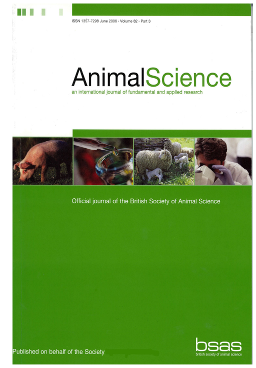

Keeping growing cattle outside during winter: behaviour, production and climatic demand

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Keeping growing cattle outside during winter: behaviour, production and climatic demand

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Abstract

Keeping cattle inside on concrete slatted floors can be detrimental to their health and behaviour and is also costly. Therefore, 22 steers of the Swedish Red and White Dairy breed were used to investigate the effect of wintering outdoors on growing cattle. The steers had a mean weight of 310 kg at the onset of the study. During winter, 11 'indoor' steers were housed in pens with concrete slatted floors and 11 'outdoor' steers were kept in a field with access to a shelter and trees. From the end of April until slaughter in September, both groups grazed together. During winter, all steers were given clover silage ad libitum. *They were weighed every month. The behaviour of the outdoor steers was recorded from November to the end of March. Outdoor temperature, wind speed and solar radiation were measured continuously. A heated model was used in order to calculate the climatic energy demand. The steers were never observed to shiver. They were not observed to use the shelter during daytime. The most frequently observed behaviour was 'eating', followed by 'standing'. The lower the temperature, the more time the steers were observed lying down (P < 0·01). 'Moving' increased with increasing temperature (P < 0·05) as well as with increasing wind speed (P < 0·01). During the grazing period following the experiment, the former outdoor steers grew significantly (P < 0·05) better than the former indoor steers. However, there was no significant difference in overall growth rate from start to slaughter. This study suggests that the winter climate in this part of Sweden (latitude 60°N) did not affect in a negative way the welfare or the growth rate of steers kept outdoors.*

Keywords: *behaviour, cattle, winter hardiness.*

Introduction

Housing for growing cattle intended for beef production varies, both within and between countries in Europe. In many countries, however, the most common system is to keep the animals indoors from start to slaughter, often with intensive feeding. Most of the bulls and steers kept in this way originate from the dairy breeds, since dairy cows represent 69% of the total cows in the European Union (Meat and Livestock Commission, 1993). In Scandinavia, the dominant housing system for growing cattle intended for slaughter is insulated buildings with concrete slatted floors in the pens. This system, however, may be detrimental to their health and behaviour and thus to their welfare (Andreae and Smidt, 1982; Madsen, 1986 and Lidfors, 1992).

The demand for simpler housing has increased as housing costs have risen. In Sweden, where investment costs for cattle housing are relatively high compared with for example Great Britain and Germany, real costs for agricultural buildings doubled during the last decade. During the same period, public concern for the welfare of farm animals has greatly increased. Thus, there is both a demand for cheaper housing as well as a need for systems that allow the animals to stay healthy and to approach a natural behavioural repertoire, without negative influence on production.

Insulated buildings for growing cattle have been used with the good intention of protecting the animals from low winter temperatures. However, the assumed gain in production that an insulated building should provide has seldom materialized in experiments in northern latitudes (Jensen and Konggaard, 1982; Mossberg, Lindell, Johnsson, Törnquist and Engstrand, 1991; Mossberg, Lindell, Johnsson and Törnquist, 1993). Open buildings as well as very simple solutions such as sheds or wind breaks have been used with good results.

In pens with slatted floors, animals are usually kept at a high stocking density. Boucqué, Geay and Fiems (1992) state that the space allowance most commonly adopted for beef cattle in western Europe is 0·75 m^2/100 kg for animals on slatted floors but the Swedish regulations permit even smaller allowances. High animal densities are known to be one of the most important factors associated with social stress (e.g. Andreae, Unshelm and Smidt, 1980; Unshelm, 1983). Slatted floors are often slippery and this creates disturbed behavioural patterns and health problems such as tail-necrosis and lameness (Kunz and Vogel, 1978; Madsen, 1986; Murphy, Hannan and Monaghan, 1987).

There is an urgent need for investigations of cheaper and potentially more welfare-friendly systems. One such system may be to keep the cattle outside during the whole year. This system is commonly used for cattle of beef breeds in some countries but is rare among growing cattle of dairy breeds. This may be either because growing dairy cattle are not believed to be hardy enough to withstand low temperatures or that production would be negatively affected with higher food costs and a lower weight gain. The Swedish law for animal protection states that cattle kept outside during winter must have access to a sheltered indoor lying area. In general, growing cattle, including those of dairy breeds, have very low critical temperatures and are well adapted to cold (e.g. Young, 1981). Theoretically, with free access to good-quality roughage, water, dry resting places and some shelter from the wind, steers or bulls of the dairy breeds should not be adversely affected by winter climate.

There are, however, very few studies where the effects of different climatic variables on the behaviour and production of growing dairy cattle have been investigated. Thus, the aim of this pilot study was to examine the climatic impact on behaviour, food intake and weight gain in dairy steers kept outside during winter.

Material and methods

Animals and environment

Twenty-two steers of the Swedish Red and White breed, a breed used mainly for milk production, with a mean age of 1 year, and with an initial mean weight of 310 kg were used. They were transferred from pasture, where they had spent their first grazing season, to the experimental farm 45 km east of Uppsala at latitude 60°N, and randomly divided into two groups of 11 steers each. One of the groups (the 'indoor' steers) was housed indoors in group pens with concrete slatted floors at 2·5 m^2 per steer, and the other group (the 'outdoor' steers) stayed outside in a 7 ha field with grazing areas as well as areas of woodland. They also had free access to a simple 32 m^2 shelter. The shelter was designed to provide protection from rain, snow and wind at a minimal cost. It was a simple timber structure covered with a polythene sheet and a woven windbreak material on the four sides with an opening in one side for the animals to go in and out. The ground inside the shelter was covered with dry straw. At the end of April the indoor and the outdoor group were transferred to a fresh pasture where they grazed together until slaughter on 21 September 1994.

All steers were weighed on the 1st and 3rd day of the experiment and then regularly once every month until slaughter. The day before the start of the experiment, all steers were examined by veterinarians and found to be healthy and in good condition.

Feeding

From 18 October until the end of April all the steers had free access to silage. No concentrate was given to keep the feeding system simple, to save labour and to allow for compensatory growth on the cheap summer pasture (e.g. Wright, Russel and Hunter, 1986). The clover silage had average dry matter (DM) content of 380 g/kg, 10 MJ/kg DM metabolizable energy and 104 g/kg DM digestible crude protein. Each steer was also offered about 1 kg of hay daily. Minerals and vitamins were available on an *ad libitum* basis.

Behavioural recording

The behaviour of the outdoor steers was recorded on one fixed day per week from November to the end of March. The behaviour of each steer was recorded every 5 min during four periods: 08.10 to 09.20 h, 10.00 to 11.10 h, 12.00 to 13.10 h and 14.00 to 15.10 h, after which it was too dark to make reliable observations. Hence, each observation day included 660 recordings.

The initial ethogram comprised 17 different behaviours but since several of these had a very low frequency some of the behaviours have been summarized in larger groups. The statistical analyses were then based upon the following seven behavioural categories: eating (grabbing, chewing and swallowing any foodstuff); lying (without doing anything else, besides ruminating); standing (without doing anything else, besides ruminating); movement (walking or running); social behaviours (all agonistic as well as non-agonistic behaviours); comfort behaviours (grooming or scratching); other (behaviours that did not fit any other category).

Climatic recordings
Outdoor temperature, wind speed and solar radiation were measured continuously at the experimental site. A heated model (Webster, 1971; Burnett and Bruce, 1978; Jones and Bruce, 1978) was used to measure the combined effect of temperature, wind, thermal radiation and precipitation on the sensible (non-evaporative) heat loss from an animal. The model was assembled from a metal cylinder (diameter 0·6 m, length 0·9 m) covered with a synthetic coat (thermal resistance approximately 0·20°C m^2 per watt). Jones and Bruce (1978) found that the thermal properties of this material were very close to that of cattle. An electrical heater was placed inside the cylinder. The electrical energy required to maintain internal temperature at 39°C was recorded every 30 min together with the climatic parameters. These values were later used to calculate 24 h averages of temperature and climatic energy demand (CED, W/m^2) used in the statistical analysis of the experiment.

Statistics
All behavioural data were analysed with SYSTAT (Wilkerson, 1992). The mean frequency for the group from each observation day was used in the analyses of the different behaviours. Due to technical problems four of the observation days lacked a complete set of the climatic variables and hence these days were excluded from some of the analyses. Differences between months in frequency of behaviours were tested with univariate repeated measures ANOVA. Relations between different behavioural categories and climatic variables were analysed with Spearman rank correlation analyses (r_s). Tests for linear relations were conducted with simple linear regression analyses. In the latter cases the behavioural frequences were arcsin-transformed before the analyses to obtain normality. The weight gain comparison between groups was analysed using the general linear model in Statistical Analysis Systems Institute (1985). Alfa level was set at 5%.

Results

Generally, the outdoor air temperatures during the experiment were normal for the Uppsala area with a warm period in January and a cold period in February (Figure 1). The CED provides a better measure of the impact of the climate on the animals

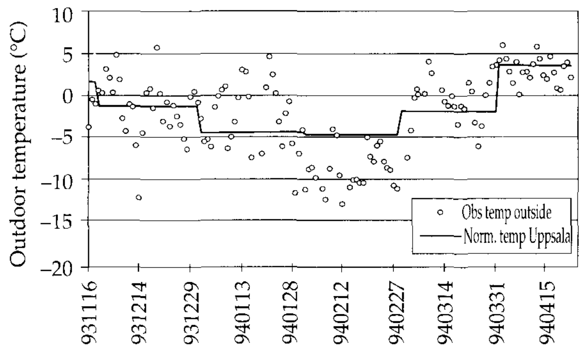

Figure 1 Outdoor temperatures (24 h averages) during the experimental period.

than the air temperature alone. Figure 2 shows the measured CED values during the experiment. Due to the strong influence of wind and precipitation, the coldest conditions (highest CED values) occurred not only at low air temperatures but also at higher temperatures.

A mathematical model of heat and moisture dissipation (Ehrlemark, 1991) has been used to estimate the maximum rate of sensible heat (non-evaporative) loss from the steers. This rate would occur in a thermal environment that corresponds to the lower critical temperature of the animal. Based on the estimated thermoneutral heat production of the steers and their minimal rate of evaporative heat loss, the maximum rate of sensible heat loss at thermal neutrality (i.e. at the lower critical temperature) should be in the range of 120 to 150 W/m^2. The measured CED-values were higher than this level during most of the experimental period, implying an outdoor climate below the lower critical

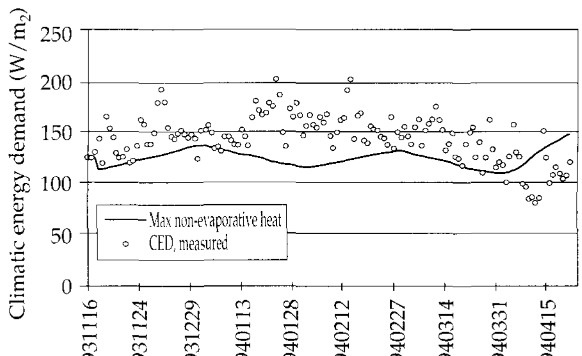

Figure 2 Climatic energy demand (CED, W/m^2) as measured with the heated model. The continuous line represents estimated maximal sensible heat loss at thermal neutrality.

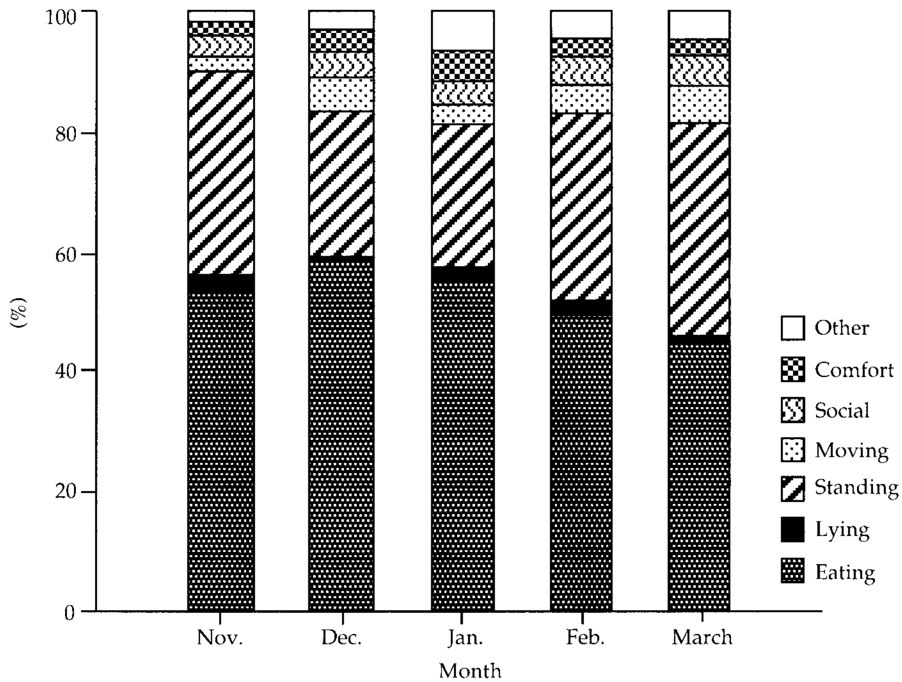

Figure 3 Percentage of recordings of different behaviours during 5 winter months.

temperature of the steers. However, the thermal resistance (maximal tissue + coat) of the experimental animals may have been higher than the thermal resistance of the heated model. The thermal resistance of the heat model was 0·20°C m^2 per watt which would correspond to the coat and minimal tissue thermal resistance of the steers. The maximum thermal resistance of the steers (at LCT) should be in the range 0·35-0·40°C m^2 per watt (Ehrlemark, 1988). Thus, the rate of sensible heat loss from the steers would be about 0·75 of the measured CED value. Furthermore, the heated model was located in an open field, whereas the steers could reduce their heat loss by adapting their behaviour to the climatic demand, as discussed below.

Table 1 *Variables, statistical analyses and significance levels of behavioural and climatic data*

Variable	Statistical analysis	Significance level
Eating: Nov.-March	Univariate Repeated Measures ANOVA	$P < 0{\cdot}003$
Standing: Nov.-March	Univariate Repeated Measures ANOVA	$P < 0{\cdot}001$
Eating × standing	Spearman Rank Correlation Analysis	$P < 0{\cdot}001$
Standing × sun radiation	Spearman Rank Correlation Analysis	$P < 0{\cdot}01$
Lying × temperature	Simple Linear Regression Analysis	$P < 0{\cdot}02$
Moving × temperature	Simple Linear Regression Analysis	$P < 0{\cdot}05$
Moving × wind speed	Simple Linear Regression Analysis	$P < 0{\cdot}03$

The outdoor steers were never observed to shiver although the mean CED values were sometimes high (Figure 2). The most frequent behaviour over the observation period was eating followed by standing (Figure 3). During the 5 winter months November to March there was a significant variation in frequency

Table 2 *Weight gain, live weight and carcass evaluation of steers kept indoors or outdoors during winter*

	Outdoor steers	s.e.	Indoor steers	s.e.
Growth rate (g/day)				
start in October to turn-out	533	26	553	26
turn-out to slaughter	825	40	705*	40
start to slaughter	664	20	622	20
Live weight (kg)				
at start	311	5·6	309	5·6
at slaughter	534	8·1	517	8·1
Carcass weight (kg)	251	3·8	250	3·8
Dressing-out (g/kg)	470	4	480*	4
Fat score (EUROP)	6	0·4	6	0·4

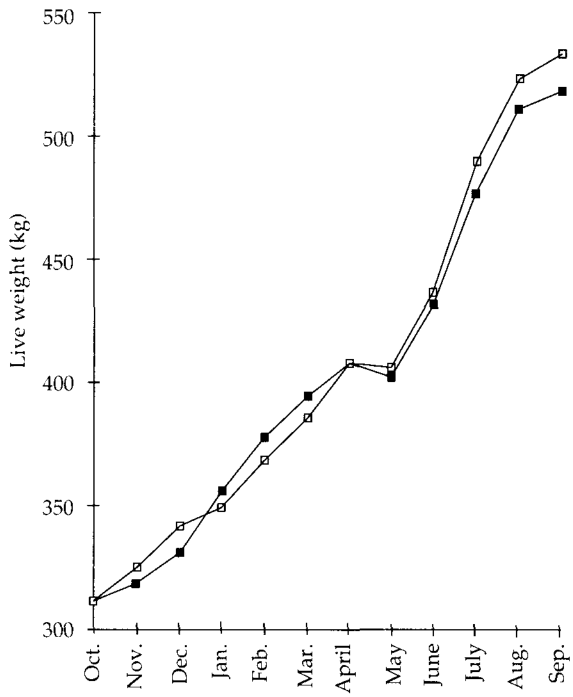

Figure 4 Live weight from start to slaughter. ■ indoor steers; ❑ outdoor steers. Turn-out was in April. The highest mean growth rate occurred between June and July and was 1556 g/day for the former outdoor steers and 1326 g/day for the former indoor steers.

of recordings when the animals were eating ($P = 0{\cdot}003$), with the highest frequency in December and the lowest in March. The curve was significantly adapted to a quadratic model ($F_{1,10} = 8{\cdot}869$; $P = 0{\cdot}014$) but fitted even better to a linear model ($F_{1,10} = 14{\cdot}795$; $P = 0{\cdot}003$). There was a significant negative correlation between the behaviour eating and standing ($r_s = -0{\cdot}842$; no. = 16; $P < 0{\cdot}001$). Eating decreased over the period December to March, whereas standing increased during this time. Standing was also correlated to sun radiation ($r_s = 0{\cdot}587$; no. = 14; $P < 0{\cdot}01$) and the steers frequently moved away from the feeding place in order to stand in the sun. The temperature was negatively correlated to lying down behaviour ($r_s = -0{\cdot}400$; no. = 14; $P < 0{\cdot}02$), thus, the steers were more passive during cold days. On the other hand the steers moved significantly more with increasing temperature ($R^2 = 0{\cdot}310$; no. = 14; $P < 0{\cdot}05$) but also with increasing wind speed ($R^2 = 0{\cdot}380$; no. = 13; $P < 0{\cdot}03$) (Table 1).

The amount of silage given to the outdoor steers during the winter period was proportionately 0·12 higher than that given to the indoor steers. It was not possible to weigh residues continuously but a sample from the animals indoors showed that they wasted proportionately about 0·10 of the silage and estimated by eye, the residues were twice as big outdoors.

There was no significant difference between the indoor steers and the outdoor steers in weight gain during the winter period (Table 2). During the grazing period, however, the outdoor steers grew significantly ($P < 0{\cdot}05$) better than those which had been kept indoors during winter (Figure 4). The outdoor steers had a higher live weight at slaughter than the others but their carcass weight was similar and thus their dressing-out proportion lower ($P < 0{\cdot}05$) than that of the indoor steers. There was no significant difference between groups in classification or fat score at slaughter. Of all the steers, 86% were graded conformation class O- and fat score 6 according to the EUROP classification system.

Discussion

There may be several reasons for the decrease in eating frequency found in the present study. If the quality and palatability of silage is reduced, due to decreasing DM content, increasing pH and an increasing concentration of NH_4^+–N (ammonium nitrogen) then the intake is also reduced (Mossberg, 1992). The steers might gradually have changed their temporal distribution of eating bouts as a response to increasing day lengths. Since our daily observations stopped at 15.10 we have no data about possible eating bouts later in the evening or night. It is intriguing that in spite of the steers lowered eating frequency their weight still increased during this period (Figure 4). It is possible that increasing day length in the spring could increase weight gain without an increase in energy retention by repartitioning energy from fat to lean tissue growth. Results supporting this hypothesis were found by Mossberg (1992) in an investigation of growing bulls, who showed that on a seasonal basis, growth rate started to increase before the actual energy intake increased. Similar results have been found by Dijkstra and Bergström (1989). The amount of silage given to the animals in the present experiment was gradually decreasing from 25·4 kg per animal per day in November to 20·5 kg per animal per day in March. The animals could not obtain any significant additional amount of food from winter pasture under the snow since the low winter temperatures in Sweden do not allow the grass to grow.

The lower the temperature, the more time the steers were observed lying down. Similar results were found by Gilbert and Bateman (1983), in a study of farmed deer, where the percentage of observations when the deer were lying increased with decreasing temperature. Gonyou, Christopherson and Young (1979), also reported that steers kept outside spent more time lying during cold weather. The authors suggested that availability of a dry lying place was a causative factor. In our study, the steers had access to straw bedding in the shelter, and although they did not use it during daytime, tracks and faeces indicated that they probably used it during night-time. They were not observed to use the shelter as a windbreak by standing close to it, but were rather clustering together in windy weather. This was not due to any fear of the building itself, since they had been very curious of it during the first weeks of the experimental period (before the behavioural observations began) and explored it by frequently moving in and out of the shelter. Instead of using the shelter during cold days, they lay down in the snow. The snow was probably dry enough to provide an acceptable stimulus for lying down. It may be a good strategy for an animal to remain more passive in low temperatures in order to save heat and energy, and by lying down it reduces the area of body surface that is exposed to air.

The time spent eating in this study was not significantly related to any climatic variable. Similar results have been reported in earlier experiments where the daily grazing time of free ranging beef cows either was not influenced (Dunn, Havstad and Ayers, 1988) or only slightly influenced (Beverlin, Havstad, Ayers and Petersen, 1989) by temperature fluctuations. Thus, regardless of whether the animal has to search for its food or has a constant, predictable food source, it seems that the total daily time spent foraging and eating is resistant to climatic influence, at least within a normal range. Responses to climatic factors may be reflected in alterations in other behaviours within the time-budget of the animal, such as lying, standing or moving.

An increase in activity with increasing temperature was found in a herd of farmed deer whose activity was significantly greater in each of four progressively warmer temperature ranges (Gilbert and Bateman, 1983). This is in agreement with the findings in our study where the outdoor steers moved significantly more with increasing temperature and with increasing wind speed. The latter result was also found in a study by Malechec and Smith (1976), where beef cows moved more as wind speed increased. However, we found that the steers did not move very far. Even though they had a large area (7 ha) to exploit, they spent most of their time close to the shelter, the feeding station and the water-bowl, all of which were placed about 100 m apart.

The outdoor steers remained in good health during the winter period, while the indoor steers had to be treated for ectoparasites, and some also received minor injuries from the fittings in the house in which they were contained.

The live-weight gain during the winter period was acceptable and expected from the silage *ad libitum* feeding. Calculated over the entire rearing period from start to slaughter, there was no significant difference in growth rate between indoor or outdoor steers which indicates that there was no apparent benefit from housing in this experiment. Although the outdoor steers had a higher live weight at slaughter than the others, their carcass weight was similar and thus their dressing-out proportion lower than that of the indoor steers. The reason for this is not clear but the result may have been due to a larger gut caused by a greater food intake.

Most of the extra food that was given to the outdoor steers was probably wasted and not consumed since it was obvious that the design of the feeding rack used outdoors was not optimal. Food racks designed to make the animals raise their heads before withdrawing from the food rack results in significantly less waste of food than if they are allowed to withdraw their head without raising it, as was the case outdoors, but not indoors, in this experiment (Petchey and Abdulkader, 1991).

In the present experiment, steers from the Swedish Red and White breed adapted their behaviour to the different climatic demands. During the experimental period, the winter climate corresponded to the lower range of the thermoneutral zone of the steers. Occasional periods of cold conditions (below the lower critical temperature) did not seem to affect the animals in any negative way. Productivity was similar whether kept indoors on slatted floors or outdoors having access to a shelter. Thus, steers from dairy breeds may be kept outdoors during winter in northern latitudes without any apparent negative effect on welfare or growth rate.

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References

Andreae, U. and Smidt, D. 1982. Behavioural alterations in young cattle on slatted floors. In *Disturbed behaviour in farm animals* (ed. W. Bessei), pp. 51-60. Verlag Eugen Ulmer, Stuttgart.

Andreae, U., Unshelm, J. and Smidt, D. 1980. Verhalten und anpassungsphysiologische Reaktionen von Mastbullen bei unterschiedlicher Belegungsdichte von Spaltenboden-buchten. *Der Tierzüchter* **32:** 467-473.

Beverlin, S. K., Havstad, K. M., Ayers, E. L. and Petersen, M. K. 1989. Forage intake responses to winter cold exposure of free-ranging beef cows. *Applied Animal Behaviour Science* **23:** 75-85.

Boucqué, CH. V., Geay, Y. and Fiems, L. O. 1992. Bull beef production in western Europen. In *Beef cattle production* (ed. R. Jarrige and C. Béranger), pp. 307-321. Elsevier, Amsterdam.

Burnett, G. A. and Bruce, J. M. 1978. Thermal simulation of a suckler cow. *Farm Building Programme* **54:** 11-13.

Dijkstra, M. and Bergström, P. L. 1989. The effect of increased day length in winter on the growth of beef bulls. *Rapport, Instituut voor Veeteeltkundig Onderzoek, 'Schoonord', no. B-337.*

Dunn, R. W., Havstad, K. M. and Ayers, E. L. 1988. Grazing behaviour responses of rangeland beef cows to winter ambient temperatures and age. *Applied Animal Behaviour Science* **21:** 201-207.

Ehrlemark, A. 1988. Calculation of sensible heat and moisture loss from housed cattle using a heat balance model. *Swedish University of Agricultural Sciences, Uppsala, Department of Farm Buildings, report 60.*

Ehrlemark, A., 1991. Heat and moisture dissipation from cattle. Measurements and simulation model. *Swedish University of Agricultural Sciences, Uppsala, Department of Farm Buildings, report 77.*

Gilbert, F. F. and Bateman, M. C. 1983. Some effects of winter shelter conditions on white-tailed deer Odocoileus virginianus fawns. *Canadian Field-Naturalist* **97:** 391-400.

Gonyou, H. W., Christopherson, R. J. and Young, B. A. 1979. Effects of cold temperatures and winter conditions on some aspects of behaviour of feedlot cattle. *Applied Animal Ethology* **5:** 113-124.

Jensen, V. and Konggaard, S. P. 1982. Production responses of young calves, fattening bulls, and replacement stock to different types of housing. In *Current topics in veterinary medicine and animal science 19* (ed. J. P. Signoret), pp. 209-214. Martinus Nijhoff Publishers, London.

Jones, C. G. and Bruce, J. M. 1978. Shelter studies using thermal models of cattle. *Progress in biometeorology, vol. 2,* pp. 83-98.

Kunz, W. and Vogel, O. 1978. Schwanzspitzenentzündung — ein neues Gesundheitsproblem in der Rindermast. *Tierärtzliche Umschau* **33:** 344-353.

Lidfors, L. 1992. Behaviour of bull calves in two different housing systems: deep litter in an uninsulated building versus slatted floor in an insulated building. *Swedish University of Agricultural Sciences, Department of Animal Hygiene, report 30.*

Madsen, E. B. 1986. Tail tip inflammation in young fattening bulls on slatted floors. In *Welfare aspects of housing systems for veal calves and fattening bulls* (ed. M. C. Schlichting and D. Smidt), *Agriculture Commission of the European Communities, seminar,* pp. 131-138. *Mariensee.*

Malechec, J. C. and Smith, B. M. 1976. Behaviour of range cows in response to winter weather. *Journal of Range Management* **29:** 9-12.

Meat and Livestock Commission. 1993. *Beef yearbook,* Meat and Livestock Commission, Milton Keynes.

Mossberg, I. 1992. Environmental influences on growing bulls in two housing systems. *Swedish University of Agricultural Sciences, report 217.* (Doctor's thesis).

Mossberg, I., Lindell, L., Johnsson, S. and Törnquist, M. 1993. Insulated and uninsulated housing systems for growing bulls fed grass silage *ad libitum. Acta Agriculturae Scandinavica, Section A, Animal Science* **43:** 107-115.

Mossberg, I., Lindell, L., Johnsson, S., Törnquist, M. and Engstrand, U. 1991. Two housing systems for intensively reared bulls slaughtered in two weight ranges. *Acta Agriculturae Scandinavica, Section A, Animal Science* **42:** 167-176.

Murphy, P. A., Hannan, J. and Monaghan, M. 1987. A survey of lameness in beef cattle housed on slats and on straw. In *Current topics in veterinary medicine and animal science, vol. 40* (ed. H. K. Wierenga and D. J. Petersee), pp. 67-72. Martinus Nijhoff, Dordrecht.

Petchey, A. M. and Abdulkader, J. 1991. Intake and behaviour of cattle at different food barriers. *Animal Production* **52:** 576-577 (abstr.).

Statistical Analysis Systems Institute. 1985. *SAS user's guide: statistics. Version 5.* SAS Institute Inc., Cary, NC.

Unshelm, J. 1983. Applicability of indicators in animal welfare research. In *Current topics in veterinary medicine and animal science, vol. 23* (ed. D. Smidt), pp. 225-232. Martinus Nijhoff, The Hague.

Webster, A. J. F. 1971. Prediction of heat losses from cattle exposed to cold outdoor environments. *Journal of Applied Physiology* **30:** 684-690.

Wilkerson, L. 1992. *SYSTAT version 5.2.* SYSTAT, Evanston, Illinois.

Wright, I. A., Russel, A. J. F. and Hunter, E. A. 1986. The effect of winter food level on compensatory growth of weaned, suckled calves grazed at two sward heights. *Animal Production* **43:** 211-223.

Young, B. A. 1981. Cold stress as it affects animal production. *Journal of Animal Science* **52:** 154-163.

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