Preferences of sheep for different types of pen flooring

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Abstract

In countries where the climate makes it practical with indoor housing during cold periods of the year and access to straw is limited, e.g. Iceland and Norway, housing of sheep on slats or expanded metal floors is common practice. However, European regulations for organic farming require that all animals should have access to a lying area with solid floor. The objective of this experiment was to investigate sheep preferences for different types of pen flooring.

In experiment 1, a total number of 16 ewes, divided into four groups, were subjected to four different treatments. In each treatment, the ewes could choose between two lying areas with one of the following flooring materials: 1. solid wood vs. rubber mats, 2. expanded metal vs. solid wood, 3. solid wood vs. straw, 4. expanded metal vs. straw. In experiment 2, a total number of 8 ewes were individually subjected to the same treatments, first fully coated and then sheared. The ewes were video taped for 48 hours in each treatment period.

In experiment 1, the first animal that lay down after feeding preferred to lie down on straw or wood to expanded metal and straw to wooden floor ($P < 0.05$), but this first choice did not reflect the overall flooring preference for unsheared ewes. The groups of unsheared ewes showed no significant preferences for lying area.

In experiment 2, single housed, unsheared ewes preferred wooden floor to rubber mats ($P < 0.05$), and tended to prefer expanded metal floor to straw ($P = 0.08$). There were no significant preferences in the two other treatments. After shearing, the ewes' preferred wooden floor to expanded metal ($P < 0.05$), straw to wooden floor ($P < 0.05$), and straw to expanded metal floor ($P< 0.0001$). There were no significant preferences between rubber mats and wooden floor. Mean lying time (% of observations) for all treatments was 64.7 % for unsheared ewes, and there were no significant differences between treatments. Mean lying time (% of observations) for all treatments the first 2-3 days after shearing was 43 %. Significant differences in pre- vs. post-shearing lying times (% of observations) existed when the ewes were housed in pens with no straw ($P < 0.05$), this was not the case when the ewes had access to straw.

In conclusion, sheared but not unsheared ewes, preferred softer floors with low thermal conductivity (straw and wood). The less dramatically reduction in lying time (% of observations) after shearing when the ewes had access to straw, suggest that access to straw the first weeks after shearing may improve animal welfare.

Keywords: sheep, pen flooring, preference, lying area

Introduction

In areas where a cold climate during the winter makes it practical with indoor housing of sheep, and the supply of straw or other bedding material is scarce, e.g. Iceland and Norway, sheep is commonly housed in pens with fully slatted floor. Such pens keep the sheep clean with a minimum of working effort, without straw or bedding and with a low space allowance. However, concerns have been expressed about the welfare of farm animals housed in pens with fully slatted floor (e.g. pigs: Fraser et al, 1991, cattle: Dumelow, 1993), and the European regulations for organic farming (Council Regulation (EC) No 1804/1999) demand that a comfortable, clean and dry lying/resting area of sufficient size and of solid construction must be provided for all farm animals. Hence, it is a challenge to find a suitable flooring material that is comfortable and attractive for the ewes, and at the same time not too labour requiring for the farmer.

It is assumed that factors of the floor like thermal conductivity and softness will affect both animal preferences and maybe also animal welfare. The thermal conductivity and the softness of the floor will often be correlated, as soft floors will usually be well insulated and have a low thermal conductivity (Nilsson, 1988). The thermal conductivity of the floor will influence the thermoregulatory behaviour of the animals, both under cold and warm climatic conditions. Different studies show that straw bedding significantly reduces the LCT (lower critical temperature) compared to bare concrete (Bruce, 1979; Bruce and Clark, 1979). Furthermore, preference studies conducted at different ambient temperatures shows that both pigs (Fraser, 1985) and dairy cows (Manninen et al., 2002) prefer a floor that minimise heat loss at low ambient temperatures, and a floor that maximises heat loss at high ambient temperatures. In sheep, however, the thickness of the fleece will influence their LCT and most likely also

their preference for different flooring materials. For a fully coated sheep the LCT is very low (- 40 °C), after shearing the LCT will rise to + 13 ° C (Webster, 1976). Bøe (1990) found that unsheared lambs showed no preference for slatted floors with different thermal conductivity (wooden slatted floor vs. expanded metal floor), whereas the lambs after shearing almost exclusively preferred to lie on the floor with lowest thermal conductivity (wooden slatted floor).

When compared to bare concrete and different types of draining floors, softer floors with low thermal conductivity is associated with increased comfort. This is confirmed in several studies which shows that both cattle and pigs prefer softer floors like straw bedding, rubber mats or mattresses to harder floors such as bare concrete and different draining floors (Cattle: Herlin, 1997; Haley et al., 2001; Hultgren, 2001; Lowe et al., 2001; Stefanowska et al., 2002; Pigs: Mwanjali et al., 1983; Pearce, 1993; Phillips et al., 1996; Kelly et al., 2000). Resent studies show that sheep prefer straw to wooden slats (Gorden and Cockram, 1995), but there are generally few data on the preference of flooring materials in sheep.

The cleanliness of the floor will probably also influence the preference for lying area. In contrast to pigs where the majority of the defecation is deposited outside the lying area, sheep do not have specific locations for dunging. Therefore we must expect both defecation and urination in the resting area in a sheep pen. The absorption capacity of the flooring material will therefore be of some importance for the cleanliness of the lying area.

When studying preferences for lying area in group-housed animals, social conditions and total lying space must be considered. Recommendations for space allowance in confinement sheep production vary a lot (from 0.6 m^2 to 1.1 m^2, Czernek and Pilarczyk, 1977; Loynes, 1983; Hutson, 1984; Dalholdt, 1985; Midwest Plan Service, 1987), and there is little scientific evidence for how space allowance affects the performance and social behaviour of sheep (Dalholt, 1985).

In order the fulfil the European regulations for organic farming and give indoor housed sheep access to comfortable and attractive lying place, knowledge about sheep preferences for different flooring materials is important. The aim of these experiments was to investigate the preferences of sheep for different types of pen flooring.

Material and methods

Experimental design

Two separate experiments were conducted. In Experiment 1, four groups with four ewes in each group were subjected to four different treatments. In each treatment, the ewes could choose between two lying areas with the following flooring materials:

Treatment 1. Solid wood vs. rubber mats

Treatment 2. Expanded metal vs. solid wood

Treatment 3 Solid wood vs. straw*

Treatment 4. Expanded metal vs. straw*

*Concrete covered with straw to a depth of approximately 0.25 m.

The order of treatments was rotated systematically (Table 1), and the animals were allowed five days to become accustomed to each treatment before two days of video recording (each treatment period lasted seven days).

Table 1. Order of experimental treatments, experiment 1.

Period	Group			
	1	2	3	4
1	Treatment 1	Treatment 2	Treatment 3	Treatment 4
2	Treatment 2	Treatment 3	Treatment 4	Treatment 1
3	Treatment 3	Treatment 4	Treatment 1	Treatment 2
4	Treatment 4	Treatment 1	Treatment 2	Treatment 3

In Experiment 2, two batches of four single ewes were subjected to the same order of treatments as shown in table 1. After going trough all four treatments, the eight ewes were sheared, and again subjected to the same treatments. The time of accustoming to each treatment before the video recording started was two days (each treatment period lasted four days).

Experimental pens

Each of the four experimental pens consisted of two separate lying areas (2.0 m x 2.0 m) and a feeding area with concrete floor (Figure 1). To prevent the sheep from lying in the feeding area, beams (38 x 49 mm) where installed at c/c 0.40 m on the floor. Solid walls prevented ewes in adjacent pens from having physical and visual contact. The building were insulated and mechanically ventilated, and the ambient temperature during the experimental period ranged from 1.4 º C to 8.6 º C.

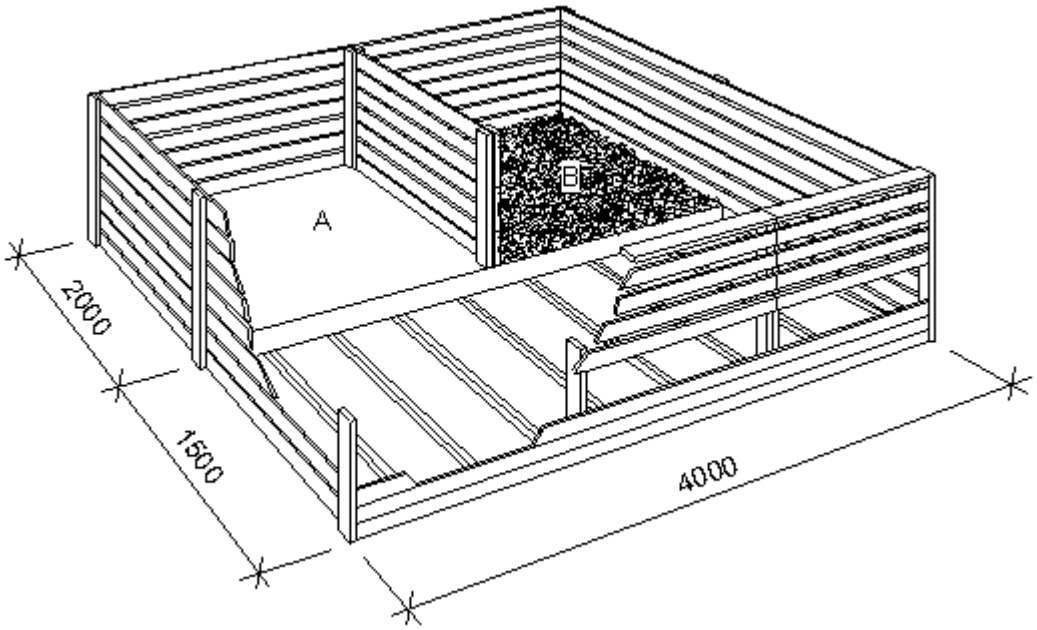

Figure 1. The experimental pen.

Animals and feeding

The ewes (> 1.5 year) were a Norwegian breed (Dala) randomly chosen from the resident herd at the Agricultural University of Norway. All ewes were weighed before the experiment started. The weight of the ewes ranged from 79 kg to 101 kg. The ewes are normally kept in an insulated building in pens with expanded metal floor during wintertime and on pasture after lambing in April. In experiment 1 (February and March), 16 ewes were sheared and mated in November and introduced to the experimental pens in the beginning of February. In experiment 2 (September – December), the ewes were introduced into the experimental pens after six months on pasture. The ewes were fed, the lying area cleaned and new bedding material provided at 15:00 h. Each ewe was given a ration of 0.3 kg concentrate and roughage was fed ad libitum.

Behavioural observations

The individually marked ewes were video recorded continuously for 48 hours in the end of each experimental period. Two video cameras (Panasonic WV – BP 310 G) was suspended over the pens. The video cameras were connected to a multiplexer (MV 16) and a time-lapse video recorder (Panasonic AG 6720). When analysing the videotapes, the behaviour and position in the pen were scored using instantaneous sampling at 15 min intervals using the following ethogram:

1. Lying in area A, close to the side wall
2. Lying in area A, close to the back wall
3. Lying in area A, in the middle
4. Lying in area B, close to the side wall
5. Lying in area B, close to the back wall
6. Lying in area B, in the middle
7. Standing in area A
8. Standing in area B
9. Standing in the eating area

Area A and area B represent the two different lying areas in the pen (Figure 1).

In experience 1, the preferred lying area of the first ewe that lay down after feeding (all other ewes standing in the eating area) was also recorded in experiment 1.

Statistics

A Mann Witney U- test (Hatcher and Stephanski, 1994) were used to analyse the preferences of different flooring materials and the first chosen lying area after feeding in the different treatments. A Kruskal-Wallis Test (Hatcher and Stephanski, 1994) was used to analyse the effect of shearing on lying time (% of observations) within flooring treatment (1 – 4) and the effect of days after shearing (4 periods) on lying time. Differences between means were analysed by using a Student - Newman Keul test (SNK). In experiment 1, means ± SE for the four groups of ewes were used in the calculations. In experiment 2, means ± SE for 8 ewes are presented.

Results

Experiment 1

Preferences for lying area

The group-housed ewes showed no significant preference for a specific flooring material in any of the four treatments (% of observation lying: wood vs. mats: 55.5 ± 8.3 vs. 44.5 ± 8.3, exp. met. vs. wood: 51.5 ± 9.6 vs. 48.5 ± 9.6, wood vs. straw: 51.8 ± 8.3 vs. 42.8 ± 8.3, exp.met. vs. straw: 50.9 ± 10.8 vs. 49.1 ± 10.8).

First choice of lying area after feeding

The first ewe that lay down after feeding preferred wooden floor to expanded metal floor, straw to wooden floor, and also straw to expanded metal floor (Figure 2). There were no significant preferences of lying area after feeding in the treatment where the ewes could choose between wooden floor and rubber mats.

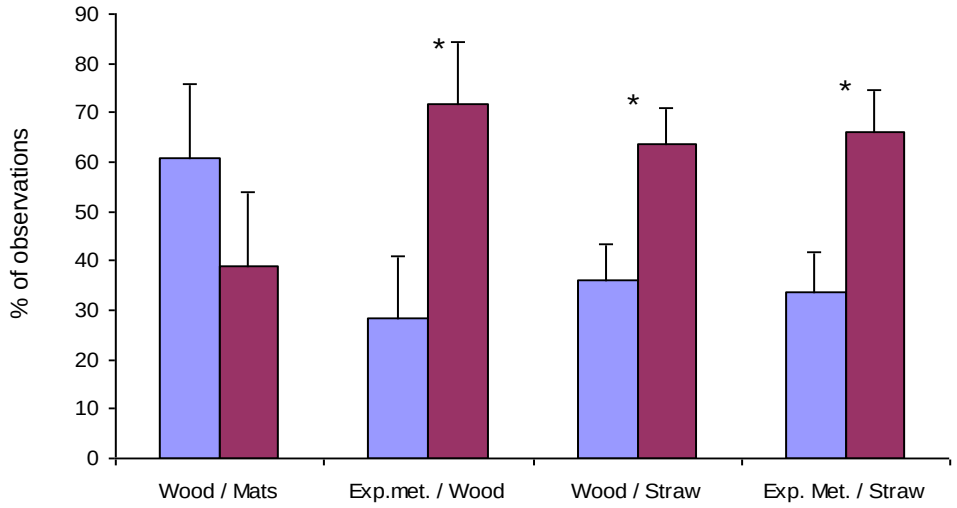

Figure 2. First choice of lying area after feeding, ($P < 0.05$).*

Lying time in the different treatments

The mean lying time (% of observations) for all treatments was 68.0 ± 1.0 %. There were no significant differences in lying time (% of observations) between treatments (wood vs. mats: 65.7 ± 2.2, exp.met. vs. wood: 66.5 ± 2.8, wood vs. straw: 69.0 ± 0.5, exp.met. vs. straw: 70.7±1.2).

Position in the pen

Irrespective of treatment, 53 % of the animals chose the same lying place in more than 80 % of the observations. The ewes also showed a clear preference for lying next to a wall (98.2 % of observations lying). The observations of ewes lying in the middle of the lying area (1.8 % of observations lying) was almost exclusively on lying areas with straw. Despite the fact that each of the lying areas had a total area of 1.0 m^2 per ewe, the

four ewes in each group hardly ever lay together in the same lying area (0.03% of observations lying).

Experiment 2

Preferences for lying area before shearing

Unsheared ewes showed a significant preference for wooden floor to rubber mats and tended to prefer expanded metal floor to straw ($P = 0.08$; Figure 3). The ewes showed no significant preferences for lying area in the treatments where they could choose between expanded metal floor and wooden floor, or in the treatment where they could choose between wooden floor and straw. The variation between the ewes was large for all treatments.

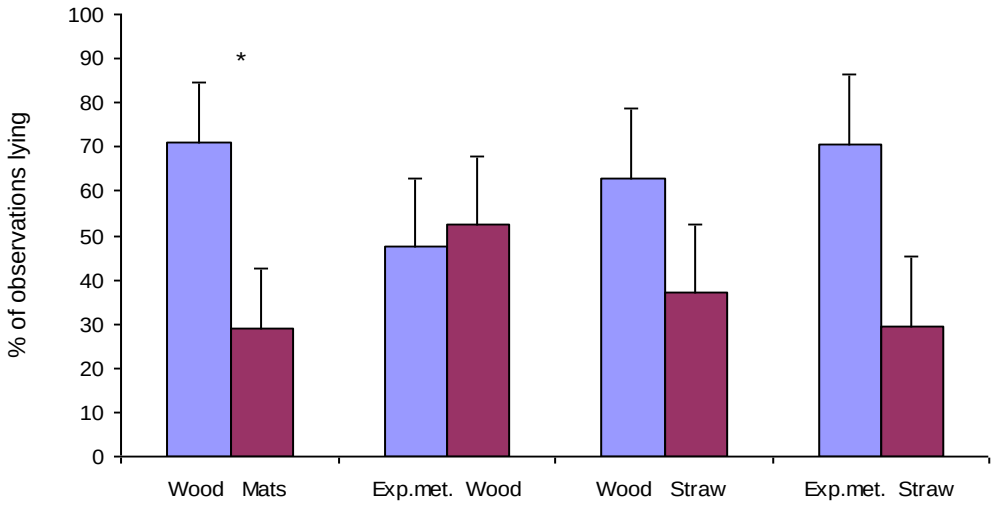

*Figure 3. Preference of lying area before shearing, experiment 2, (* P < 0.05).*

Preferences for lying area after shearing

After shearing, the ewes showed a significant preference for wooden floor to expanded metal floor, straw to wooden floor, and straw to expanded metal floor (Figure 4). The sheared ewes also showed a tendency to prefer wooden floor to rubber mats, but the preference was not significant.

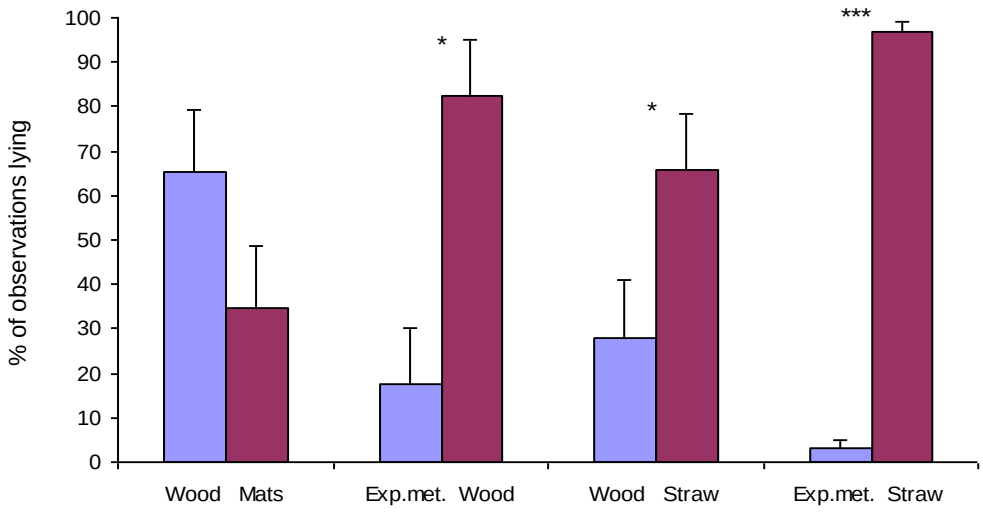

Figure 4. Preference of lying area after shearing, experiment 2, (P < 0.05, *** P< 0.001).*

Lying time in the different treatments

Before shearing, the mean lying time for all treatments (% of observations) was 64.7 ± 0.9 %, and there were no significant differences between the four treatments (Figure 5). The lying time was dramatically reduced to 43.0 ± 4.9 % the first 2 to 3 days after shearing (Figure 6), and shivering was frequently observed when the ewes' were standing. However, the lying time gradually approached the level before shearing, and at the end of the experimental period (15 to 16 days after shearing), the lying time was 60.9 ± 3.7 % (Figure 6). Significant differences in pre- vs. post-shearing lying times

existed when the ewes were housed in pens without straw, but there were no significant differences in pre- and post-shearing lying times when the ewes had access to straw (Figure 5).

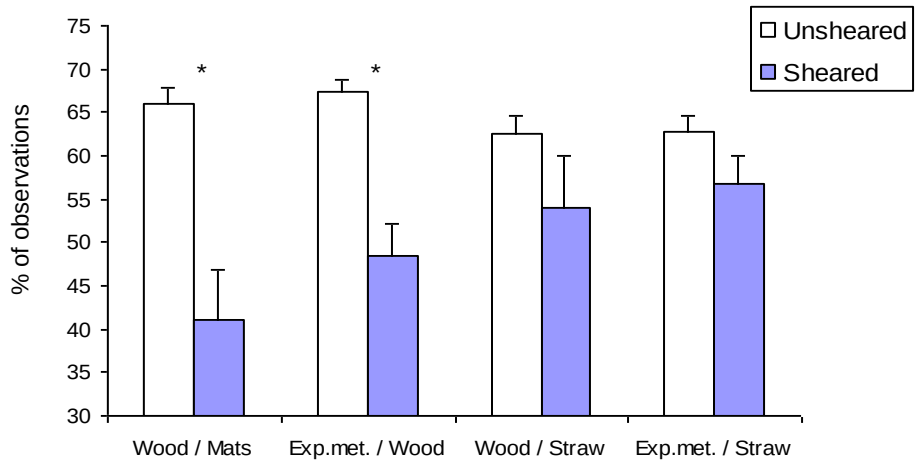

*Figure 5. Mean ± SE lying time (% of observations) for unsheared and sheared ewes in the different treatments, (Differences between sheared and unsheared ewes within treatments, * $P < 0.05$).*

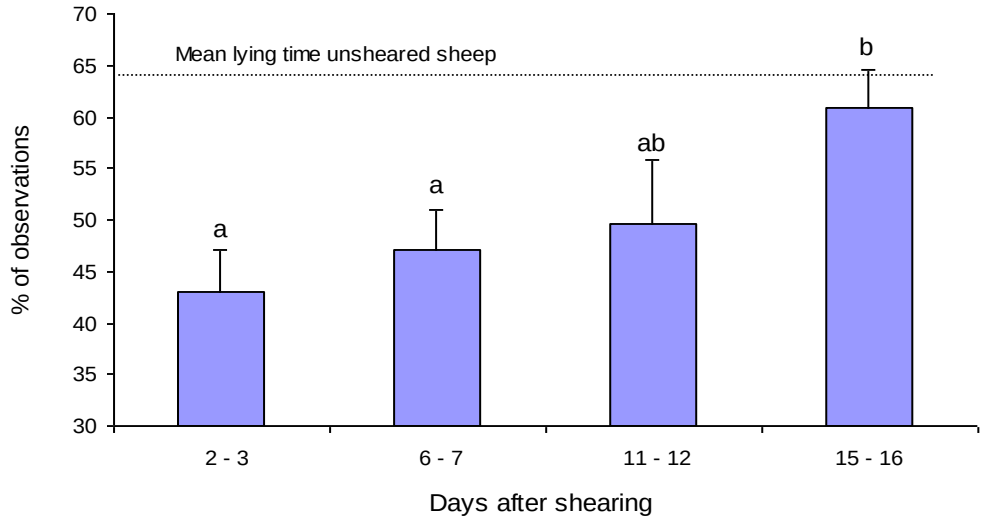

Figure 6. Mean ± SE lying time (% of observations) irrespective of treatment in days after shearing (^{a,b} $P < 0.05$).

Discussion

The results show that unsheared ewes housed in groups did not have any preferences for particular types of flooring materials. When subjected to the different treatment alone, unsheared ewes preferred solid wooden floor to rubber mats and tended to prefer expanded metal floor to straw. In contrast to this, we found that single housed sheared ewes preferred wooden floor to expanded metal floor, straw to wooden floor and straw to expanded metal floor. This is in accordance with Gordon and Cockram (1995) who found that sheep preferred straw to wooden slats (1995). Thus, the study of Gordon and Cockram did not include any information on temperature or if the sheep were sheared or not.

In the groups of unsheared ewes, the first animal that lay down after feeding preferred to lie down on straw or wood to expanded metal and straw to wooden floor. This first choice did not reflect the overall flooring preference for unsheared but for sheared ewes. The softness of the floor seems to be less important for unsheared sheep than e.g. cattle and pigs that show a significant preference for softer floors (cattle: e.g. Nilsson, 1988; pigs e.g. Phillips et al., 1996). The thick fleece could be a reasonable explanation for the lack of preference for softer floors in fully coated ewes. In the treatments where the unsheared single housed ewes showed any flooring preferences, they preferred a floor with high thermal conductivity (wood to rubber mats and expanded metal to straw). A floor with low thermal conductivity could be perceived as attractive, but probably uncomfortably warm at temperatures of 1 C^{o} to 8 C^{o}. However, this is not documented in the literature. Generally, farm animals prefer a floor that maximizes the heat loss (high thermal conductivity) when the temperature is above the comfort zone (Curtis, 1983).

Expanded metal floor, solid wooden floor, rubber mats and straw do have different thermal conductivity and softness. Expanded metal floor, which is the hardest of this flooring materials will give the largest heat loss, and straw which is the softest, will give the lowest heat loss (Nilsson, 1988).

In a social group of animals, other factors than flooring material may influence the preference for lying area. In accordance with the findings of Marsden and Wood-Gush (1986), the ewes in the present study lay constantly next to a wall. The few number of observations of ewes lying in the middle of the lying area was in pens with access to straw. Each of the lying areas was larger than the recommended space requirements for ewes (0.6 – 1.1 m^2, Czernek and Pilarczyk, 1977; Hutson, 1984; Dalholt, 1985). This implies that it should have been enough total lying space for all of them to lie together at the same time. However, because the ewes seemed to prefer lying next to a wall, not only the total lying area available, but also the length of the pen wall (perimeter) may influence the number of favoured lying places.

After shearing in experiment 2, the ewes preferred wood and straw to expanded metal floor and straw to wood. The exception was the treatment where the ewes could choose between wooden floor and rubber mats, where they did not show any significant preference. The results show that in contrast to unsheared ewes, the softness and the thermal conductivity of the floor is of great importance for sheared ewes. This is in accordance with the findings of Bøe (1990), who found that lambs preferred wooden floor to expanded metal floor after shearing, but not before shearing. The preference for solid wooden floor to rubber mats both in experiment 1 and in experiment 2 can be

explained by the fact that the rubber mats very soon became wet and dirty due to a poor absorption capacity. This illustrates that not only the thermal conductivity but also the cleanliness of the floor can be of importance for sheep preference for different types of flooring materials. Use of sawdust in the lying areas with rubber mats could probably improved the cleanliness and thereby the preference of lying area in this experiment.

Not only the ewes' preferences for different types of flooring materials, but also the lying time (% of observations), irrespective of treatment, were changed after shearing. The results from the second experiment showed that the mean lying time for all treatments was dramatically reduced from 65 % before shearing to 43 % the first 2-3 days after shearing. However, the lying time gradually approached the level before shearing, and 15 -16 days after shearing the lying time was almost the same as before shearing. A similar reduction in lying time after shearing is reported in previous studies as well (Hutchinson and McRae, 1969; Bennet, 1972; Lynch and Alexander, 1976; Bøe 1990).

In contrast to pigs, were changed body posture (Mount 1967; Andersen et al., 2000) and social thermoregulation (Mount, 1968; Bruce and Clark, 1979) is common in order to reduce heat loss, sheep increase time spent standing in cold environments (Bøe….). The heat loss to the environment is in fact larger when the sheep is standing (Done-Currie et al., 1984), but the increase in heat production because of the higher summit metabolism makes standing to a preferable strategy for newly sheared sheep (Bennet, 1972; McDonald et al., 1988). However, when giving the sheep access to a floor with low thermal conductivity like e.g. straw bedding, the heat loss by conduction will be reduced and the advantage by standing will be considerably reduced. The mean ambient

temperature in the present study was below the LCT for sheared sheep, and the ewes had to adjust their behaviour in order to maintain a normal body temperature. The thermoregulatory behaviour of the sheared sheep in the present study was to reduce the lying time and to choose a floor that minimised the heat loss when lying.

The fact that the reduction in lying time after shearing was less dramatically in pens were the ewes had access to straw, suggest that the welfare of sheared ewes is improved if straw is provided the first weeks after shearing. This assumption is supported by the observations of standing ewes that was shivering during the first two weeks after shearing.

Conclusion

In contrast to unsheared ewes that showed no clear flooring preferences, sheared ewes preferred softer floors with low thermal conductivity (straw or wood). Thermoregulatory needs seem to be the most reasonable explanation for the observed preference of flooring materials. Lying time (% of observations) was lower for sheared than for unsheared ewes when housed in pens without straw, but this difference was not found when straw was present. The results suggest that the welfare of sheared ewes is improved if straw is provided the first weeks after shearing.

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References

Andersen, I.L., Bøe, K.E., Hove, K., 2000. Behavioural and physiological thermoregulation in groups of pregnant sows housed in a kennel system at low temperatures. Can. J. Anim. Sci. 80, 1 – 8.

Bennet, J.W., 1972. The maximum metabolic response of sheep to cold: Effects of rectal temperature, shearing, feed consumption, body posture and body weight. Aust. J. Agric. Res. 23, 1045 – 1058.

Bruce, J.M., 1979. Heat loss from animals to floors. Farm Buildings Progress 55: Scottish Farm Buildings Investigation Unit., 1 – 4.

Bruce, J.M., Clark, J.J., 1979. Models of heat production and critical temperature for growing pigs. Anim. Prod. 28, 353 – 369.

Bøe, K., 1990. Thermoregulatory behaviour of sheep housed in insulated and uninsulated buildings. Appl. Anim. Behav. Sci., 27, 243 – 252.

Czernek, S., Pilarczyk, A., 1977. The use of slatted floor for housing long-wooled sheep during the grazing season. Roczniki Naukowe Zootechniki, 4.2, 267 – 274.

Council Regulation (EC) No 1804/1999 of 19 July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production.

Done-Currie, J.R., Wodzicka-Tomaszewska, M., Lynch, J.J., 1984. The effect of thermoregulatory behaviour on the heat loss from shorn sheep as measured by a model ewe for microclimate integration. Appl. Anim. Behav. Sci. 13, 59 – 70.

Dalholt, G., 1985. Pen area for sheep. Diplomae work, Agricultural University of Norway, Ås, Norway.

Dumelow, J., 1993. Unbedded self cleaning sloped floors as alternatives to fully slotted floors for beef cattle. Livestock environment IV. 4th international symposium. University of Warnic, Coventry, England, 209 – 216.

Fraser, D., 1985. Selection of bedded and unbedded areas by pigs in relations to environmental temperature and behaviour. Appl. Anim. Behav. Sci. 14, 117 – 126.

Fraser, D., Phillips, P.A., Thompson, B.K., Tennessen, T., 1991. Effects of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 30, 307 - 318.

Gorden, G.D.H. and Cockram,M.S., 1995. A comparison of wooden slats and straw bedding on the behaviour in sheep. Animal Welfare, 4, 131 – 134.

Haley, D.B., de Passillé, A.M., Rushen, J., 2001. Assessing cows comfort: effects of two floor types and two tie stall design on the behaviour of lactating dairy cows. Appl.Anim.Behav.Sci. 71 (2), 105 – 117.

Hatcher, L., Stephanski, E.J., 1994. A step – by – step approach to using the SAS system for univariate and multivariate statistics, Cary, NC: SAS institute INC., 1994.

Herlin, A.H., 1997. Comparison of lying area surfaces for dairy cows by preference, hygiene and lying down behaviour. Swedish jour. of agricult. res. 27 (4), 189 – 196.

Hultgren, J., 2001. Effects of two stall flooring systems on the behaviour of tied dairy cows. Appl. Anim. Behav. Sci. 73 (1), 167 - 177.

Hutchinson, K.J., McRae, B.H., 1969. Some factors associated with the behaviour and survival of newly shorn sheep. Aust. J. Agric. Res. 20, 513 – 521.

Hutson, G.D., 1984. Spacing behaviour of sheep in pens. Appl. Anim. Behav. Sci. 12, 111 – 119.

Kelly, H. R.C., Bruce, J.M., English, P.R., Fowler, V.R., Edwards, S.A., 2000. Behaviour of 3-week weaned pigs in Straw-Flow®, deep straw and flatdeck housing systems. Appl. Anim. Behav. Sci. 68 (4), 269 - 280.

Lynch, J.J., Alexander, G., 1976. Sheltering behaviour of lambing Merino sheep in relation to grass hedges and artificial windbreaks. Aust. J. Agric. Res. 28, 691 – 701.

Loynes, I.J., 1983. Sheep house design. In: Housing sheep. Farm Buildings Information Centre, Stoneleigh.

Lowe, D.E., Steen, R.W.J., Beattie, V.E., 2001. Preferences of housed finished beef cattle for different floor types. Animal welfare, 10 (4), 395 – 404.

McDonald, T.P., Jones, D.D., Barret, J.R., Albright, J.L., Miles, G.E., Nienaber, J.A., Hahn, G.L., 1988. Measuring the increasement of activity in growing-finishing swine. Trans. ASAE, 31, 1180 – 1186.

Manninen, E., de Passillé, A.M., Rushen, J., Norring, M., Saloniemi, H., 2002. Preferences of dairy cows kept in unheated buildings for different kind of cubicle flooring. Appl. Anim. Behav. Sci. 75 (4), 281 – 292.

Marsden, M.D., Wood-Gush, D.G.M., 1986. The use of space by group-housed sheep. Appl. Anim. Behav. Sci. 15, 178.

Midwest Plan Service, 1987. Structures and environment handbook, MWPS-1. 11th Edition 1987. Iowa State University, Ames, Iowa.

Mount, L.E. 1967. The heat loss from new – born pigs to the floor. Res. Vet. Sci. 8, 175 – 186.

Mount, L.E. 1968.The climatic physiology of the pig. Edward Arnold, London, UK. pp. 103 – 108.

Mwanjali, S., Smidt, D., Ellendorf, F., 1983. A multiple free choice model for pigs. Appl. Anim. Ethol. 9, 263 – 271.

Nilsson, C., 1988. Floors in animal houses. Technical design with respect to the biological needs of animals in reference to the thermal, friction and abrasive characteristics and the softness of the flooring material. Institutionen för landbrukets byggnadsteknik (LBT), Swedish University of Agricultural Sciences, Report 61.

Pearce, C.A., 1993. Behaviour and other indices of welfare in growing / finishing pigs kept on Straw-Flow®, bare concrete, full slats and deep straw. PhD thesis, University of Aberdeen.

Phillips, P.A., Fraser, D., Thompson, B.K., 1996. Sow preference for types of flooring in farrowing crates. Can. J. Anim. Sci. 76, 485 – 489.

Stefanowska, J., Swierstra, D., Smits, A.C., van den Berg, J.V., Metz, J.H.M., 2002. Reaction of calves to two flooring materials offered simultaneously in one pen. Acta agricult. Scand. Section A- animal sci. 52 (2), 57 – 64.

Webster, A. J. F., 1976. Effects of cold on energy metabolism of sheep. In: Johnsen, H. D. (Ed.), progress in animal biometeorologi, Vol. 1, Del 1, Swets and Zetlinger, Amsterdam, 218-226.