting of around 2.2 m, which corresponds well with observations done on free ranging Blackface sheep at rest (Lynch et al. 1985). The difference in individual distance between the two breeds in the present experiment is difficult to explain without noticing the difference in the two breeds' domestication history. Even though the Spæl sheep probably were less influenced by human selection for meat quality than the Nor-X sheep, this breed must still be considered fully domesticated with some human selection criteria being followed (Eikje 1979).

Earlier studies on farmed fish and their wild counterparts have proposed a correlation between artificial selection for growth and a decreased threshold for agonistic behaviour (Ruzzante 1994). In environments where resources are limited in space and monopolizable, animals that show more agonistic behaviours will have an advantage. Furthermore, if this

natural selection within the domestic environment is accompanied by an artificial selection for growth, humans unintentionally might have selected for increased aggression (review: Huntingford & Adams 2005) which might also be manifested in increased individual distances as animals try to keep out of each others way (Ruzzante 1994). On the other hand, articles comparing behaviour in breeds that has been more or less selected for production traits all show a common trend, high yielding breeds are more docile, they spend more time feeding and less time in social interactions (cattle: Sæther et al. 2006). This is explained by the theory of resource allocation (Schütz & Jensen 2001).

Due to the cold winter climate and relative low temperatures in early lambing season, sheep husbandry is more or less similar throughout Norway, changing more according to the availability of spring pasture than according to sheep breed. It is therefore not likely that the Spæl sheep have been more exposed to predators the last hundred years, than the Nor-X breed. On the other hand, the Nor-X breed is a composite between Dutch (Texel) and heavy Norwegian sheep breeds with a noticeable influence of British breeds. As previously mentioned, British sheep breeds have been without the influence of large carnivores for more than 300 years (Schwartz et al. 2003) compared to Norwegian breeds that had less than 100 years without substantial influence of carnivores (Swenson et al. 1994). If these breed differences were large enough between the early Spæl sheep and the ancestors of the Nor-X sheep, then these behavioural mechanisms might still be visible today, after a rather limited time under similar intensive husbandry.

Over 50 percent of the resting observations in the present experiment were scored as pairs lying in a “Head to Back” orientation. One might expect that a subordinate ewe would try to maximize her distance to a dominant ewe, especially if they were orientated “Head to Head”. This eventual link between individual distance, body orientation and social rank was not investigated in our experiment. Lynch & colleagues (1985) however, described that sheep

tried to manoeuvre so that they did not face another sheep when resting, and our data showed that the individual distance was depending on body orientation where pairs lying “Head to Head” kept a larger distance to each other than individuals lying “Back to Back”.

We did not find any significant breed differences in behavioural synchrony, but looking at the mean values for synchrony of resting behaviour, the prediction that a less selected breed would have a higher synchrony of resting behaviour than a more selected one should be further investigated. It is undoubtedly important for group living animals to synchronize their behaviour in order to maintain group cohesion (Michelena et al. 2006), which in turn is beneficial in relation to anti-predator strategies.

In conclusion, the heavier Nor-X sheep kept a significant larger individual distance to their pen mates than the lighter Spæl sheep both during feeding and resting. Spæl sheep kept smaller distance to their pen mates when resting than when feeding, while the Nor-X sheep showed no difference in individual distance according to activity. This supports our hypothesis that animals will keep closer to each other during resting as an anti-predator strategy, and indicate that the heavier breed has experienced a relaxed selection pressure for predator avoidance.

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Norwegian White sheep and lambs resting at pasture. Photo: Natasa Djakovic



Nor-x lambs grazing the autumn pasture. Photo: GHM Jørgensen

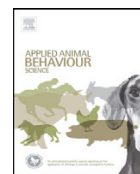
*“When a distinguished but elderly scientist states that something is possible,
he is almost certainly right. When he states that something is impossible,
he is very probably wrong”*

Arthur C. Clarke



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Feeding, resting and social behaviour in ewes housed in two different group sizes

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ABSTRACT

The aim of this experiment was to investigate the effects of increased group size on eating- and resting behaviour, aggression and feed intake in housed ewes. During an initial period of 14 days 36 adult (2–6 years old) ewes of the domestic Norwegian Dala breed were divided into four groups of 9. In the second period (14 days), these ewes were merged into one group of 36 ewes. This experiment was repeated with a second batch of ewes, but this time starting with a group of 36 individuals in the first period, then splitting them up into four groups of 9 ewes in the second period. From 24 h video recordings we scored activity behaviours using instantaneous sampling every 10 min. Aggressive interactions were continuously observed the first 10 min every hour during the 24 h (4 h in total). A mixed statistical procedure with group size, day, batch and the interactions between them were included as fixed effects, whereas individual and group were specified as random effects.

Ewes in large groups (36) had a larger variation in lying time at day one ($P < 0.01$), less synchronized lying ($P < 0.05$) and eating behaviour ($P < 0.01$), and spent less time queuing at the feed barrier ($P < 0.001$) compared to in the small group size (9). There were no effects of group size on aggressive interactions or feed intake.

In conclusion, a larger group size decreased synchrony in resting and feeding behaviour and reduced the time spent queuing in front of the feed barrier. It is possible that the aggression level in sheep is more sensitive to changes in space allowance than to changes in group size per se.

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1. Introduction

Group size varies to a large extent in wild populations of sheep, but the most frequent group sizes are between 7 and 49 individuals for Soay sheep and up to 61 individual for Bighorns, with an average of approximately 8 (Grubb and Jewell, 1966; Woolf et al., 1970). Larger groups may divide into subgroups during migration and grazing (Festa-Bianchet, 1988; Boissy and Dumont, 2002). In free-ranging Soay sheep group size mainly depend on the need for anti-predatory vigilance (Hopewell et al., 2005). Larger group sizes in periods with higher predation risk is also revealed for several other species (review: Lima and Dill, 1990;

wallabies: Blumstein et al., 1999; lizards: Downes and Hoefer, 2004).

Aggressive interactions have been documented to decrease with increasing group sizes in domestic fowl (Lindberg and Nicol, 1996; Hughes et al., 1997; Estevez et al., 1997, 2003, 2007), turkeys (Buchwalder and Huber-Eicher, 2005) and pigs (Nielsen et al., 1995; Turner et al., 2001; Andersen et al., 2004). Similar results have also recently been found in goats (Andersen et al., unpublished). In weaned pigs, a larger proportion of animals will change towards more defensive strategies with increasing group size, but a few individuals with a high competition capacity appear to engage in fights that last longer and are more intensive (Andersen et al., 2004). Furthermore, it appears that when animals originate from large groups and grow up experiencing a low aggression level over a long time period, these animals

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will behave less aggressively when introduced to new group members. The latter has been shown both in weaned pigs (Turner et al., 2001) and young turkeys (Buchwalder and Huber-Eicher, 2005), but these effects may depend on the length of the period that the animals are members of a large group.

For animals with a low level of aggression, such as young calves, an increased group size is associated with fewer displacements, higher activity, and an increased tolerance towards group mates (i.e. resting in a closer proximity to neighbouring calves) (Færevik et al., 2007). Displacements from the feed barrier and the resting area are also more commonly seen in adult sheep than the more intensive butting (Bøe et al., 2006). The increased locomotion with increasing group size may both be explained by an increased level of social stimuli in larger groups, but also that individuals are moving more to avoid others. Social complexity increases with increasing group size, and as suggested by Croney and Newberry (2007), this may create higher cognitive demands on each individual in the group. Individual recognition appears to be essential for group functioning. Sheep is able to visually recognize at least 50 other individuals (Kendrick et al., 2001), which is a number close to the upper limit group size reported in wild populations (e.g. Grubb and Jewell, 1966; Woolf et al., 1970).

The overall aim of this experiment was to study activity pattern, social interactions and feed intake of ewes housed in a small (9) vs. large group (36) shortly after mixing and after two weeks. Based on previous results in other farm animal species, we predict that the amount of agonistic interactions, including displacements from feed or resting area, will be lower in the largest group size. One way to reduce competition in larger groups is that more individuals will choose to perform important activities less simultaneously (e.g. Nielsen et al., 1995; Boissy and Dumont, 2002). Thus, we predicted to find a lower incidence of queuing in front of the feed barrier and less synchronous feeding and resting behaviour in the largest group size.

2. Materials and methods

2.1. Experimental design

The effect of group size was investigated in two batches. In batch 1, 36 ewes were divided into 4 groups of 9 ewes (small group size) in the first period (14 days) and then merged into 1 group of 36 ewes (large group size) in the second period (14 days). In batch 2, 36 ewes were kept as 1 group in the first period and then split into 4 groups of 9 ewes in the second period.

2.2. Experimental pens

The experimental pens had a space allowance of 1.5 m² per ewe. When the ewes were split into groups of 9, the experimental pens were divided into four, maintaining the same space allowance per animal. In each of the four pens there was a water bowl and a feeding barrier with three separate openings (allowing three animals to feed simultaneously). This means that there were three ewes per feeding place, irrespective of group size. Approximately 2/3 of the pen was deep straw bedding, whereas the area in the front at the feed barrier was bare concrete. Total available perimeter length (pen wall length minus feed barrier length) in the pens with 9 ewes was 1.4 m/ewe, and 0.6 m/ewe in the pen with 36 ewes. Additional straw material was provided twice a week to maintain a dry lying surface.

2.3. Animals and feeding

In each of the two batches, 36 pregnant (2–6 years old), medium sized ewes of the Dala breed were randomly chosen from the resident herd at the Norwegian University of Life Sciences in January and February, respectively. The ewes are normally kept indoors in pens with expanded metal flooring (October to April) and were shorn and mated in the beginning of November. Before entering the experiment, the ewes were individually marked with numbers on the back and weighed (weight range batch 1: 75–85 kg, batch 2: 85–95 kg).

A ration of 0.2 kg per ewe of standard concentrate was offered every morning at 08:00 h. Good quality hay (¹DM: 90.4%; NDF: 587.5 g/kg; CP: 65.8 g/kg) was offered *ad libitum* so that the amount of hay supplied every morning was 120% of the feed intake the last day. The daily ration of hay and the leftovers were weighed on an electronic balance, and the quality of the hay did not change during the experiment.

2.4. Behavioural observations

The ewes were video recorded for 24 h on day 1 and 14 in each two-week period. Two wide-angled video cameras covered the experimental pens, so that two small groups were recorded by one camera and the large group pen was recorded by two cameras. The cameras were connected to a multiplexer (Robot MV99P) and a time-lapse video recorder (Panasonic AG 6720), and mounted 3–4 m above the floor. The following behaviours were scored for each individual during the 24 h, using instantaneous sampling at 10-min intervals:

- Eating hay (head trough feed barrier).
- Lying.
- Queuing (standing < 1.5 m away from the feed barrier, with head directing towards it).
- Walking/standing (except for queuing).
- Other behaviours (drinking water, eating concentrate).

The number of ewes lying by the wall (<15 cm from the wall) and in the middle of the pen (>15 cm from the wall) were scored within the same time period, also at 10-min intervals.

All instances of aggressive interactions (Bøe et al., 2006) were scored continuously for the first 10 min of each hour during the 24 h video recording (a total of 4 h). This was done to calculate the overall aggression level throughout a 24-h period. The initiator and receiver of the aggressive behaviour were also recorded:

- Pushing another ewe/forcing past another ewe.
- Mounting (jumping on another ewes back).
- Kicking another ewe with front leg.
- Butting another ewe, head to head or butting with the head towards other parts of the receivers body.
- Threatening another ewe by walking towards her, and the other ewe moves away.
- Displacements (physically forcing another ewe to leave their place at the feed barrier or resting place).

The behaviours pushing, mounting, kicking, butting and threatening were summed into other aggressive interactions (displacements not included).

2.5. Statistical analysis

The effect of group size on feed intake was analyzed using a mixed model of analysis of variances with the following class variables: group size (9, 36), batch (1, 2) and the interaction between group size and batch. Batch was specified as a random effect (Hatcher and Stepanski, 1994).

In order to test the effects of group size on general activity and number of social interactions we used a mixed model (MIXED) procedure of Statistical Analysis System (SAS). The model included group size (9, 36), batch (1, 2), day (1, 14), the interaction between group size and batch, and the interaction between group size and day as fixed effects. Individual

¹ Hay quality measures, DM = dry matter, NDF = neutral detergent fibre, CP = crude protein.

Table 1

Differences in behavioural measures between the two group sizes on the day of grouping and 14 days after grouping (activity variables are given as mean% of tot. obs. \pm S.E., whereas displacements and aggressive interactions are given as mean number of incidents per ewe). Means with different superscript letters (a and b) differ significantly.

	Day 1		Day 14		Group size		Day	
	9 ewes	36 ewes	9 ewes	36 ewes	F-value	P-value	F-value	P-value
Eating roughage	19.4 \pm 0.5 ^a	18.6 \pm 0.6 ^a	18.6 \pm 0.6 ^b	20.6 \pm 0.5 ^c	0.98	ns	1.44	ns
CV eating roughage	24.1 \pm 2.0	22.9 \pm 1.8	28.8 \pm 2.4	20.6 \pm 4.2	0.04 ^a	ns	0.65 ^a	ns
Resting	66.0 \pm 0.6 ^a	61.9 \pm 0.9 ^b	63.8 \pm 0.6 ^c	62.8 \pm 0.6 ^c	6.6	<0.05	1.01	ns
CV resting	6.9 \pm 0.5 ^a	12.2 \pm 0.1 ^b	8.4 \pm 0.6 ^c	8.6 \pm 0.8 ^c	10.08 ^a	<0.01	1.46 ^a	ns
Queuing	3.8 \pm 0.3 ^a	2.8 \pm 0.2 ^b	4.4 \pm 0.3 ^c	3.0 \pm 0.3 ^d	11.3	<0.01	2.0	ns
Standing/walking	9.8 \pm 0.4 ^a	15.5 \pm 0.7 ^b	11.7 \pm 0.4 ^c	12.5 \pm 0.5 ^c	29.5	<0.0001	0.88	ns
Displacements	6.0 \pm 0.5	6.3 \pm 0.5	8.2 \pm 0.7	8.6 \pm 0.6	0.14	ns	16.3	<0.001
Other aggressive interactions ^b	11.6 \pm 0.8	10.8 \pm 0.8	12.4 \pm 0.9	13.6 \pm 0.8	0.05	ns	5.4	<0.015

Df = 1, 31 for most variables.

^a Df = 1, 19. CV for eating roughage and CV for resting are values calculated per group and were therefore analyzed separately.

^b Other aggressive interactions included pushing, mounting, kicking, butting and threatening.

ewe and group were specified as random effects in the model. To ensure a conservative test we set the maximum number of degrees of freedom to 31.

In order to test the effect of group size on synchrony and CV for lying and feeding behaviour within day 1 or day 14 in the treatment, we used a mixed model of analysis of variance with the following class variables: group size (9, 36) and batch (1, 2). Batch was specified as a random effect.

The same model was used to test the effect of group size on mean number of ewes lying against the wall of ewes lying.

A Student Newman Keuls test was used to find differences between means.

3. Results

On day 1 (the day of grouping), the ewes were resting significantly less when kept in a large compared to in a small group, but this effect was no longer significant on day 14 (Table 1). A significant interaction effect between group size and day was detected ($F_{1,31} = 5.7$, $P < 0.05$). In both batches, as much as 50% (18 animals) to 73% (26 animals) of the ewes spent less time resting when kept in the large compared to in the small group size.

The variation in individual resting time (CV) was significantly larger in group size 36 on day 1 (range 38.9–76.4%) than in group size 9 (range 54.1–78.5%), but not on day 14 (group size 36: range 47.2–77.7%; group size 9: range 51.4–76.4%; Table 1).

Mean proportion of observations resting simultaneously were significantly higher when the ewes were kept in small than in large groups (Fig. 1).

Of the ewes that were resting, significantly more animals were lying against a wall in the small than the large group size (Fig. 2).

Time spent standing or walking was significantly higher in the large than in the small groups on day 1, but not on day 14 (Table 1). This could be explained by a significant interaction effect between group size and day ($F_{1,31} = 21.3$, $P < 0.0001$).

On day 1, there were no significant differences in time spent eating roughage in large and small groups (Table 1). However, on day 14 the ewes spent significantly more time feeding in the large groups, than in the small groups (interaction effect between group size and day: $F_{1,31} = 7.6$, $P < 0.01$). The interaction between batch and group size was also significant for this behaviour ($F_{1,31} = 6.9$, $P < 0.05$).

The individual variation in feeding time (CV eating roughage) did not differ significantly between the large and small group size on any of the observation days (Table 1). However, the mean proportion of observations where all feeding places were occupied was significantly higher in groups of 9 than 36 ewes (Fig. 3).

On average, the ewes spent significantly less time queuing at the feed barrier in the large compared to in the small groups on both days (Table 1). However, this was only significant in batch 2 (large: $3.1 \pm 0.2\%$ vs. small: $4.5 \pm 0.3\%$; $P < 0.001$) and not in batch 1 (large: $3.2 \pm 0.2\%$ vs. small: $3.7 \pm 0.2\%$). There only tended to be an interaction effect between group size and batch: $F_{1,31} = 3.5$, $P = 0.072$).

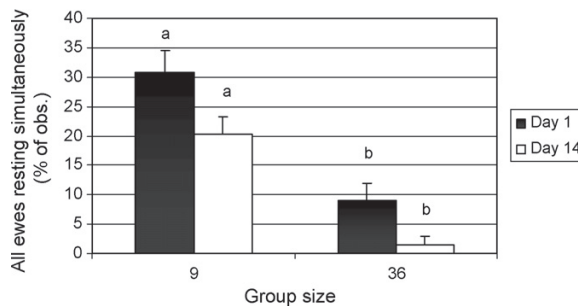


Fig. 1. Percent of observations where all ewes were resting at the same time (means \pm S.E.). Bars with different superscript letters (a and b) differ significantly, $P < 0.05$.

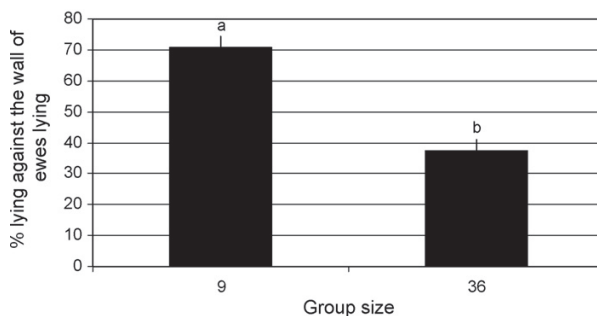


Fig. 2. Percent of ewes lying against a wall (means + S.E.). Bars with different superscript letters (a and b) differ significantly, $P < 0.0001$.

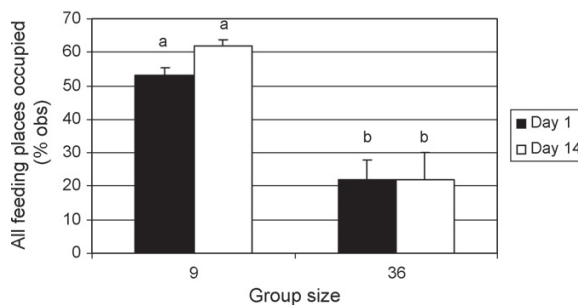


Fig. 3. Percent of observations when all feeding places were occupied (means + S.E.). Bars with different superscript letters (a and b) differ significantly, $P < 0.01$.

Daily feed intake did not differ significantly between group size 9 and 36 (mean \pm S.E. per ewe: group size 9: 1.7 ± 0.1 kg, group size 36: 1.8 ± 0.1 kg, $F_{1,12} = 0.46$). Overall, the ewes in batch 2 had a significantly higher feed intake (1.9 ± 0.02 kg) than the ewes in batch 1 (1.5 ± 0.03 kg; $F_{1,12} = 42.7$, $P < 0.0001$).

Mean number of aggressive interactions per ewe were similar in both group sizes (Table 1). The most prevalent aggressive behaviour was pushing another ewe (mean $6.2 \pm 0.5\%$ of total observations), but there was no significant difference between the two treatments concerning this behaviour. Furthermore, all the ewes were observed performing displacements, but there was no effect of group size on number of displacements and other aggressive interactions in general (Table 1). No interaction effects were found for displacements and other aggressive interactions.

4. Discussion

As predicted, ewes in large groups had a larger variation in resting time, rested and fed less synchronously, spent less time resting on day one and spent less time queuing at the feeding barrier. However, in contrast to similar experiments in pigs (e.g. Nielsen et al., 1995; Turner et al., 2001; Andersen et al., 2004), dairy calves (Færevik et al., 2007) and fowl (e.g. Estevez et al., 1997; Hughes et al., 1997), the ewes in the present experiment did not behave less aggressively in a larger group size. Compared to for instance pigs and goats which under natural

conditions live in a rather limited home range and in small and stable groups, larger groups of sheep may divide into subgroups during migration and grazing (Festa-Bianchet, 1988; Boissy and Dumont, 2002). It is likely that this continuous change from small to larger groups and vice versa during grazing make the sheep more tolerant towards new group members. In contrast to some other farm animals, clear dominance relationship in groups of ewes is not much documented (e.g. Arnold and Dudzinski, 1978).

The most prevalent aggressive interaction was pushing, used to displace another ewe from the feed barrier or a resting place. In general, the level of aggression in sheep is relatively low compared to other female ungulates (Fournier and Festa-Bianchet, 1995), but it is documented that the level of aggression in ewes is sensitive to changes in space allowance, especially in the resting area (Bøe et al., 2006). It is possible that the decrease in perimeter length per ewe in the largest group size contributed to increased competition for attractive resting places, and thus diminished the predicted group size effect on aggression. This is in accordance with Færevik et al. (2005) and Bøe et al. (2006) who showed that ewes had a distinct preference for lying next to a wall. Hence, wall space in the resting area might be regarded as an important source of competition in ewes. The focus in the present paper was to get the overall aggression level in an entire 24-h period shortly after mixing, and then two weeks later. If we have studied aggression only around feeding time this may have

resulted in more aggression incidents per time unit, but then we would have lost all aggressive competition for resting places in the rest of the 24 h.

Similar to other species (cattle: Benham, 1982; horses: Sweeting et al., 1985; Rifa, 1990), sheep synchronize their activities at pasture (Rook and Penning, 1991). This synchronisation of maintenance behaviours is used to increase predator avoidance (Pulliam, 1973; Pulliam and Caraco, 1984). Both individual vigilance (Roberts, 1996) and behavioural synchrony (Boissy and Dumont, 2002) declines as group size increases, making more time available for feeding and resting. This is in accordance with the results of the present experiment, showing that the individual variation in resting time was higher in the largest group size. Low-ranked animals may thus show a substantial decrease in resting time, as earlier found in goats (Andersen and Bøe, 2007). A lower perimeter length in the largest group size may have strengthened this effect further since the competition for attractive resting places with access to a wall increased.

These results are of importance since many sheep farmers wish to keep more sheep in larger groups, making the animals share feed barrels, water and resting space. As more animals are grouped together, individuals are difficult to visually assess without physical contact. Low ranked animals in particular might show a substantial reduction in resting time in larger groups compared to in small, and care should be taken so that there are resources enough even when the majority of the animals seem to share without problems.

As expected, the ewes spent more time feeding in large groups, which is in accordance with earlier observations on sheep at pasture (Penning et al., 1993) and dairy calves kept indoors (Færevik et al., 2007). A change in feeding strategy to maintain the feed intake is also documented in large groups of weaned pigs (Nielsen et al., 1995). However, the actual feed intake in the present experiment did not differ between the two group sizes. Ewes in batch 2 had a higher feed intake than the ewes in batch 1, which may be due to a larger mean body weight. The lower incidence of queuing at the feed barrier can be explained by the reduced synchronisation of feeding in the largest group size.

The significant interaction between batch (rotation of treatments) and group size in resting and queuing behaviour shows that the effect of group size is dependent on the order of treatments (from small to large group size vs. from large to small group size). To start with the largest group size (24) and change towards smaller (6) generally reduce the conflict level in goats, compared to the opposite order (Andersen et al., unpublished). Experience from being in a large group also appear to reduce the aggression level in later group situations in weaned pigs (Turner et al., 2001) and young turkeys (Buchwalder and Huber-Eicher, 2005). This has to be further investigated.

In conclusion, a larger group size decreased synchrony in resting and feeding and reduced the time spent queuing in front of the feed barrier. However, in contrast to what was predicted from results in other species, the overall aggression level was not affected by the increased group size. It appears that the social behaviour of sheep is less

dependent on group size than in other farm animals. Aggression in sheep is more sensitive to changes in space allowance, and especially wall space in the resting area, than to changes in group size.

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Pictures from the experiment reported in Paper III. Photos: Kjartan Nyhammer

"Ignorance more frequently begets confidence than does knowledge: it is those who know little, and not those who know much, who so positively assert that this or that problem will never be solved by science"

Charles Darwin



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The effect of shape, width and slope of a resting platform on the resting behaviour of and floor cleanliness for housed sheep

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ABSTRACT

The aim of this experiment was to investigate how the shape (U-shaped, L-shaped or platform, both in the front and back (FB-shaped) of the pen), width (0.5 m or 0.6 m) and slope (0% or 5%) of a solid wooden resting platform, together with the cleaning frequency (daily or every 2nd day) would affect the resting behaviour of ewes and floor cleanliness. The experiment was conducted in three different commercial farms in Norway, and within each herd, two of the factors were tested in a 2×2 factorial design using four experimental pens, while the effect of cleaning frequency (daily or every other day) was replicated within the herd using four additional experimental pens (eight experimental pens within each herd). Ewes were systematically rotated between pens within herds and the ewes' resting behaviour was scored for the last 6 days of each experimental period. The manure on the solid resting platforms was collected and weighed, while moisture on the surface of the resting platforms was scored for the 2 last days of each experimental period.

In all herds, significantly more sheep were observed resting in pens with FB-shaped resting platforms than in pens with U- or L-shaped platforms ($P < 0.0001$). A reduced amount of time on resting platforms was mainly compensated for an increase in the number of sheep lying on the slatted floor and partly by an increase in the number of sheep that was standing. An effective perimeter length (EPL) with a minimum of 0.9 m per ewe was needed to enable all sheep to rest simultaneously on the resting platform. Increasing the slope of the resting platform had no effect on resting behaviour, but decreasing the width of the platforms resulted in more ewes resting on the original pen floor ($P < 0.01$). A slope of 5% resulted in a significantly lower amount of manure ($P < 0.0001$) and a lower moisture score ($P < 0.0001$). In two of the herds, cleaning every 2nd day increased the amount of manure ($P < 0.01$), but not the moisture score.

In conclusion, FB-shaped resting platforms of solid wood may be a relatively cheap and convenient way of increasing the resting time and comfort of sheep housed in fully slatted floor pens, as long as there is a sufficient amount of effective perimeter length available.

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1. Introduction

In Nordic countries (Robinson, 1981), Canada (Canada Plan Service, 1981) and parts of the USA (Outhouse, 1981), sheep are kept indoors during winter and then often housed in pens with fully slatted floors with a space

allowance of 0.7–0.9 m² per animal (Bøe and Simensen, 2003). In contrast to conventional sheep production, the regulations for organic sheep farming (Council Regulation (EC) No. 1804/1999) demand a resting area with a solid floor. Earlier experiments have shown that unshorn sheep have no particular preference in floor type for resting (Bøe, 1990; Færevik et al., 2005), but that shorn sheep show a very clear preference for resting on flooring materials with a low heat conductivity (e.g., straw, solid wood or rubber mattresses) (Færevik et al., 2005). As the

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availability of bedding material is often scarce in some Nordic countries, installing resting platforms made of solid wood in the slatted floor pens can be a convenient and cheap alternative to help improve the animals' resting comfort. However, because of the low total space allowance in their pens, the available space for such resting platforms is limited.

Marsden and Wood-Gush (1986) found that after feed, limited lying space caused most of the displacement in sheep. A reduction in resting space from 1.0 m² to 0.5 m² per ewe not only resulted in an increased number of displacements, but total resting time and resting synchrony were also reduced (Bøe et al., 2006). Both sheep and goats have shown a clear preference for lying against a wall when resting (sheep: Marsden and Wood-Gush, 1986; Færevik et al., 2005; goats: Andersen and Bøe, 2007). Consequently, when considering the layout for resting platforms, maximizing perimeter length is important for ensuring an attractive lying space for the sheep. Both the size and shape of the pen affect the available wall perimeter (Bøe et al., 2006), and the ratio of perimeter to area decreases as group and pen size increases (Stricklin et al., 1995). In an effort to create not only a visual barrier, but also increase the accessible wall length to lie against when resting, Jørgensen et al. (2009) installed additional walls in the resting area for ewes (actually increasing the perimeter length). Nevertheless, this measure did not prove successful in increasing resting time, presumably because these walls also gave some individuals the possibility to block off access to the resting area.

As sheep do not seem to have specific dunging areas, hygiene and cleanliness are a major challenge when intro-

ducing solid floor areas. Studies of cattle suggest that the design of the lying area influences the cleanliness of the animals (e.g., Herlin et al., 1994; Zurbrigg et al., 2005), and that cleanliness again affects claw (e.g., Bergsten and Pettersson, 1992) and udder health (e.g., Schreiner and Ruegg, 2003). Although cattle seem to actively avoid surfaces covered with excreta (Phillips and Morris, 2002), we do not know if sheep behave in a similar manner. A slope (between 2% and 5%) on a solid floor is both recommended and used in piggens (e.g., Anonymous, 1993) and stalls for cattle (e.g., Anonymous, 2005) in order to drain off urine. Interestingly, there seems to be few scientific papers supporting these slope recommendations (Ye et al., 2007), and knowledge is thus needed on how different levels of slope affect floor cleanliness.

The aim of this experiment was to investigate how the shape (U-shaped, L-shaped or front and back (FB-shaped)), width (0.5 m or 0.6 m) and slope (0%, 5% or 10%) of a solid resting area, together with cleaning frequency (daily or every other day) would affect resting behaviour in ewes and floor cleanliness.

2. Materials and methods

2.1. Experimental design

This field experiment was conducted in three private farms involved in organic sheep production in the western region of Norway from January to March 2004.

The following factors were tested in our study:

1. Shape of the resting area (U-shaped (U), L-shaped (L) or both at the back and front of the pen (FB-shaped)).
2. Width of the resting platform (0.5 m or 0.6 m).

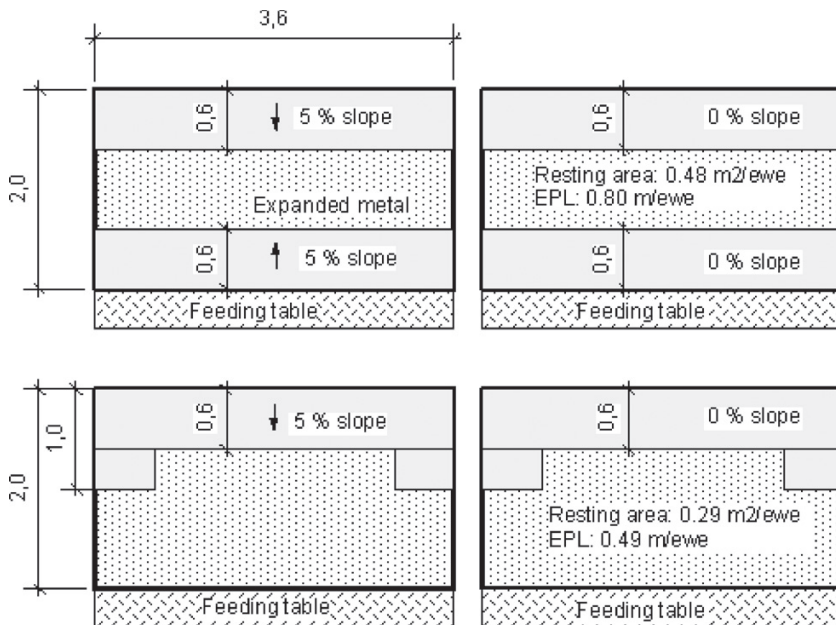


Fig. 1. Shape, slope and width of the solid resting area in herd A.

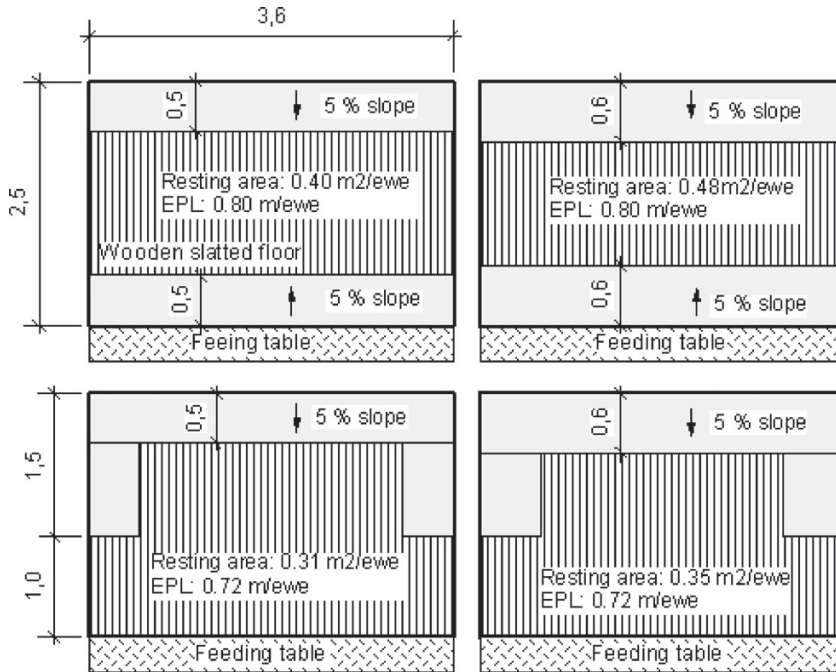


Fig. 2. Shape, slope and width of the solid resting area in herd B.

3. Slope of the resting platform (0% or 5% slope).
4. Cleaning interval (daily or every 2nd day).

In each herd, two of these factors (1–3) were tested in a 2×2 factorial design (Latin square) using four experimental pens (Figs. 1–3); the same set-up was replicated within each herd so that the resting areas in the first

four experimental pens were cleaned out daily, while the resting areas in the other four pens were cleaned out every 2nd day. Furthermore, within each herd and cleanliness treatment, the ewes were systematically rotated between the four pens so that all groups were observed in each of the four experimental pens. Each experimental period lasted for 14 days, in total a duration of 8 weeks.

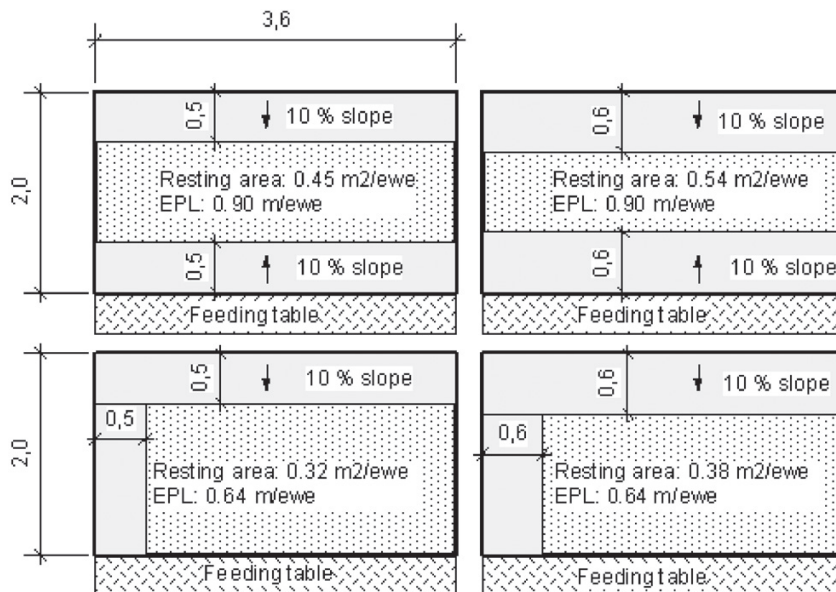


Fig. 3. Shape, slope and width of the solid resting area in herd C.

Table 1
Information on management, sheep breeds and pen treatments.

Herd	A	B	C
Sheep breed	Norwegian white	Spælsheep	Spælsheep
Number of animals per pen	9	9	8
Pen size (m)	3.60 × 2.00	3.60 × 2.45	3.60 × 2.00
Area/animal (m ²)	0.80	0.98	0.90
Pen flooring	Exp. metal	Wooden slats	Exp. metal
Roughage type	Predried silage	Hay	Silage

2.2. Animals, pens and feeding

Two of the herds consisted of the Spælsau breed, a native light Norwegian breed mainly used for wool production. The last herd consisted of Norwegian white sheep, a relatively heavy breed selected for meat production (Table 1). All sheep were pregnant and unshorn during the experiment, and space allowance varied from 0.85 m² to 0.98 m² per ewe. In two herds, the pen floor consisted of expanded metal, whereas the last herd had slatted wooden floors (Table 1).

The resting platforms were 5.0 cm high and made of solid wooden boards placed directly on top of the existing pen floor. We defined 'effective perimeter length' (EPL) as the length of accessible walls along the resting platform that sheep could lean against when resting.

In herd A, the shape (resting platform in both the front and back of the pen) (FB vs. U-shaped) and slope (5% vs. 0%) of the resting platform were investigated (Fig. 1), while the width of the platforms was kept at 0.6 m. The perimeter length was 0.80 m and 0.49 m per ewe in pens with FB- and U-shaped resting platforms, respectively. An automatic drinking vessel was located in each pen on the side wall close to the feed barrier.

In herd B, the shape (FB-shaped vs. U-shaped) and width (0.5 m vs. 0.6 m) of the resting platform were investigated (Fig. 2). The slope of the resting area was 5% in all pens, the perimeter length was 0.80 and 0.72 m per ewe, respectively, and two nipple drinkers were located at the rear pen wall.

In herd C, the shape (FB-shaped vs. L-shaped) and width (0.5 m vs. 0.6 m) of the resting platform were investigated (Fig. 3). The slope of the resting areas was 10% in all pens, and the perimeter length was 0.90 and 0.64 m per ewe, respectively. One automatic drinking vessel was located on the side wall of each pen.

2.3. Behavioural observations

Every day for the 6 last days of each experimental period, the ewes' resting behaviour within each of the eight experimental pens was scored by the farmer during a quiet time of the day when the sheep were supposed to be resting (herd A: 1200 h, herd B: 1200–1300 h, herd C: 2200–2300 h). The following parameters were scored:

- number of sheep resting in the resting area;
- number of sheep resting partially in the resting area;
- number of sheep resting outside the resting area;
- number of sheep standing.

2.4. Cleanliness

Every morning for the 2 last days of each experimental period, all manure in the resting area was carefully collected into a container and weighed on an electronic scale. In addition, moisture on the surface of the resting area was scored using the following categories: (1) dry or only small spots are wet, (2) <1/3 of the resting area is wet, (3) 1/3 to 1/2 of the resting area is wet and (4) >1/2 of the resting area is wet.

2.5. Statistical analysis

In order to test the effects of resting area treatments on each sheep's resting behaviour and the resting area cleanliness within each herd, we applied a mixed model of analysis of variance with the following class variables: shape of the resting area (U-, L- or front and back), slope (0% or 5%—only herd A), width (0.5 m or 0.6 m—only herds B and C) and cleaning frequency (daily or every 2nd day) as class variables. Since groups of sheep were systematically rotated between treatment pens within herds,

Table 2
Resting behaviour of the sheep in relation to the shape of the resting areas.

Means ± S.E. % of total observations	Herd A			Herd B			Herd C		
	U-shape	FB-shape	P-value	U-shape	FB-shape	P-value	L-shape	FB-shape	P-value
Lying on the resting area	34.0 ± 0.9	56.4 ± 0.8	284.0	29.9 ± 1.1	44.7 ± 1.2	78.1	32.0 ± 1.5	49.0 ± 2.1	<0.0001
Lying partially on the resting area	7.5 ± 1.2	7.5 ± 1.0	0.0	5.9 ± 1.1	1.4 ± 0.4	16.3	0.9 ± 0.4	6.3 ± 1.2	<0.0001
Lying on the original pen floor	40.3 ± 2.0	20.7 ± 1.6	83.0	53.8 ± 0.8	47.2 ± 1.0	32.8	18.0 ± 1.9	3.2 ± 0.7	<0.0001
Standing	18.1 ± 2.1	15.2 ± 1.0	1.5	10.3 ± 0.7	6.7 ± 0.9	12.7	49.2 ± 3.1	41.3 ± 2.8	<0.05
^a Maximum number of animals observed lying on the resting area	5	8		5	6		5	8	
EPL in % of probable need 0.9 m per animal	54%	88%		80%	88%		71%	100%	
Theoretical maximal number of animals able to lie in the resting area simultaneously ^a	4.86–5	7.92–8		7.20–7	7.92–8		5.68–5	8.00–8	

^a Measure given in number of animals and not in % of total observations. Herd A and B had nine ewes per group, while herd C had eight ewes per group.

we specified 'group' as a random effect (Hatcher and Stepanski, 1994). In addition, we tested for the following interaction effects: shape \times width (or slope), cleaning frequency \times shape and cleaning frequency \times width (or slope).

Differences in resting behaviour and resting area cleanliness between the front and the back resting areas in pens with an FB-shape were tested using a two-tailed *t*-test.

The effect of resting area treatments on moisture scores was analysed using a contingency analysis of moisture scores by shape, slope or cleaning frequency within the herd, using Pearson's Chi-square tests with JMP® 7.0 software from SAS Inc.

Data are presented in means and standard errors (S.E.) from eight groups per herd.

3. Results

3.1. Resting behaviour

In all herds, the number of sheep resting on the platforms was significantly higher in pens with FB-shaped platforms than in those using U- or L-shaped platforms (Table 2). A reduction in resting time for the other resting platform shapes was primarily compensated by an increase in the number of sheep lying on the slatted floor and partly by an increase in the number of sheep standing. In herd B, the number of sheep lying partially on the platform and standing was higher in pens with U-shaped platforms than in FB-shaped resting platforms, whereas in herd C the opposite occurred with L-shaped platforms. The number of sheep standing was generally much higher in herd C than in herds A and B.

In all herds, the maximum number of sheep observed lying on the resting platforms was higher in the pens with FB-shaped platforms than in pens with U- or L-shaped platforms (Table 2). The only treatment in which all group members were observed lying simultaneously on the resting platforms was in pens with FB-shaped platforms within herd C where the EPL was 0.9 m per ewe. The maximum theoretical number of sheep resting on the platforms was then calculated using an EPL of 0.9 m per ewe for the different treatments of resting area shape. As seen in Table 2, the actual maximum number of sheep resting simultaneously on the resting platforms and the calculated maximum number of sheep lying simultaneously were nearly identical in herds A and C, but somewhat lower in herd B.

In herds A and C, the sheep seemed to distribute themselves evenly between the front and back platforms in pens with FB-shaped resting areas (herd A, mean \pm S.E.: $28.6 \pm 1.4\%$ vs. $27.9 \pm 0.5\%$; herd C: $25.4 \pm 1.4\%$ vs. $23.7 \pm 1.1\%$), while in herd B, the ewes had a preference for lying on the resting area in front of the pen ($27.8 \pm 0.7\%$ vs. $16.9 \pm 0.4\%$, $T = 2.0$, $P < 0.0001$).

More ewes rested on the original pen floor in pens with a narrow resting area compared to pens with a resting area containing an extra 10 cm in width in herd B ($52.1 \pm 1.3\%$ vs. $48.9 \pm 1.1\%$, $F_{1,24} = 7.4$, $P < 0.05$), although no such effect was found in herd C.

In herd A, no slope effect was discovered on resting behaviour, but a significant interaction effect between the shape and slope of the resting area was found ($F_{1,24} = 5.6$, $P < 0.05$). More sheep were partially resting in the area with a 5% slope compared to a 0% slope in pens with FB-shaped resting platforms ($10.1 \pm 1.0\%$ vs. $5.0 \pm 1.8\%$),

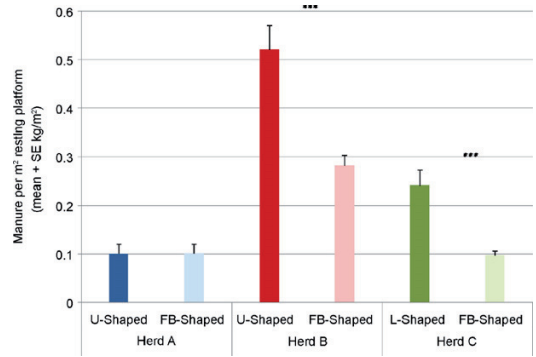


Fig. 4. Amount of manure gathered in relation to resting platform shapes (*** $P < 0.0001$).

whereas the opposite occurred in pens with U-shaped platforms ($6.9 \pm 1.7\%$ vs. $8.2 \pm 1.8\%$). No interaction effects of shape and slope were found in any other herds.

More ewes were resting on the original pen floors in herd B in pens in which the resting areas were cleaned out daily compared to pens where the resting areas were cleaned out only every 2nd day ($52.8 \pm 1.2\%$ vs. $48.9 \pm 1.3\%$, $F_{1,24} = 7.4$, $P < 0.05$), but cleaning frequency had no effect on resting behaviour in herds A or C.

No significant interaction effects between cleaning frequency and shape, width or slope were discovered for the different resting behaviours.

3.2. Floor cleanliness

The amount of manure per m² of resting area was significantly lower on FB-shaped platforms than on U- and L-shaped platforms in herds B and C, although this effect was not found in herd A (Fig. 4). In general, the amount of manure was much higher in herd B, especially in the U-shaped resting area. The manure in all FB-shaped pens was quite evenly distributed between the front and rear resting platforms.

Resting area shape also affected the mean moisture score in herd B, in which U-shaped resting platforms had higher moisture scores than FB-shaped resting platforms, but this difference was not significant in herd A and only showed a tendency in herd C (Table 3). In general, most observations were scored using moisture category 1, except in pens with U-shaped resting areas within herd B, in which category 3 scored the most (Table 3).

In herd A, a floor slope of 5% resulted in a significantly lower amount of manure than in floors with no slope (0.03 ± 0.006 kg/m² vs. 0.2 ± 0.02 kg/m², $F_{1,24} = 69.2$, $P < 0.0001$) and a significantly reduced mean moisture score (0% slope: 1.8 ± 0.2 vs. 5% slope: 0.8 ± 0.03 , $X^2_{1,62} = 16.6$, $P < 0.01$). It was only in herd B that increasing the width of the resting platform resulted in a significantly higher amount of manure gathered (0.5 ± 0.05 kg/m² vs. 0.3 ± 0.05 kg/m², $F_{1,24} = 10.2$, $P < 0.01$). However, the width of the resting platforms did not affect moisture scores in herds B or C (herd B—0.50 m: 2.8 ± 0.05 vs. 0.60 m: 2.9 ± 0.2 ; herd C—0.50 m: 1.2 ± 0.2 vs. 0.60 m: 1.3 ± 0.2), and no inter-

Table 3

Distribution of moisture score and means in relation to resting area shape within herds (frequency in % of total observations).

Herd	Resting area shape	Moisture score (frequency in % of tot obs)				Differences between shapes		Mean moisture score \pm S.E.
		1	2	3	4	$\chi^2_{1,62}$	P-value	
A	U	71.8	18.7	6.3	3.13	5.0	ns	1.2 \pm 0.3
	FB	62.5	25.0	12.5	0.0			
B	U	0.0	12.5	84.4	3.1	36.3	<0.0001	2.9 \pm 0.08
	FB	46.8	12.5	34.9	6.3			
C	L	68.7	28.1	3.1	0.0	4.9	0.08	0.9 \pm 0.5
	FB	95.3	4.7	0.0	0.0			

action effects between width and slope were discovered. Cleaning every 2nd day increased the amount of manure on the floor compared to cleaning every day in both herd B (0.5 ± 0.06 vs. 0.3 ± 0.02 kg/m², $F_{1,24} = 33.2$, $P < 0.0001$) and herd C (0.2 ± 0.03 kg/m² vs. 0.1 ± 0.01 kg/m², $F_{1,24} = 22.6$, $P < 0.0001$), although no such effect was found in herd A.

In both herds B ($F_{1,24} = 20.7$, $P < 0.0001$) and C ($F_{1,24} = 8.4$, $P < 0.01$), a significant interaction effect between the shape and cleaning frequency of the resting platform was found for the amount of manure gathered. More manure was found on U- (0.7 ± 0.05 kg/m² vs. 0.3 ± 0.03 kg/m²) and L-shaped resting platforms (0.33 ± 0.03 kg/m² vs. 0.1 ± 0.02 kg/m²) when these pens were cleaned out every 2nd day compared to being cleaned on a daily basis. The differences between FB-shaped platforms regarding cleaning frequency were less prominent (herd B, daily vs. every 2nd day: 0.2 ± 0.03 kg/m² vs. 0.3 ± 0.03 kg/m²; herd C, 0.07 ± 0.01 kg/m² vs. 0.1 ± 0.01 kg/m²). No other interaction effects were found for moisture scores or manure gathered.

4. Discussion

Both the average and maximum number of sheep lying on the resting platform were significantly higher in pens with the FB-shape than in the U- or L-shaped platforms. This was mainly compensated by an increase in the number of sheep lying on the original pen floor in pens with U- or L-shaped platforms. However, the number of standing sheep also increased in these pens, suggesting that sheep have a preference for lying on the resting platforms and experience the platforms as an improvement in their environment. On the other hand, Færevik et al. (2005) found no clear preference for the type of flooring in the resting area for unshorned sheep, although shorned sheep had a clear preference for solid flooring over one of expanded metal. Experiments with dairy goats showed corresponding results (Bøe et al., 2007).

The number of sheep resting on the platform was very closely correlated to EPL (effective perimeter length), and it was only when the EPL was 0.9 m per ewe that all the sheep in the pen were observed to lie simultaneously. Studies on the body measurements of sheep confirm that adult ewes with a mean live weight of 80 kg (similar to the Norwegian white breed) have a body length of approximately 0.8 m from the point of the shoulder to the pin bone (e.g., Riva et al., 2004). This further supports our assumption that a minimum EPL of 0.9 m per ewe is necessary. This can either be

achieved by adding platforms in both the front and the back of the pen and/or by increasing the total space allowance in the pen. Alternative ways of increasing EPL have been to add additional walls in the pen (Jørgensen et al., 2009) or to organize the resting areas into two levels (Hansen and Lind, 2008), but these measures neither increased the resting time nor the synchrony of resting.

The width of the resting platform had no effect on the resting behaviour in herd C and gave only a limited effect in herd B, suggesting that ewes experience a resting platform width of 0.5 m as sufficient. Because of the strong preference for lying next to a wall as opposed to lying side by side with other sheep (e.g., Færevik et al., 2005; Bøe et al., 2006), a further increase in the width of the platform will probably have no effect on resting behaviour. In earlier experiments with loosehoused dairy cows given moderate slopes (8–10%) in the resting area, Keck et al. (1992) found that slopes modified the resting pattern but not the time spent resting, while another study on fattening bulls reported more incidents of slipping and falling when resting areas sloped to more than 5% (Schulze Westerath et al., 2006). In the present experiment, the floor slope of the resting platforms did not seem to have a significant effect on the number of ewes resting, though on the other hand, the width of the resting platform also restricted the ewes' freedom to choose other resting patterns or positions. Phillips and Morris (2002) showed that cattle actively avoid surfaces covered with excreta, resulting in a possible effect on cleaning frequency, but no such effects were found in the present study. This might be explained by the relatively low amounts of manure gathered in general, as well as the fact that the manure was quite dry and the moisture scores low.

4.1. Floor cleanliness

The amount of manure was quite low in two of the herds, and actually lower on FB-shaped platforms compared to U- and L-shaped platforms, which seems strange because the total area of the FB-shaped platforms is larger. In pens with FB-shaped platforms, the ewes were also standing on the front platform during feeding; hence, it is possible that the ewes were shuffling the manure off the platform when backing out of the feed barrier. In herd B only, the moisture score was higher on U-shaped than FB-shaped platforms, and could not be explained by a difference in water spillage from the drinking nipples since they were mounted on the back wall in all pens regardless of resting platform shape.

Contrary to what has been reported in experiments with cattle (Schulze Westerath et al., 2006), we found that increasing the slope improved the cleanliness of the floor by both reducing the amount of manure and moisture score. This confirms the positive effect of a floor slope on cleanliness commonly pointed out in recommendations for pigs (e.g., Anonymous, 1993) and cattle (e.g., Anonymous, 2005). A wider resting platform resulted in an increase in the amount of manure which is reasonable because of the increased area, although there was no increases in moisture score with the latter indicating that a sufficient floor slope will drain off moisture, as the width of the platform is of minor importance for moisture levels.

Not surprisingly, cleaning every 2nd day increased the amount of manure on the platform floor. Nevertheless, since this did not affect lying behaviour, the only negative consequence of the increased amount of manure is a possible long-term effect of fleece, skin and claw contamination.

In conclusion, resting platforms of solid wood may be a relatively cheap and convenient way of increasing the resting comfort of sheep housed in fully slatted floor pens, but it is important that there is a sufficient amount of available effective perimeter length. The resting platforms were relatively clean and dry, even when they were cleaned out every 2nd day.

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A ram of the Norwegian Wild sheep breed. Photo: Kleo Delaveris



*Mouflon rams at Langedrag.
Photos: GHM Jørgensen*

"Science is organized common sense where many a beautiful theory was killed by an ugly fact"
Thomas Huxley



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The effect of different pen partition configurations on the behaviour of sheep

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ABSTRACT

The aim of our experiment was to test if different configurations of additional walls would increase total resting time and synchrony of resting behaviour while decreasing displacements from the resting area in small groups of sheep. A total of 24 adult pregnant ewes of the Nor-X breed were rotated between five treatment pens and one control pen (each with 4 ewes) in a Latin Square design. In five treatment pens solid walls were mounted on the resting area in different configurations (parallel wall: PAR; cross wall: CRO; perpendicular wall: PER; resting cubicles: CUB; three walls: THR), while one pen was kept without additional walls (control: CON). The ewes were acclimatized to each treatment pen for 6 days before 24 h video recordings were performed. Social interactions were scored continuously for 6 h during daytime while resting behaviour was scored using instantaneous sampling every 10 min during the entire 24 h. No significant differences were found between treatments in total resting time, resting synchrony or displacement behaviour. However, when housed in the CUB configuration the ewes performed more blocking behaviour ($P < 0.0001$), consequently resulting in more ewes resting in the activity area ($P < 0.05$). More head butting was observed in the THR treatment than in the CRO treatment ($P < 0.05$). In conclusion, additional walls did not increase the resting time, reduce aggressive social interactions or increase the synchrony of resting behaviour in ewes. It is probably more important for sheep to have enough resting space to lie simultaneously and the ability to keep within visual contact with group mates.

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1. Introduction

In areas with cold winter climate, sheep are often housed indoors during winter. The typical way of housing sheep in Norway is in pens with slatted flooring and a space allowance of 0.7–0.9 m² per animal (Bøe and Simensen, 2003). In contrast, new regulations for organic sheep farming demands a minimum of 1.5 m² total area per animal, and half of this should be a resting area with a solid floor (0.75 m² per sheep) (Council Regulation (EC) No. 1804/1999).

In a production environment, animals often have to compete for resources. This may have major negative

effects on feed intake (goats: Jørgensen et al., 2007), weight gain (e.g. sows: Brouns and Edwards, 1994), reproduction (e.g. Sinervo et al., 2000; Smith and Dobson, 2002) and disease (e.g. Hessing et al., 1994). Marsden and Wood-Gush (1986) found that next after feed, limited lying space caused most of the displacements in sheep. Moreover, a reduction in resting space from 1.0 to 0.5 m²/ewe not only resulted in more displacements but total resting time and the degree of resting synchrony were also reduced (Bøe et al., 2006).

Domestic sheep and goats show a preference for lying next to a wall when resting (sheep: Marsden and Wood-Gush, 1986; Færevik et al., 2005; goats: Andersen and Bøe, 2007). One could argue that this preference for lying against a wall may only be a result of the animals' wishes to maximise the individual distance between them (Stricklin et al., 1998). Resting time also increases with increasing

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perimeter length (Bøe and Nyhammer, 2004). In general, increasing the pen area only involves a minor increase in available perimeter length, and hence large pens have a low proportion of accessible wall length per animal (e.g. Bøe et al., 2006). Partitions or walls between the animals at the feeding place have successfully been used to decrease food competition (pigs: Andersen and Bøe, 1999; cattle: DeVries and von Keyserlingk, 2006). Furthermore, partitions in the middle of a pen have been used to distribute animals more equally (e.g. Cornetto and Estevez, 2001). Providing additional walls not only serves to increase the overall vertical surface area in which the sheep could lay against but also decrease visual contact between individuals when available space is limited. We expect that “out of sight – out of mind” is a relevant explanation for what is occurring, since physical barriers create ways to flee and visually disappear from an attacker.

The aim of this experiment was to investigate how different configurations of additional pen walls in the resting area would affect resting pattern, overall use of the resting area and competition for resting space in small groups of ewes. We predicted that additional walls would increase resting time and the synchrony of resting, that fewer individuals will be resting in the activity area, and that the amount of aggressive interactions will decrease.

2. Materials and methods

Six groups of four animals were systematically rotated in a Latin Square design between six pens with different layouts of additional walls in the resting area (Fig. 1). One of the pens had no additional walls and served as control (CON). All groups were kept for 1 week in each of the experimental pens, of which 6 days was the time to get accustomed to the pens before the ewes' behaviour was recorded.

2.1. Experimental pens and additional walls

The experiment was conducted in an insulated building with mechanical ventilation, at the Norwegian University for Life Sciences, for 6 weeks in January and February 2007. Each experimental pen measured 3.0 m × 2.0 m (6.0 m²), giving a total area per animal of 1.5 m², which equals the demand for space allowance in organic farming (Council Regulation (EC) No. 1804/1999). The pen had a concrete floor, but half of the pen (3.0 m²) served as resting area with solid wooden floor elevated 10 cm from the ground (Fig. 2). The activity area in front of the feed barrier was

covered with wooden grids (approx. 5.0 cm high and 15.0 cm openings between beams) to make this area provide less support if the sheep should choose to use this as an alternative resting place.

For diagrams and further details on the treatment pen configurations, see Fig. 1.

2.2. Animals and management

A total of 24 adult, pregnant ewes were divided into groups according to body weight so that the mean weight did not differ between groups (mean ± S.E. weight per group: 65.8 ± 0.7 kg; range: 65.0–66.7 kg). Each group was placed in an experimental pen and given *ad libitum* access to good quality hay and free access to water from buckets. Along the length of the front pen wall (2.0 m) there was a horizontal feed opening (post and rail design), which gave the ewes 0.5 m feed space per animal and ensured easy access to the feed. Once a day hay residues were removed and the sheep were fed a standard concentrate pellet feed (approximately 0.2 kg per ewe) before fresh hay was administered. In addition to this, ewes had *ad libitum* access to mineral blocks.

Faeces and urine was removed from the resting area twice a day and a thin layer of sawdust was administered to ensure a dry and non-slippery surface. The activity/dunging area was cleaned out twice a week, so that the level of faeces always was kept below the wooden grids.

2.3. Observations

Within each group the animals were marked with a number (1–4) on their back using a marker spray for animals.

A wide-angle video camera mounted above each pen was directly connected to a computer using the MSH video system[®] (www.guard.lv). We recorded the ewes' behaviour for 24 h (from 10:00 a.m. to 10:00 a.m. the next day), at the seventh day in each experimental week. In the video analysis we used instantaneous sampling every 10 min to score the following behaviours:

- Lying in contact with an original pen wall.
- Lying in contact with an additional wall.
- Lying in the resting area without any wall contact.
- Lying in contact with an additional wall, but blocking access to resting area for other sheep (occupying half or more than half of the opening needed to enter the resting area).
- Lying in the activity area.

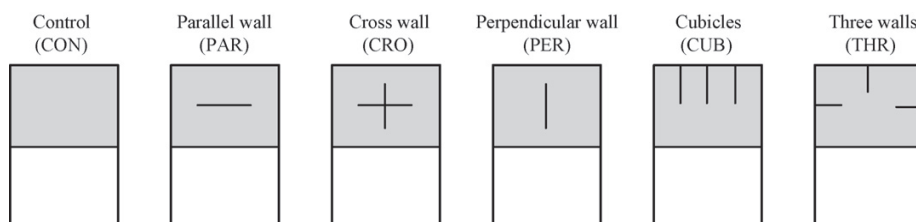


Fig. 1. The different configurations of the additional walls on the resting area in the six treatment pens.

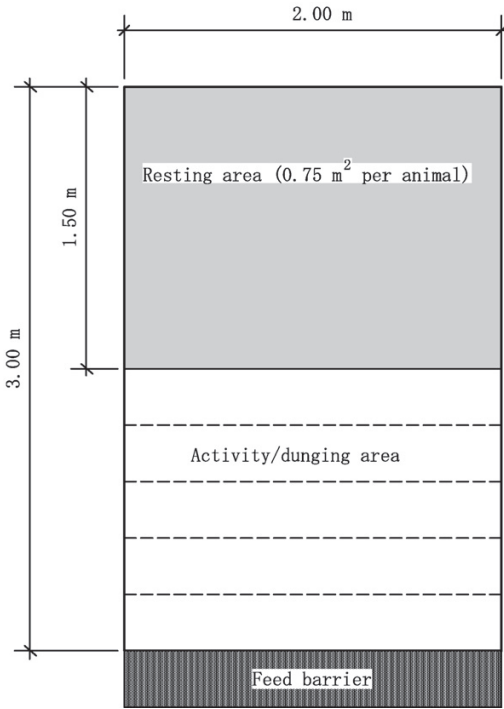


Fig. 2. The experimental pen with resting area (grey), feed barrier and activity area with wooden grids on the floor.

In order to determine if sheep were lying resting against a wall or just accidentally in contact with it, we defined 'lying in contact' when a sheep was lying resting in physical wall contact with at least its front half of the body (neck to belly). If the ewe was lying with its hind half of the body in contact with the wall, the behaviour was categorized in relation to how much of the body was in physical contact with the wall. A sheep resting not only with its shoulder in contact with an additional wall but also with its hindquarters touching an additional wall was scored as resting against the original pen wall.

All observations of resting behaviours were later summed to give the percent of total observations lying, and for each observation we also calculated how many ewes were resting simultaneously.

The following social interactions were scored continuously for 6 h during daytime (10 a.m. to 4 p.m.):

- Displacing (a ewe has to leave her feeding or resting place after being physically pushed, butted or kicked by another ewe).
- Unsuccessfully attempting to displace (one ewe tries to use physical force either by pushing or kicking another ewe that is feeding or resting, but the receiving ewe does not give up her place).
- Head butting (using forehead to forcefully push or clash against another ewe's head).

In addition, we identified the initiator and receiver of the social interactions.

2.4. Statistical analysis

A mixed model of analysis of variance was applied to test the effects of additional wall configuration on all types of behaviours with wall configuration (six different types) and group (1–6) as class variables. Group was specified as a random effect (Hatcher and Stepanski, 1994).

The LS MEANS procedure was used to test the differences between means. Mean values per group were used as statistical unit.

3. Results

3.1. Resting behaviour

There was no significant effect of the treatments on the mean resting time (mean \pm S.E. for all groups: $70.3 \pm 0.4\%$ of observations; Table 1).

On average 2.8 ± 0.02 animals rested simultaneously on the resting area. The highest number of animals resting simultaneously was found in the cross wall pen (CRO: 2.9 ± 0.03) and in the parallel wall treatment (PAR: 2.9 ± 0.04), but synchrony of resting did not differ significantly between treatments (CON: 2.8 ± 0.05 ; PAR: 2.8 ± 0.06 ; CUB: 2.8 ± 0.04 ; THR: 2.8 ± 0.05).

Ewes spent significantly more time resting in the activity area in the cubicle (CUB) treatment than in the other treatments (Table 1). Total resting time, time spent resting in the activity area and resting synchrony did not differ significantly between groups.

3.2. Resting against additional walls

In $2.1 \pm 0.6\%$ of all resting observations, ewes were lying without wall contact and this occurred more often in the control than in the PAR, CRO or CUB treatments (Table 1).

The ewes spent $34.3 \pm 2.2\%$ of observations resting against an original pen wall. A mean of $15.4 \pm 1.5\%$ of observations were spent resting against an additional pen wall. The additional walls were used significantly more in CUB compared to in PER (Table 1). The behaviour: 'lying against an additional wall blocking access to resting area for other sheep' was observed significantly more in CUB than in any other treatments (Table 1). There was no significant effect of ewe group on the proportion of time spent resting against a wall.

3.3. Social interactions

In general, there were few social interactions. Therefore we only used observations of ewes initiating social interactions. There was no significant effect of the treatments on the number of displacements (Table 2). Unsuccessful displacement attempts were rare (mean \pm S.E.: 0.7 ± 0.09 instances per ewe) and none of these behaviours differed significantly between treatments. We observed significantly more head butting in the THR treatment compared to in the CRO treatment (Table 2).

Table 1
Resting behaviours and use of additional walls in the resting area (mean \pm S.E.).

Resting behaviours	Control (CON)	Parallel wall (PAR)	Cross wall (CRO)	Perpendicular wall (PER)	Cubicles (CUB)	Three walls (THR)	$F_{5,25}$	P -value
Total lying (% of total observations)	69.5 \pm 1.0	70.1 \pm 1.0	71.2 \pm 1.0	71.3 \pm 1.1	69.5 \pm 1.0	70.0 \pm 1.1	0.94	ns
Lying in the activity area (% of resting observations)	18.0 \pm 6.9 ^a	17.2 \pm 4.9 ^a	15.8 \pm 2.9 ^a	12.0 \pm 3.5 ^a	30.6 \pm 5.7 ^b	19.1 \pm 3.0 ^a	3.6	<0.05
Lying in the resting area without wall contact (% of resting behaviours)	8.9 \pm 3.9 ^a	0.23 \pm 0.1 ^b	0.8 \pm 0.6 ^b	4.4 \pm 1.3 ^{ab}	0.3 \pm 0.1 ^b	3.8 \pm 1.4 ^{ab}	3.2	<0.05
Lying against original pen wall (% of resting behaviours)	72.2 \pm 4.2 ^a	55.5 \pm 4.8 ^b	55.0 \pm 5.0 ^b	62.8 \pm 2.7 ^{ab}	5.0 \pm 2.4 ^c	41.5 \pm 2.5 ^d	51.9	<0.0001
Lying against additional wall (% of resting behaviours)	–	25.5 \pm 0.5 ^{ab}	25.3 \pm 3.8 ^{ab}	17.8 \pm 2.8 ^a	32.3 \pm 5.4 ^b	29.6 \pm 4.4 ^{ab}	11.9	<0.001
Lying against additional wall blocking for others (% of resting behaviours)	–	1.5 \pm 0.9 ^a	2.9 \pm 1.2 ^a	2.8 \pm 0.8 ^a	31.6 \pm 3.4 ^b	5.8 \pm 3.0 ^a	41.8	<0.0001

Means with same superscript letters (a,b,c,d) does not differ significantly ($P < 0.05$).

The amount of social interactions did not differ between ewe groups.

4. Discussion

Contrary to what was predicted, provision of additional walls in the resting area did not significantly affect total resting time or synchrony of resting. The total resting time in the present experiment was somewhat longer than in previous, comparable experiments with sheep (Færevik et al., 2005; Bøe et al., 2006). Deep pens of the same size as the one used in our experiment are also reported to give a similar resting time as pens with a wide shape (Bøe et al., 2006). However, a smaller sized resting area may limit the effects of additional walls since these walls may allow some individuals to block others from resting. It is still unlikely that a larger resting area will be used under commercial conditions. Unfortunately, to our knowledge, few if any have looked at the effects of providing additional walls on the resting patterns of farm animals. When the ewes were offered cubicles on the lying area, they rested more in the activity area. This effect is most certainly due to some ewes blocking the entrance, and thus preventing others from lying in the resting area. An alternative explanation for the low success of the cubicle configuration is that the ewes did not prefer to rest in cubicles with solid walls that strongly limited the opportunity for vigilance and visual contact with the other group members. However, even in this inappropriate configuration, the total lying time was maintained. The fact that total resting time is very similar in all treatments, confirm the results found in cattle that resting is a high priority and an inelastic behavioural need (Jensen, 2005). In the present

experiment, the synchrony of lying was relatively high. Often complete synchrony of resting was achieved by some individuals lying in the less attractive activity area. This is probably due to a general high level of synchronisation of maintenance behaviours like resting and feeding in sheep (Rook and Penning, 1991).

The provision of additional walls did not decrease the number of displacements from the resting area compared to the control treatment, and the number of displacements did not differ between treatments. This shows that additional walls did not decrease competition for lying space. Head butting was less commonly observed in the CRO (cross wall) than the THR (three wall) treatment, possibly due to a greater opportunity to monopolize the resting area in the latter or that the CRO treatment function better as a hide area. The same could be true for the cubicle configuration where the most blocking behaviour was observed. Comparatively, the use of partitions in the feeding area successfully reduces displacements and other aggressive interactions both in pigs (e.g. Andersen and Bøe, 1999) and cattle (DeVries and von Keyserlingk, 2006).

Sheep have been observed to lie very close to each other in up to 70% of total resting observations (Bøe et al., 2006) whereas dairy goats only rest in contact with another goat in 5% of resting observations (Andersen and Bøe, 2007). Furthermore, the number of sheep resting close together was still high (59.4%) even when given 1.0 m² per animal resting space (Bøe et al., 2006), while goats decreased this behaviour to only 2.9% of total resting observations when given the same resting space (Andersen and Bøe, 2007). This indicates that the need for visual separation on the resting area is less for sheep than for goats. From earlier experiments we know that sheep prefer to lie against a

Table 2
Social interactions in the different treatments (mean \pm S.E.).

Social interactions (total number per ewe)	Control (CON)	Parallel wall (PAR)	Cross wall (CRO)	Perpendicular wall (PER)	Cubicles (CUB)	Three walls (THR)	$F_{5,25}$	P -value
Displacements in total	6.3 \pm 1.4	3.8 \pm 0.7	4.7 \pm 1.2	5.2 \pm 0.4	5.4 \pm 0.9	3.2 \pm 0.6	1.6	ns
Displacements from the resting area	1.8 \pm 0.3	1.1 \pm 0.4	2.1 \pm 0.8	0.9 \pm 0.3	1.6 \pm 0.4	0.9 \pm 0.3	1.9	ns
Unsuccessful displacement attempts	0.7 \pm 0.3	0.5 \pm 0.3	0.9 \pm 0.2	0.8 \pm 0.05	0.9 \pm 0.2	0.5 \pm 0.2	0.78	ns
Head butting	1.8 \pm 0.3 ^{ab}	1.2 \pm 0.4 ^{ab}	0.4 \pm 0.2 ^a	1.2 \pm 0.4 ^{ab}	2.2 \pm 0.6 ^{ab}	3.8 \pm 1.6 ^b	2.6	<0.05

Means with the same superscript letters (a,b) does not differ significantly ($P < 0.05$).

wall when resting (e.g. Færevik et al., 2005), and that they prefer to rest simultaneously even when the resting area is limited (this experiment).

In conclusion, additional walls did not increase the resting time, reduce aggressive social interactions or increase the synchrony of resting behaviour in ewes. It is probably more important for sheep to have enough resting space and the ability to rest simultaneously than the ability to avoid visual or physical contact with other sheep.

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Pictures from the experiment reported in Paper V. Photos: GHM Jørgensen

"In order to make an apple pie from scratch, you must first create the universe"
Carl Sagan

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 every 20 minutes. 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.

Abbreviations: LCT, lower critical temperature.

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 m² per animal (Bøe and Simensen 2003). New regulations for organic sheep farming demands a minimum of 1.5 m² total area per animal, and half of this should be a resting area with a solid floor (0.75 m² 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.

In regions with cold winters and snow, sheep need some kind of housing. 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 (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's 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.

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).

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). Roughage was provided inside in two of the pens (pen 1 and 2) while in the other two pens (pen 3 and 4) the roughage 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, whereas the upper parts had PVC coated polyester wind breaker (Galebreaker®). Each pen measured 3.76 m x 2.40 m, providing a total area of 1.80 m² 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.

Animals and Feeding

20 adult ewes (aged 1.5-3.5 years) of the Norwegian White breed (mean weight \pm STD: 77.1 \pm 9.5 kg) were randomly allotted to 4 groups à 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, 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.

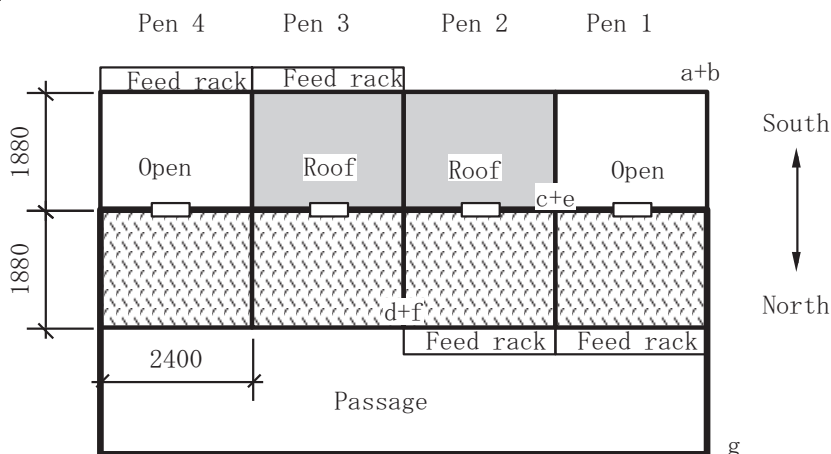


Figure 1. A schematic presentation of the experimental building with the four pens. A solid roof was present over the whole building, including the inside area of the pens (dotted) and the passageway in front. Only the outdoor yards of pen 3 and 4 were covered with a roof, and pens 3 and 4 were fed outdoors 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.

Prior to the experiment the animals had been on pasture from May to October, and were housed in groups of 12-15 (space: $1.0 \text{ m}^2/\text{ewe}$) 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. No ewes were sheared and 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.

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, leading to the exclusion of this parameter from our datasets. 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)

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.ly). 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.

Statistical Analysis

In order to test the effect of pen, weather, time of day, 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), weather categories (1-5), 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 (Hatcher and Stepanski 1994).

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 location 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[®].

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 1).

Feeding made up approximately 25 % of total observations, but still 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 1) 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 yards, 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 1). Furthermore, the total resting time was longer when the outdoor yard was covered and also when feed was located outdoors (Table 1).

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 %). 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 %). 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 1).

Table 1. 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			F _{1,114}	P-value	Effect of feed location		F _{1,114}	P-value
	Roof	No roof				Indoors	Outdoor yard		
In outdoor yard	43.8 ± 1.3	36.3 ± 1.4	24.1	<0.0001	34.8 ± 1.4	45.2 ± 1.2	24.2	<0.0001	
Resting	60.6 ± 1.7	58.1 ± 1.7	17.1	<0.0001	57.7 ± 1.7	60.9 ± 1.7	25.6	<0.0001	
- inside barn	36.3 ± 1.6	42.6 ± 1.8	32.2	<0.0001	31.6 ± 1.5	47.4 ± 1.5	180.1	<0.0001	
- outdoor yard	24.2 ± 1.4	15.5 ± 1.2	75.9	<0.0001	26.2 ± 1.4	13.5 ± 0.7	121.7	<0.0001	
All sheep resting simultaneously	34.0 ± 1.2	29.1 ± 1.3	12.1	<0.001	31.4 ± 1.3	31.7 ± 1.3	0.7	ns	
Feeding	26.0 ± 1.2	24.7 ± 1.3	0.9	ns	25.3 ± 1.2	25.5 ± 1.3	0.01	ns	
Stand /walk	13.4 ± 0.8	17.1 ± 0.8	20.9	<0.0001	16.9 ± 0.9	13.6 ± 0.7	20.3	<0.0001	
- inside barn	6.8 ± 0.5	8.7 ± 0.5	21.1	<0.0001	8.2 ± 0.45	7.4 ± 0.5	12.8	<0.001	
- outdoor yard	6.5 ± 0.4	8.4 ± 0.6	10.1	<0.01	8.7 ± 0.6	6.2 ± 0.4	13.7	<0.001	

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.

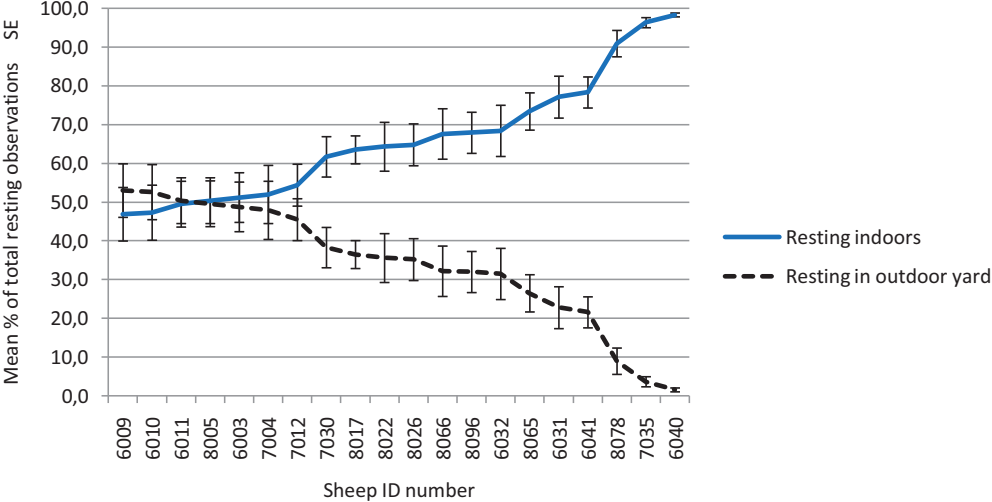


Figure 2. Individual sheep’s choice of resting area throughout the experimental period.

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, with 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).

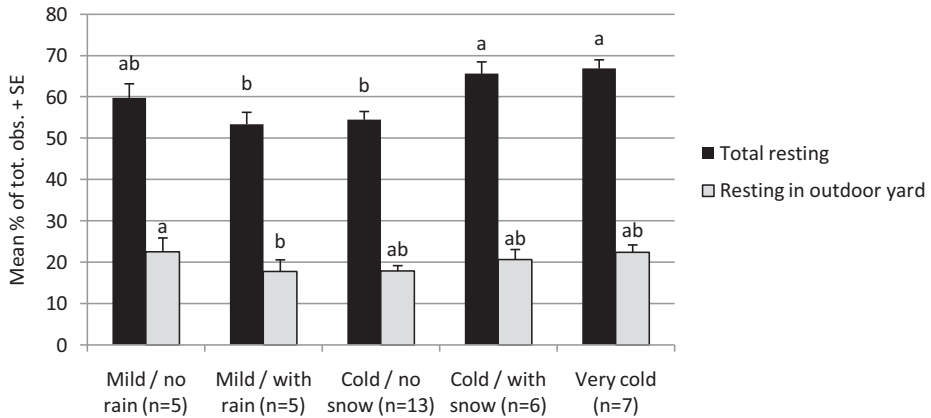


Fig 3. The effect weather on the proportion of sheep resting in total and in the outdoor yard. Different letters above bars depict significant differences between weather categories ($P < 0.05$).

Within weather category 2 (mild, with rain), significantly more sheep were observed resting in the outdoor yards that were covered with a roof ($24.5 \pm 3.9\%$), compared to when yards were not covered ($10.9 \pm 3.2\%$) (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: $34.6 \pm 2.3\%$ of tot obs.), compared to days with mild temperatures and rain (category 2: $23.8 \pm 2.0\%$) ($F_{4,114}=5.4$, $P < 0.01$). Resting synchrony on days with weather categories 1, 3 and 5 was $31.4 \pm 2.2\%$, $30.1 \pm 1.4\%$ and $34.6 \pm 2.3\%$ 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 \pm SE pen 3: 11.1 \pm 0.8 kg; pen 4: 14.0 \pm 1.3 kg) compared to in pens where the feed was offered inside the barn (pen 1: 5.2 \pm 0.4 kg; pen 2: 5.2 \pm 0.3 kg) ($\chi^2_{55}=71.3$, $P=0.068$).

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).

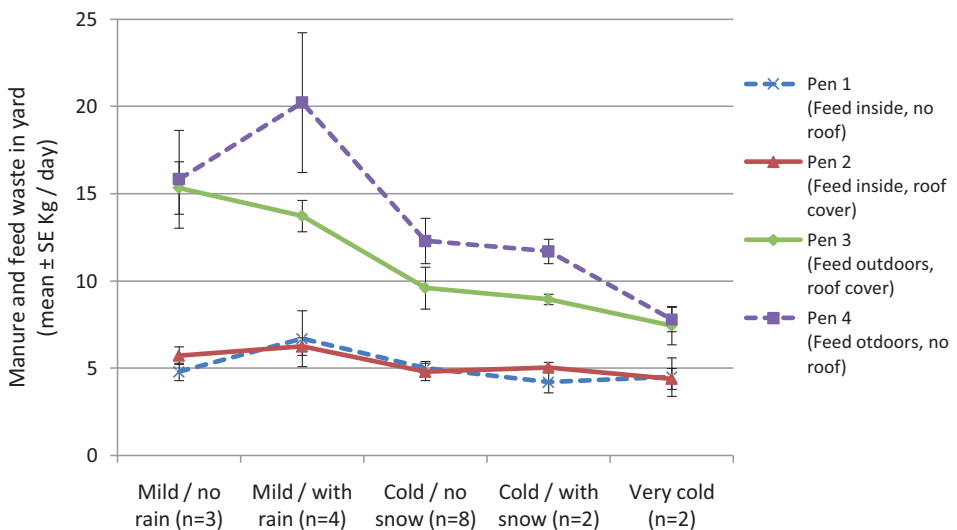


Figure 4. Effect of weather, roof cover and feed location on daily build-up of manure and feed residues in the outdoor yards.

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 2007) in earlier experiments. 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 at all during the period, and this factor was therefore omitted from the weather categories. The rather modest effect of weather on sheep behaviour 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 m²/ewe is minimum space allowance for ewes just for resting. 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 feed barrier 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 show that frequent cleaning is imperative. While a much larger yard would reduce the animal density and also reduces the need for frequent cleaning, the cost of ensuring surface drainage to prevent mud would increase accordingly (e.g. Andersson et al. 2007). Canadian recommendations state that soil surface feedlots should only be used in areas with less than 500 mm annual rainfall (Canadian Plan Service 2008).

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.

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