ELSEVIER

Veterinary Parasitology 83 (1999) 291–300

veterinary parasitology

The behaviour of sheep with sheep scab, *Psoroptes ovis* infestation

Murray J. Corke *, Donald M. Broom

Animal Welfare and Human–Animal Interactions Group, Department of Clinical Veterinary Medicine, Madingley Road, Cambridge CB3 OES, UK

Abstract

Methods of behavioural data collection as applied to the study of sheep scab are described. The behaviour of a number of marked animals within an affected flock was recorded using an event recorder. Focal sampled data were analysed for duration and frequency of the observed behaviours. In addition, the flock was observed at intervals and the instantaneous behaviour of each animal recorded. These data were compared with similar observational data from the same flock recorded at intervals during post-treatment recovery. Sheep scab resulted in pathological behaviours of rubbing, scratching and biting at the lesion, and these resulted in interruption of the normal behaviours, grazing, cudding and idling, but did not result in reduced levels of these behaviours. Infested sheep showed stereotypic mouthing behaviour, initiated by rubbing or scratching, or in some cases without any external stimulus. No stereotypic behaviour was seen in animals after treatment. The implications of the behavioural data for the welfare of the sheep is discussed. ©1999 Elsevier Science B.V. All rights reserved.

Keywords: Psoroptes ovis; Behaviour; Welfare; Sheep

1. Introduction

The symptoms of field outbreaks of sheep scab include the development of abnormal behaviour patterns, such as restlessness, rubbing on fence posts, biting at the flanks, and scratching at the body and ears with the hind feet (Sargison, 1995; Bates, 1997). This is associated with discoloured areas of fleece and wool loss, which starts as displacement of small tags of wool from the shoulders and flanks, but may progress to affect large areas of the body. These symptoms have been related to the development of the scab lesion (Bates, 1997), which is believed to result from an allergic response to the faecal antigen of the sheep

* Corresponding author. Tel.: +44-1223-330840; fax: +44-1223-330886; e-mail: mjc56@cam.ac.uk

0304-4017/99/$ – see front matter
PII: S0304-4017(99)00065-5

scab mite, *Psoroptes ovis* (Stromberg and Fisher, 1986). A 'nibble' reflex characterised by lip smacking and protrusion of the tongue without external stimulation has been described, in addition sheep may show hyperaesthesia and may nibble in response to tactile stimuli (Sargison, 1995). Epileptiform fits may occur in some cases (Bygrave et al., 1993). Death may occur in severe cases.

The study and measurement of behaviour has been widely used in the assessment of farm animal welfare (Fraser and Broom, 1990). Behaviour is changed in response to many environmental conditions. Abnormal behaviour may differ in pattern, duration, frequency or context, from behaviour shown by animals which are not subject to the environmental difficulty, and which are free to display a full range of behaviour (Fraser and Broom, 1990). It is generally accepted that disease results in poor welfare, but there have been relatively few studies that attempt to quantify the effect of disease on the welfare of farm animals (Whay et al., 1997; Ley et al., 1994).

This paper describes a methodology for the study of the behaviour of sheep with naturally occurring sheep scab. This is illustrated with behavioural data from a single flock, before and after treatment until symptoms had subsided. Data from other flocks appears to support the findings from the single illustrative flock described. The implications of the behavioural data for the welfare of the sheep are discussed.

2. Materials and methods

2.1. Subjects

A flock, comprising 28 ewes, largely north country mule and Welsh half-breds, in the first trimester of pregnancy was used for this study. The flock was part of a livestock and arable farm on Anglesey, North Wales. The study commenced in late November 1997, and the history suggested that the infestation dated back to the purchase of the ewes at market 6 weeks previously. The extent of the lesions in some of the flock, suggested that infestation may have pre-dated purchase. It was intended to follow six marked sheep in the focal observations, but unfortunately Sheep 4 and 5, two of the most severely affected animals died in a short period of severe weather following the initial treatment, so only the remaining four marked animals were included in the study (see Table 1).

2.2. Management

The sheep were held on permanent grass, in a field approximately 0.5 ha in area whilst the initial observation was made. Following the first treatment the animals were moved to a field of permanent grass, approximately 3 ha in area, which had not been grazed by sheep during the previous three weeks. The animals were held in this field until the end of the experiment.

Table 1
Details of lesions, mite numbers[a] and hypersensitivity[b] to touch, of sheep used for focal sampling, prior to treatment

Sheep No.	Lesion site	Area (cm^2)	Mite Nos.	Hypersensitivity
1	Withers	7×9	++	+
	Mid back	8×8	+	
	Caudal back	41×56	+	
2	Mid back	34×72	+++	+++
3	Mid back	57×75	+++	+
4[c]	Withers	17×51	+++	+
	Left sacrum	9×9	+++	
5[c]	Whole back	87×90	++	–
6	Withers	5×2	++	+
	Right ischium	3×2	–	
	Perineum	26×20	+++	

[a] Mite numbers were assessed by counting the number of mites found on parting the fleece 10 times at the edge of the lesion; + (1–50 mites), ++ (51–100 mites), +++ (100 mites plus).
[b] Hypersensitivity was assessed subjectively on the basis of response to handling of the lesion.
[c] Died before second observation.

2.3. Treatment

Following the initial observation, the sheep were treated with moxidectin (Cydectin®, Fort Dodge Animal Health). The drug was administered by subcutaneous injection, 200 μg/kg body weight to each sheep. A second dose was administered to each sheep 10 days after the first.

2.4. Behavioural observation

A detailed analysis of behaviour or ethogram was constructed, based on previous studies of behaviour of normal sheep (Lynch et al., 1992), sheep infested with sheep scab, *Psoroptes ovis* (Bates, 1997; Sargison, 1995), and on preliminary observations of normal and scab infested sheep (see Table 2).

2.5. Sampling methods

2.5.1. Focal sampling

Six sheep were evaluated clinically and marked on each flank with an aerosol-coloured stockmarker so that they could be easily identified in the field. The following day the marked sheep were observed sequentially in a random order, and their behaviour recorded using a Psion Workabout. The observer remained out of sight in a hide during the observation, in order to not disturb the sheep and thus affect their behaviour. Each animal was observed for 20 min three times during day, in the morning, in the middle of the day, and in the afternoon. The observations for each sheep were summated for each day of observation to reduce the risk of diurnal variation in behaviour leading to distortion of the data. The same sheep were observed before and after treatment.

Table 2
Behaviours, postures and events recorded

Behaviours[a]	
Graze	Feeding head down
Cud	Regurgitating and chewing cud
Sleep	Eyes closed head resting on ground
Urination	Crouching position passing urine
Alert	Head up, ears forward facing perceived threat
Rub[b]	Rubbing body or head on (a) head or body, (b) object, (c) ground
Scratch[b]	Scratching body or head with hind leg
Bite	Bite at body or leg
Mouthing	Nibbling of jaws, lip smacking and protrusion of tongue
Epileptic fit	Recumbent, unconscious, opisthotonus, mouthing, paddling with feet
Walk	Moving at a walk
Run	Moving at a run
Postures[c]	
Lie	Lying in sternal or lateral recumbency
Stand	Fully upright position
Events	
Defaecate	Voiding faeces
Happening	Occurrence of an event
Push	Pushes another sheep
Pushed	Pushed by another sheep
Social	Other social interactions with another sheep

[a] Behaviours are mutually exclusive, only one from this list can occur at one time.
[b] Modifiers were used in rub and scratch to allow recording of mouthing behaviour associated with these activities.
[c] A postures will occur in conjunction with one behaviour or event.

2.5.2. Scan sampling

The whole group was scanned every 20 min for 2 h, three times during the day of observation, working in the intervals between focal sampling. The behaviour and posture of each animal in the group were recorded.

2.5.3. Ad libitum sampling

Abnormal behaviours not present in the ethogram were recorded as they occurred.

2.5.4. Timing of observations

The sheep were observed during the course of one day, following the protocols given in Sections 2.5.1–2.5.3, whilst still infested. Following this observation the sheep were treated and moved to fresh pasture. The animals were treated a second time 10 days later. A second behavioural observation was carried out 4 days after the second treatment (14 days after the initial treatment). A third behavioural observation was carried out 20 days after the second observation (34 days after the initial treatment).

2.6. Statistical analysis

The ethogram was used to write a configuration for the Observer Version 3.0 (Noldus Information Technology, Wageningen, The Netherlands) for the Mackintosh, running on

Table 3
Focal sample data showing mean duration of behaviours, compared between treatments using Friedman two-way ANOVA ($n = 4$)

Treatment[a]	Mean (s) (SEM) Infested (i)	Mean (s) (SEM) 14 days treated (t1)	Mean (s) (SEM) 34 days treated (t2)	Friedman *P* value i : t1 : t2
Graze	875.0(148.6)	1412.0 (387.9)	1967.6 (273.0)	0.1054
Cud	1181.4(137.3)	78.5 (46.2)	765.5 (287.0)	0.1054
Idle	606.6(139.2)	1632.8 (502.7)	595.3 (274.2)	0.0388
Lie	1498.6(545.7)	202.0 (135.9)	0 (0)	0.0679
Stand	2101.4(545.7)	3398.0 (135.9)	3600.0 (0)	0.0679
Rub	17.2(17.2)	11.1 (11.1)	0 (0)	0.8290
Self-rub	33.3(26.7)	0 (0)	0 (0)	0.4724
Scratch	60.1(28.69)	0 (0)	0 (0)	0.1850
Bite	112.9(59.3)	0 (0)	0 (0)	0.0498
Mouth	40.9(33.6)	0 (0)	0 (0)	0.1850

[a] Treatment status of sheep: infested (i), treated 14 days (t1), and treated 34 days (t2).

a desktop computer Mackintosh LC II. This programme is designed for recording and analysing behavioural observation information.

The configuration file was exported to a Psion Workabout palmtop computer running the Observer Support for the Psion Workabout. This was used for event recording in the field. Field observations were transferred from the Psion to the Mackintosh for analysis. Summary statistics were generated using the Observer programme, and then exported to Microsoft EXCEL 4.0 (Microsoft Corp.), to allow the data to be arranged in a suitable format for export to a statistics programme, SPSS 6.1 (SPSS, Chicago, Illinois).

The data from the focal and scan sampling was analysed using SPSS, for non-parametric analyses. Friedman two-way ANOVA by ranks analysis was performed to test the hypothesis that for each behaviour, the infested (i), the 14 days treated (t1) and the 34 day treated samples (t2) (the treatment samples) were the same population ($P = 0.05$ or less was considered statistically significant in all experiments).

3. Results

3.1. Focal sampling

The results of focal sampling of behavioural durations are shown in Table 3 ($n = 4$) and of behavioural frequency in Table 4 ($n = 4$). The behaviours, sleep, alert, walk, run, urination, and the events push, pushed, social interaction, happening and defaecation, did not differ significantly between the treatment samples. For clarity these have been omitted from Tables 3 and 4, and will not be discussed further.

The results of this study suggest that the time spent grazing did not differ significantly between the observations (Table 3), although the duration of grazing increased during the course of the study. The frequency of grazing (Table 4) was greater in the infested observation (i) than in either of the post treatment observations (t1 and t2), ($P < 0.05$).

More time was spent idling (Table 3) during the first post treatment observation than in either of the other two observations ($P < 0.05$). The frequency of occurrence of idling

Table 4
Focal sample data showing mean frequencies of behaviours, compared between treatments using Friedman two-way ANOVA ($n = 4$)

Treatment[a]	Mean (SEM) Infested (i)	Mean (SEM) 14 days treated (t1)	Mean (SEM) 34 days treated(t2)	Friedman *P* value i : t1 : t2
Graze	8.25 (0.63)	5.88 (0.72)	5.00 (0.41)	0.0284
Cud	5.5 (0.96)	1.25 (0.75)	2.25 (0.75)	0.0874
Idle	9.75 (0.85)	6.13 (0.72)	3.00 (0.71)	0.0183
Lie	2.25 (0.75)	0.88 (0.52)	0 (0)	0.1054
Stand	3.25 (0.48)	3.25 (0.25)	3.00 (0)	0.1054
Rub	0.75 (0.75)	0.25 (0.25)	0 (0)	0.8290
Self-rub	0.5 (0.29)	0 (0)	0 (0)	0.4724
Scratch	2.75 (1.11)	0 (0)	0 (0)	0.1850
Bite	5.5 (2.33)	0 (0)	0 (0)	0.0498
Mouth	1.25 (0.63)	0 (0)	0 (0)	0.1850

[a] Treatment status of sheep: infested (i), treated 14 days (t1), and treated 34 days (t2).

(Table 4) was greater in the infested observation (i) than in either of the post treatment observations (t1 and t2), ($P < 0.05$).

The durations of lying and standing approached a significant difference between the observations, with more lying and less standing in the infested observation (i) compared to either of the post treatment observations (t1 and t2), ($P < 0.07$ for both lie and stand). The frequency of lying and standing did not differ significantly between the observations.

The self-traumatising behaviours, self-rub, scratch and bite occurred almost exclusively during the infestation, compared with the two post treatment observations, but was only significant for bite ($P < 0.05$ for bite for both durations and frequencies). Rubbing occurred during the infestation and was still seen 14 days after the first treatment (t1). Mouthing was seen only during the infestation in the focal sampling, in comparison with the two post treatment observations.

3.2. Scan sampling

The results of scan sampling are shown in Table 5 ($n = 26$). The number of animals grazing, sleeping, idling, walking, lying and standing did not differ significantly between the observations.

Significantly fewer animals were observed cudding at the observation 14 days post treatment (t1) compared to the observations of infested (i) or 34 days post treatment (t2) ($P < 0.005$).

Animals were observed rubbing during the observation of the flock whilst it was infested. A small number of animals seen rubbing at 34 days after treatment, these were recorded as rubbing their faces on a fence post. Scratching occurred only in the infested observation.

Biting was seen in the sheep during infestation (i), and at a lower level in the first post treatment observation (t1), but not at all during the second post treatment observation (t2).

Mouthing was not seen in the scan sampling.

Table 5
Scan sample data showing mean percentage incidence of behaviours, compared between treatments using Friedman two-way ANOVA ($n = 28$ for infested (i), $n = 26$ for both treated samples (t1 and t2))

Treatment[a]	Mean (s) (SEM) Infested (i)	Mean (s) (SEM) 14 days treated (t1)	Mean (s) (SEM) 34 days treated (t2)	Friedman *P* value i : t1 : t2
Graze	38.76(6.30)	44.37 (7.08)	41.31 (3.73)	0.6873
Cud	15.15(2.95)	5.40 (2.11)	13.09 (2.07)	0.0040
Sleep	1.59(0.66)	1.28 (0.93)	1.07 (0.53)	0.9074
Alert	5.56(5.56)	0.21 (0.21)	5.89 (3.58)	0.1298
Rub	0.99(0.48)	0 (0)	0.23 (0.23)	0.5818
Scratch	0.60(0.32)	0 (0)	0 (0)	0.6873
Bite	1.26(0.44)	0.21 (0.21)	0 (0)	0.2748
Idle	31.42(4.78)	46.13 (6.31)	35.14 (4.01)	0.2111
Walk	0.79(0.54)	2.40 (1.58)	2.83 (2.16)	0.9074
Lie	28.84(5.53)	27.74 (7.38)	16.26 (2.72)	0.0810
Stand	71.16(5.53)	72.05 (7.35)	83.74 (2.72)	0.0810

[a] Treatment status of sheep: infested (i), treated 14 days (t1), and treated 34 days (t2).

4. Discussion

The behaviour of sheep has been extensively reviewed by Lynch and others (1992). Considerable behavioural differences occur between breeds of domesticated sheep, for instance between the social behaviours of Merino sheep (Stolba et al., 1990) and Scottish blackface sheep (Lawrence and Wood-Gush, 1988a). The social behaviour of sheep may influence the utilisation of resources, and hence time budget allocation (Lawrence and Wood-Gush, 1988b; Waterhouse, 1996). Social behaviour of hill sheep varies depending on the time of the year as the sheep tend to aggregate in the winter (Lawrence and Wood-Gush, 1987). Behaviour is also strongly influenced by management system, see for instance Done-Currie et al. (1984) on the behaviour of Merino sheep transferred from pasture to an animal house. Champion et al. (1994) found that grazing activity is affected by diurnal rhythm.

Following a fixed group of sheep in which management remained largely constant throughout the period of study, removes many of the variables likely to produce changes in behaviour leaving the presence or absence of *Psoroptes ovis* infestation and the possible side effects of the treatment as the major influences on behaviour. Weather conditions were similar on each of the observation days, although 24 h of severe weather occurred immediately after the first treatment, resulting in the death of two of the animals marked for focal study.

Deag (1996) discussed the application of the methods of behavioural ecology (derived from studies of wild animals) to welfare studies of domesticated animals, and concluded that domesticated animals still have a rich repertoire of adaptive behaviour and that in many situations these methods are applicable. Martin and Bateson (1993) have described a range of techniques for measuring the behaviour of animals based on field observation. This study uses focal sampling and scan sampling to assay the behaviour of sheep with sheep scab. These techniques produce largely complimentary data although scan sampling is likely to underestimate short duration activities, because of the short observation times involved. For example, mouthing was not seen during scan sampling, but was evident during the focal sampling (Tables 3 and 5).

The results of this study suggest that the time devoted to grazing, was not significantly affected by the infestation (Table 3), although the length of time spent grazing increased throughout the experiment. Measurements of average sward height suggests that this may be the result of the grass in the paddock being grazed to progressively shorter length, which could necessitate a longer time spent grazing to ingest the same weight of grass. The increased frequency of grazing (Table 4), resulted from interruption associated with self-traumatising activities, self rub, scratch and bite initiated by the infestation, leading to shorter but more frequent bouts of grazing.

The reduced duration and frequency of cudding in the focal data (Tables 3 and 4), and the low level of cudding seen in the scan data 14 days (Table 5) after the first treatment was unexpected. It appears that the time which would otherwise have been spent cudding may have been reallocated to idling.

Cudding may be reduced by lack of ruminal fibre or by fear, but neither of these factors was suggested by the management or by the other behaviours shown. It has been suggested that nausea may reduce cudding (Austin, 1996); this could occur in sheep post treatment due to post infection changes in physiology or as a side-effect of the treatment used. A review of the literature revealed no reports of similar effects following the use of moxidectin, and it is possible that some other unrecorded factor may have led to this observation. Further studies are needed to elucidate this finding.

As with grazing, it appears that interruption by self rub, scratching and biting during the infestation led to more frequent shorter bouts of idling and cudding, than occurred after treatment.

The self-traumatising behaviours, self-rub, scratch and bite occurred almost exclusively during the infestation (Tables 3–5). Rubbing was still seen 14 days after the first treatment in the focal sampling, and biting was seen at a low level in the scan sampling. Unlike the treatments which involve dipping, no skin washing occurs with endectocide treatment of scab, as a result the antigen remains in contact with the skin for longer and pruritis may persist (Purnell, R., personal communication).

The small number of rubbing animals seen at 34 days after treatment (Table 5) in the scan sample appeared to be rubbing their faces on a fence post, an activity believed to be scent marking (Lynch et al., 1992); interestingly this behaviour was not seen earlier in the experiment.

Wool loss in sheep scab by biting, scratching or rubbing, in an early case may be beneficial to the animal by exposing the parasite to an unfavourable microclimate. However if the lesion survives and mite number rise (Bates, 1997), extensive wool loss is likely to prejudice the survival of the sheep, and to promote spread of the disease to other sheep. Pulling of wool may occur in uninfested housed sheep, associated with high stocking density and may be reduced, by increasing the space per sheep and also by ensuring an adequate supply of good quality roughage (Fraser and Broom, 1990).

A number of abnormal mouthing behaviours have been described by Sargison (1995) in sheep affected by sheep scab. In this study, mouthing with the tongue protruded, was seen associated with scratching the lesion with a hind foot, or with rubbing the lesion with another part of the body, or on an object such as a fence, or on the ground. Similar abnormal mouthing was also seen without associated scratching or rubbing. These behaviours were only seen whilst the sheep were infested, but because of the small sample size and the

low level of occurrence, no statistical significance could be assigned to this finding. It is suggested that these maybe stereotypic behaviours (or stereotypies).

An animal performing a stereotypic behaviour repeats a relatively invariate sequence of behaviours, which has no obvious function (Fraser and Broom, 1990). Many involve non-functional oral behaviour. Stereotypies are shown in situations where the animal lacks control of its environment and may occur in response to frustration, over-stimulation or under-stimulation. It is not known in most cases whether stereotypic behaviours help to cope with its environment, but it is believed that the welfare of an animal that is performing stereotypic behaviours is poorer than one that is not (Fraser and Broom, 1990).

Farm animals subjected repeatedly to inescapable aversive stimulus may be unresponsive (or apathetic) when faced with an aversive stimulus that produces a behavioural response in naive conspecifics. Such behaviour probably represents the animal's attempts to cope with an intractable environmental challenge, and has been described as learned helplessness (Broom and Johnson, 1993). The greater time spent lying down by the sheep whilst infested (Table 3) may represent a tendency to learned helplessness. Further studies are necessary to investigate this as the frequency and scan data analyses do not show significant differences between the treatments.

5. Conclusions

Behavioural observation is a useful tool in the assessment of welfare of sheep with sheep scab. This is the first such study of this disease and demonstrates that focal and scan sampling of affected sheep can yield useful information about normal and abnormal behaviours, indicating the effect of the disease on welfare. A number of behaviours involving mouthing behaviour alone or associated with rubbing or scratching of the lesion are believed to be stereotypic and to indicate poor welfare in the affected animals.

Acknowledgements

This study is part of a project investigating the effect of sheep scab on animal welfare sponsored by Pfizer Ltd. We acknowledge the help and cooperation of the farmer. We are grateful to Peter Bates and Bryn Groves of the Central Veterinary Laboratory, Weybridge, for their help. We are also grateful to Harry Bradshaw and to the referees for their helpful comments on earlier versions of this paper.

References

Austin, A.R., 1996. Travel sickness in pigs and sheep. Vet. Rec. 139, 575.

Bates, P., 1997. The pathogenesis and ageing of sheep scab lesions, Part 1. St. Vet. J. 7 (3), 11–15.

Broom, D.M., Johnson, K.G., 1993. Stress and Animal Welfare. Chapman & Hall, London, 56 pp.

Bygrave, A.C., Bates, P.G., Daniel, N.J., 1993. Epileptiform seizures in ewes associated with sheep scab mite infestation (letter). Vet.Rec. 132, 394–395.

Champion, R.A., Rulter, S.M., Penning, P.D., Rook, A.J., 1994. Temporal variation in grazing behaviour of sheep and reliability of sampling periods. Appl. Anim. Behav. Sci. 42, 99–108.

Deag, J.M., 1996. Behavioural ecology and the welfare of extensively farmed animals. Appl. Anim. Behav. Sci. 49, 9–22.

Done-Currie, J.R., Hecker, J., Wodzicka-Tomaszewska, M., 1984. Behaviour of sheep transferred from pasture to an animal house. Appl. Anim. Behav. Sci. 12, 121–130.

Fraser, A.F., Broom, D.M., 1990. Farm Animal Behaviour and Welfare, 3rd ed. Bailliere Tindall, London, pp. 305–317

Lawrence, A.B., Wood-Gush, D.G.M., 1987. Social behaviour of hill sheep: more to it than meets the eye. Appl. Anim. Behav. Sci. 17, 382.

Lawrence, A.B., Wood-Gush, D.G.M., 1988a. Home-range behaviour and social organisation of Scottish Blackface sheep. J. Appl. Ecol. 25, 25–40.

Lawrence, A.B., Wood-Gush, D.G.M., 1988b. Influence of social behaviour on utilisation of supplemental feedblocks by Scottish hill flocks. Anim. Prod. 46, 203–212.

Ley, S.J., Waterman, A.E., Livingston, A., Parkinson, T.J., 1994. Effect of chronic pain asociated with lameness on plasma cortisol concentrations in sheep: a field study. Res. Vet. Sci. 57, 332–335.

Lynch, J.J., Hinch, G.N., Adams, D.B. 1992. The Behaviour of Sheep. CAB International, Wallingford, Oxon, pp. 9–85.

Martin, P., Bateson, P., 1993. Measuring Behaviour, 2nd ed. Cambridge University Press, Cambridge, pp. 63–100.

Sargison, N.D., 1995. Differential diagnosis and treatment of sheep scab. In Practice 17, 3–9.

Stolba, A., Hinch, G.N., Lynch, J.J., Adams, D.B., Munro, R., Davies, H.I., 1990. Social organisation of Merino sheep of different ages, sex, and family structure. Appl. Anim. Behav. Sci. 27, 337–349.

Stromberg, P.C., Fisher, W.F., 1986. Dermatopathology and immunity in experimental *Psoroptes ovis* (Acari: Psoroptidae) infestation of naive and previously exposed Hereford cattle. Am. J. Vet. Res. 47, 1551–1560.

Waterhouse, A., 1996. Animal welfare and sustainability of production under extensive conditions – a European perspective. Appl. Anim. Behav. Sci. 49, 29–40.

Whay, H.R., Waterman, A., Webster, A.J.F., 1997. Associations between locomotion, claw lesions and nociceptive threshold, in dairy heifers during the peri-parturient period. Vet. J. 154, 155–161.