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The impact of different management systems on behaviour and milk production of dairy ewes in different stages of lactation; a case study

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Abstract

Comparisons of New Zealand dairy sheep farm systems are currently lacking. The aim of this preliminary study was to evaluate the effects of different management systems on the behaviour and milk production of East Friesian cross-bred sheep at different stages of lactation. Two study groups were evaluated. In study group 1, a mob of 479 mixed-age, mid-lactation ewes were housed 24 h/day, and a separate mob of 473 mixed-age, mid-lactation ewes were managed in a hybrid system (housed between morning and afternoon milkings; grazed lucerne overnight). Both received a total mixed ration (TMR) indoors. In study group 2, a mob of 604 mixed-age, late-lactation ewes grazed pasture 24 h/day, and a separate mob of 452 mixed-age late-lactation ewes were in a hybrid system, grazing pasture overnight. For both study groups, individual milk yield, walking distance, lying time, live weight (LW), and body condition score (BCS) were recorded. All sheep gained BCS and LW except fully grazed late-lactation ewes. For study group 1, fully housed ewes in mid-lactation lay down less during the day, but more overnight compared to those in the hybrid system, likely due to the latter grazing overnight. Lying bout times were similar between groups, while milk yield was 29% less in housed ewes compared to the hybrid ewes. For study group 2, grazing ewes in late-lactation lay down more, had longer lying bouts, and walked further daily than those in the hybrid system, but both late-lactation treatment groups had similar milk yields. In summary, the hybrid management system seems to improve milk yield in mid-lactation compared to the fully housed system, whereas there was no difference between the hybrid and fully grazed systems in late-lactation. Lying behaviour and walking distances (group 2 only) differed among different systems, however, it is unclear what this means in terms of animal welfare, and warrants further investigation.

Keywords: dairy sheep; behaviour; feeding; management; housing; milk production

Introduction

In New Zealand, the dairy sheep industry has expanded significantly in recent years (Peterson & Prichard 2015). New Zealand sheep are largely farmed in outdoor, pasture-based systems, but the majority of international work has evaluated indoor and mixed indoor-outdoor sheep dairy systems. There is currently little information on how to optimise outdoor systems for sheep dairying.

In summer, farms in warm regions with no irrigation face challenges of limited shade, high solar radiation and ambient temperatures and decreasing pasture quality and quantity (Di Grigoli et al. 2009; Litherland et al. 2002), making animals more susceptible to heat and nutritional stress, and dehydration (Alamer 2004). Providing housing for ewes may mitigate the negative effects of warm weather, while allowing farmers to control diet quality and quantity (Caroprese 2008; Di Grigoli et al. 2009). Housing provides shade, while also reducing walking distances to and from the milking parlour, which may decrease energy expenditure and increase available energy for milk production. Indoor and mixed indoor-outdoor systems, therefore, allow farmers to feed ewes a diet of high nutritive value, and may improve aspects of animal welfare (Di Grigoli et al. 2009, Morand-Fehr et al. 2007). There are, however, some reports of lower welfare in housed systems, mostly due to poor housing design and management practise (Caroprese 2008).

Many factors influence ewe milk production, including breed, nutrition, environment, and behaviour, including activity levels (Haenlein 2007; Morand-Fehr et al. 2007; Schütz 2011). Studying animal behaviour, including activity and resting behaviour, under different management conditions can increase knowledge of how ewes interact with their environment, and help assess their level of welfare. For example, sheep prefer to lie on softer flooring compared to hard surfaces (Cordon & Cockram 1995; Færevik et al. 2005) and lying behaviour is also influenced by factors, such as climate conditions (Pollard et al. 2004) and social environment (Bøe et al. 2006).

This study aimed to investigate the effects of different management systems on behaviour and milk production of ewes in different stages of lactation. We hypothesised that, for study group 1, housing animals in mid-lactation 24 h/day will reduce walking distance but will not affect milk production compared to those housed only during the day. In addition, we hypothesised that fully housed ewes would spend more time lying down than those in the hybrid system due to feed being more easily obtainable, thus reducing the need for time spent grazing. For study group 2, we hypothesised that housing late-lactation ewes during the day would increase milk production compared to those fully grazed on pasture. In addition, we hypothesised that fully grazed ewes would spend less time lying than those in the hybrid system due to more time needed for grazing activities.

Materials and methods

This study was reviewed and approved by the

AgResearch Grasslands Animal Ethics Committee (approval number 14081).

Animals and management systems

This trial took place from December 2016 to February 2017 on a commercial dairy sheep farm near Taupo, New Zealand using East Friesian cross-bred ewes, aged one to eight years.

To evaluate the impact of housing and feeding systems on behaviour and lactation in ewes in mid-lactation (study group 1, between 25 and 100 days in milk (DIM)), a mob of 952 ewes were randomly allocated to one of two groups: 1) fully housed 24 h/day in a dedicated barn (n=479; live weight (LW) 70.9±0.4 kg; body condition score (BCS) 4.1±0.02), and 2) a hybrid management system; housed indoors between a.m. and p.m. milking (7 a.m. – 1 p.m.) and grazed lucerne overnight (n=473; LW 69.9±0.4 kg; BCS 3.8±0.03). While indoors, ewes in both groups were offered a total mixed ration (TMR) diet.

To evaluate the impact of housing and feeding systems on behaviour and lactation in late-lactation (study group 2, >100 DIM), 1056 ewes were randomly allocated to one of two groups: 1) fully grazed 24 h/day on ryegrass and clover mixed sward pasture (n=604; LW 72.7±0.6 kg; BCS 4.2±0.02), and 2) a hybrid management system; housed indoors between a.m. and p.m. milking, and grazed pasture outside overnight (n=452; LW 72.2±0.4 kg; BCS 4.3±0.04). While indoors, ewes in late-lactation in the hybrid system were offered TMR.

The housing barn had a vented canvas roof and open sides to maximise air flow. Each treatment group was managed in one pen (120 x 9 m) while indoors. Each pen had deep-bedded (approximately 30 cm), kiln-dried wood chips as bedding material. Water was provided *ad libitum* in six 2-m long troughs per pen, accessible from each side. In the barn, feed (silage and concentrate, TMR; 2 kg ryegrass and lucerne silage plus 250 g grain-based concentrate supplement of canola, barley and soy meal per head) was offered on concrete pads after each milking, accessible along both sides of each pen, providing feeding space of >45 cm/head. An additional 250 g of concentrate was offered during milking to all ewes irrespective of what treatment group they were in. Grazing available to mid-lactation ewes was lucerne (*Medicago sativa*), provided overnight in paddocks ~500 m from the barn. By calculation, this provided approximately 50% of the ewes' diet. Grazing available to late-lactation ewes was ryegrass/clover (*Lolium perenne/Trifolium repens*) mixed-sward pasture, either overnight or continually. The onset of a dry period required use of supplementary feed in the fully grazed group. Pasture made up approximately 55 and 60% of the diet in the hybrid and fully grazed groups, respectively. No natural shade was available in the paddocks.

The study period consisted of a three-week transition period, which allowed animals to adjust to the change in management system, and a 47-day measurement period. Replication of treatment groups was not possible, as this would require multiple barns.

Milk yield, BCS and live weight

Individual milk yields were recorded automatically by in-line milk meters on three occasions before the trial started to establish a baseline for each group, and on 11 days spaced randomly over the trial period of 47 days (post-transition). Technical issues with the in-line milk meters prevented collection of individual daily milk yield on some days. Therefore, only sheep with milk yields from a least one day prior to the trial start, and four days within the trial period, were included.

Ewe LW and BCS (five-point scale) were recorded at the start and end of the trial by a single operator.

Walking distance and lying behaviour

Walking distance. Walking distance, a proxy for relative energy expenditure (Osuji, 1974), was calculated from data collected using global positioning system (GPS) units that recorded location every minute for two weeks (days 23-36 of the trial) (Enertrol Limited, 2009; accuracy ± 10 m). Only late-lactation treatments, where the largest difference in walking distance was expected, were monitored due to only 10 collars being available. Five GPS collars were allocated randomly to ewes within each group. A high degree of potential error exists with GPS measurements (Ganskopp & Johnson 2007; Swain et al. 2011). To establish the static error of GPS coordinates, location data from two GPS units placed in the barn and two placed in a paddock were recorded for 24 hours.

Lying behaviour. Accelerometers (Onset Pendant G data logger, Onset Computer Corporation, Bourne, MA, USA) were used to measure continuous lying behaviour in each system. The data loggers were validated prior to the trial (data not shown). The data loggers were placed in a durable fabric pouch and attached with velcro on the side of the hind leg above the metatarsophalangeal joint. A total of 20 ewes in each treatment group were monitored; i.e. for both mid- and late-lactation study groups comparisons. Animals were selected by fitting loggers to approximately every 20th ewe in each group during milking. Lying and standing times were recorded continuously for two weeks (between days 23-36 of the trial) using the data loggers set to record the y- and z-axis at a 60-s interval. Lying information was extracted from raw data in Excel, correcting for single events.

Statistical analysis

As a case study, the data is presented with descriptive statistics that describe the variation within each group. Comparison between groups does not necessarily reflect true treatment differences as the treatments were not independently replicated.

GPS data was quality-checked using R (R 3.5.0), removing any outliers by first making box plots of total walking distance per hour per sheep, and setting an upper limit for each of these totals, defined as

UQ + 1.5 IQR

where UQ is the upper quartile and IQR is the inter-quartile range.

Outliers were replaced by the upper limit for that individual on that day. Total distance travelled per hour per sheep was calculated. The average distance per hour was then calculated for each mob. Static testing of GPS measurements showed that location when outside or inside varied by an average of 0.5 and 2.02 m per recording, respectively. Data were corrected for these error values by reducing hourly average walking distances by the displacement error associated with whether sheep with indoors or outside during that hour. The contribution of horizontal walking distance to daily energy expenditure of the late-lactation groups was calculated using the estimate of 2.47 J/kg/horizontal metre (Clapperton 1964).

Lying behaviour (daily averages for each group), recorded by accelerometers, was calculated as number and duration of events, excluding milking periods (4-7 a.m. & 1-4 p.m., as with GPS data). Summaries of BCS and LW were calculated from the raw data. Hybrid ewes were indoors between 7 a.m. and 1 p.m., and outside between 4 p.m. and 4 a.m.

Daily milk yield data were summarised by first identifying the variation in yield among animals within each mob, and then taking the natural logarithms of the data to normalise the variation. Means of the logarithms for each day for each mob were fitted to a model using REML (Corbeil & Searle 2012) and a first-order auto-regressive error, correcting daily milk yield means for the ewe LW at lambing, the days in milk (within each lactation group), and ewe age.

Results

Study group 1

Milk yield. Prior to the transition period, mid-lactation ewes had similar milk yields (Fig. 1). During transition, a divergence of average daily milk yields was observed. Over the trial period, ewes in the hybrid system had 29% greater daily milk yields, on average, than ewes fully housed.

Lying behaviour. During the day, mid-lactation ewes in the hybrid system spent 35% more time lying down, on average, than those fully housed, due to lying down more often (Table 1). Overnight, the ewes fully housed spent 83% longer lying down than did hybrid ewes. At this time, lying bouts of ewes in the hybrid system occurred 30% less

Figure 1 Average daily milk yields (litres) ±SEA of dairy sheep in two study groups of two treatment groups each: study group 1: 1) mid-lactation housed indoors full-time, fed TMR, 2) mid-lactation in a hybrid housing system, housed during the day between morning and afternoon milking, fed TMR, grazing lucerne outside overnight. Study group 2: 1) late-lactation ewes grazing pasture outside full-time, 2) late-lactation ewes in a hybrid housing system, housed during the day between morning and afternoon milking, fed TMR, grazing pasture outside overnight. The vertical lines indicate the start and end of the transition period.

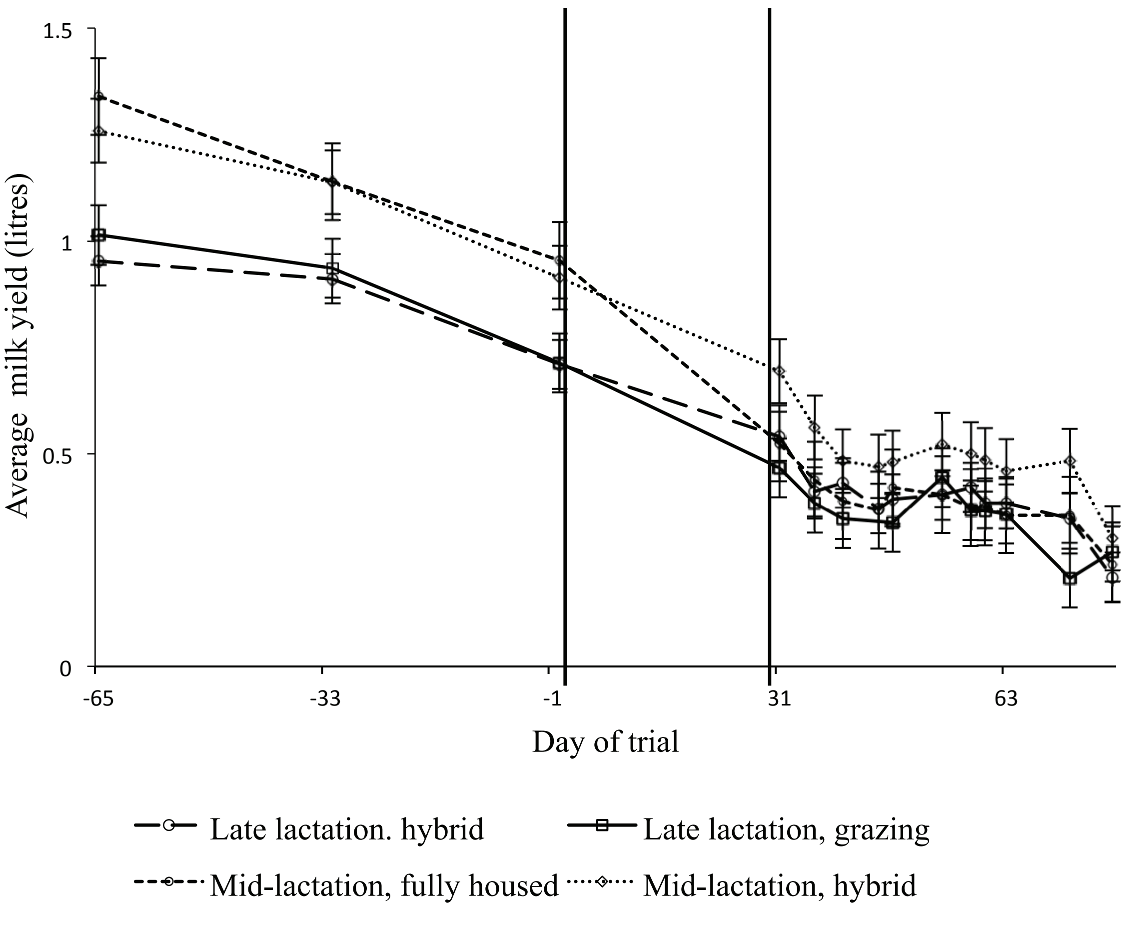

Figure 2 Average hourly walking distance (m) ±SEM of dairy sheep in late-lactation grazing full-time versus those in a hybrid housing system, housed inside during the day and outside overnight, as measured on five ewes per treatment using GPS collars over a two-week period between days 23 and 36 of a 47-day trial. Vertical lines indicate the beginning and end of milking periods in the morning (0400-0700 hrs) and afternoon (1300-1600 hrs).

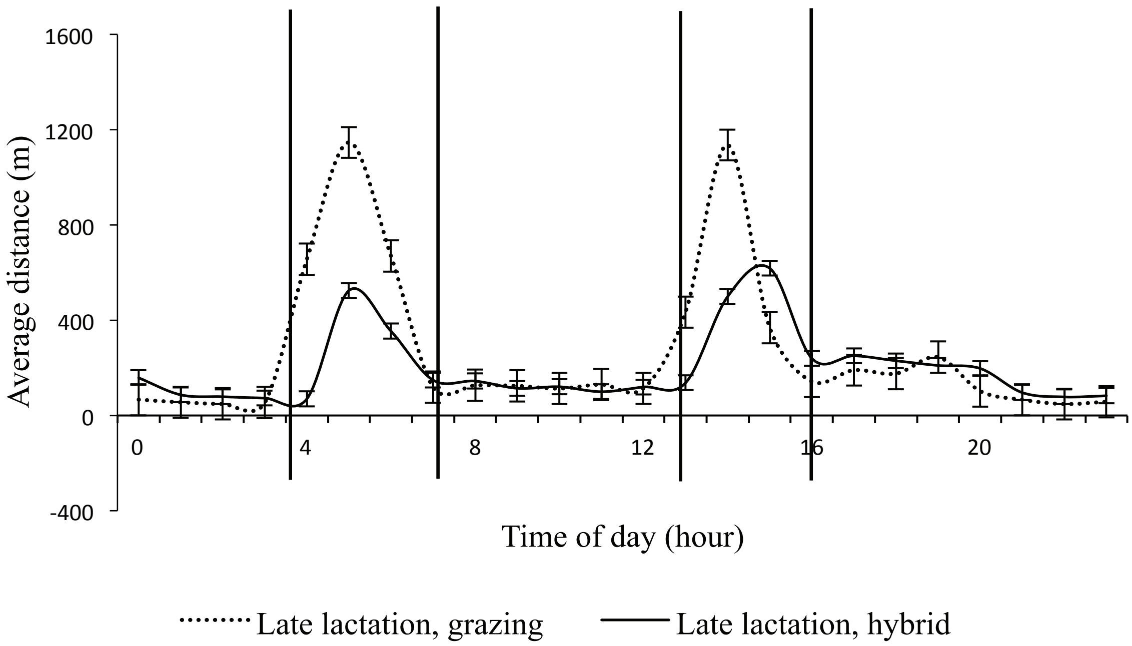

Table 1 Average lying behaviour of dairy sheep in different lactation stages and housing systems during the day and overnight, excluding milking periods (4-7 a.m. & 1-4 p.m.), as measured by accelerometers during a two-week period in summer. Values presented are averages ± SEM.

Lactation stage	Housing system	Time of day	Total lying time (min)	Number of lying bouts	Bout length (min)
Mid-lactation	Fully housed	Day	123.7±4.1	4.0±0.1	34.7±1.6
		Night	474.8±11.0	10.1±0.4	51.3±2.9
Mid-lactation	Hybrid	Day	165.2±10.1	5.1±0.3	34.2±2.1
		Night	368.4±12.4	7.1±0.3	61.1±3.6
Late-lactation	Grazing	Day	171.0±9.8	3.8±0.1	49.7±2.4
		Night	440.2±13.4	7.4±0.4	67.3±4.5
Late-lactation	Hybrid	Day	159.4±9.9	5.4±0.3	30.7±1.2
		Night	396.1±11.6	6.9±0.3	62.9±3.2

often and average bout duration was 16% shorter than that for ewes fully housed. Total lying time was longer for fully housed than for hybrid-system ewes.

Body condition score and live weight. At the end of the trial, fully housed ewes in mid-lactation had an average BCS of 4.4±0.02, and average LW 75.5±0.5 kg, which equates to an average daily gain (ADG) of 98 g/day. Ewes in the hybrid system had an average BCS of BCS 4.4±0.03, and average LW 75.6±0.4 kg at the end of the trial, equating to ADG of 121 g/day.

Study group 2

Milk yield. The late-lactation groups had similar milk yields prior to the transition period (Fig. 1), though milk yield declined to a greater extent in the grazing group than that in the hybrid group during transition. Fluctuations occurred in both groups throughout the trial period, but a difference in average milk yield was not clear.

Walking distance. Total daily walking distance for the fully grazed ewes in late-lactation was, on average, 35% greater than that of ewes in the late-lactation hybrid treatment (6390 *vs.* 4730 m, respectively), with walking to and from the milking parlour accounting for a large portion of this (62% *vs.* 43% of total daily walking distance for grazing and hybrid systems respectively; Fig. 2). No other difference in average hourly walking distances between grazing or hybrid systems were observed (Fig. 2). Fully grazing ewes expended more energy in walking each day than did the hybrid ewes (~1.14 MJME per ewe/day *vs.* 0.86 MJME per ewe/day).

Lying behaviour. During the day, ewes in late-lactation and fully grazing spent 8% more time lying down outside than did ewes in the hybrid system indoors. The lying bouts of ewes fully grazing occurred less often and for longer periods of time than ewes in the hybrid system. This trend was greater overnight (12% greater) due to slightly longer lying bouts. Total lying time was longer for ewes fully grazing than ewes in the hybrid system.

Body condition score and live weight. At the end of the trial, fully grazed ewes in late-lactation had an average BCS of 4.2±0.03, and average LW 72.4±0.6 kg, which represents no change from the beginning of the trial (average LW 72.7±0.6 kg). Ewes in the hybrid system had an average BCS of 4.5±0.04, and average LW 76.2±0.6 kg at the end of the trial, equating to ADG of 85 g/day.

Discussion

Milk yield is influenced by many factors associated with feed, feed intake, and housing, independent of type of system used. In this case study, a difference was observed in milk yields between groups of ewes in mid-lactation, with higher yield in the hybrid system than in the fully housed system. However, no strong difference was observed between grazing ewes in late-lactation and those in the hybrid system. Walking distances, as a proxy for energy expenditure, were greater in the late-lactation full-grazing system, as expected, but milk production, during the experimental period, was similar to that in the hybrid system. While walking distance was not recorded for the mid-lactation ewes, it can be expected that the daily walking distance of fully housed ewes was lower than those in a hybrid system because they were always closer to the milking shed than those outside at night. Therefore, the effect of less walking to and from the milking parlour was not translated into greater milk production.

The walking and lying data provide a mixed message about energy expenditure. Greater daytime lying times of mid-lactation ewes in the hybrid systems (when indoors) compared to when fully housed may have been an attempt to conserve energy as energy expenditure is up to 38.4 kJ/kg/day greater in standing than lying (Chappel & Hudson 1979; Osuji 1974) or to rest to compensate for the proportionally lower lying times at night. However, the overall energy expenditure when accounting for extra walking and grazing (not measured) was likely to be greater in the hybrid than in the fully housed system. This does not reflect the larger average gain in BCS and LW observed in the mid-lactation hybrid system, nor their higher milk yield. This indicates that nutrition provided in the hybrid system was likely better than that of sheep housed full-time, which may be related to the portion of the diet that was obtained by grazing (lucerne). Ewes from the hybrid system spent less time lying during the night compared to fully housed animals and we speculate that this is partially due to an increased motivation to graze the outside diet.

Sheep managed outside are likely to be able to perform a wider range of natural behaviours such as grazing and foraging compared to sheep kept indoors, (Caroprese 2008; Sevi et al. 2009), which is an important aspect in animal welfare assessments (Bracke & Hopster 2006). In this trial and in contrast with our predictions, sheep managed on pasture full time had the longest lying times in total (lowest number of lying bouts but the longest bout durations). When the sheep were housed indoors, they had relatively shorter lying bouts compared to when on pasture which may indicate some disturbance of normal lying behaviour.

It has been suggested that the effects of the outdoor environment and increased energy expenditure associated with walking and grazing (Osuji 1974) may influence performance. The 0.3 MJME/d difference in energy expenditure from walking in late-lactation ewes is much smaller than that expected to result in the observed difference in LW change. The average daily gain of 85 g/d in late-lactation ewes in the hybrid system over the experimental period would equate to a requirement of approximately 3 MJME/d (Nicol & Brookes 2007). During the day, there was no difference in corrected walking distance between confined animals and those grazing outside, in contrast to a previous study where housed sheep walked much shorter distances than those on pasture (Osuji, 1974). However, animals in the study reported by Osuji (1974) were grazing poor pastures, and walking measurements were made based on visual observation. While there was a difference in recording methodologies between this study and that of Osuji, they both illustrate potential responses to the respective environments. Both late-lactation, fully grazing and mid-lactation, fully housed sheep had the greatest total lying times. This may possibly reflect the more settled nature of sheep habituated to a constant environment. One rationale for housing sheep is to reduce exposure to solar radiation. Lying times can be greatly influenced by ambient environmental conditions (Bøe 1990) and information regarding the climatic conditions (temperature and humidity) would provide further insight to this.

Ongoing work is exploring how the changes in feeding management (including diet composition) may have contributed to the observed milk yield responses in this trial, and the influence of other environmental factors, including climatic conditions. Future controlled studies with appropriate treatment replication groups should investigate the effects of different management systems on the behaviour, welfare, and milk production in dairy sheep,

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References

Alamer M 2004. Effect of water deprivation and season on feed inake body weight and thermoregulation in Awassi and Najdi shep breeds in Saudi Arabia. Journal of Arid Environments 59: 71-84.

Berger Y, Billon P, Bocquier F, Caja G, Cannas A, McKusick B, Marnet P, Thomas D 2004. Principles of Sheep Dairying in North America (A3767). Wisconsin, USA: Cooperative Extension Publishing, University of Wisconsin-Extension.

Bøe KE 1990. Thermoregulatory behaviour of sheep housed in insulated and uninsulated buildings. Applied Animal Behaviour Science 27: 243-252.

Bøe KE, Berg S, Anderson IL 2006. Resting and behaviour and displacements in ewes – effects of reduced lying space and pen shape. Applied Animal Behaviour Science 98: 249-259.

Bracke MBM, Hopster H 2006. Assessing the importance of natural behaviour for animal welfare. Journal of Agricultural and Environmental Ethics 19:77-89.

Caroprese M 2008. Sheep housing and welfare. Small Ruminant Research 76 :21-25.

Chappel RW, Hudson RJ 1979. Energy cost of standing in rocky mountain bighorn sheep. The Journal of Wildlife Management 43: 261-263.

Clapperton JL 1964. The energy metabolism of sheep walking on the level and on gradients. British Journal of Nutrition 18: 47-54.

Corbeil RR, Searle SR 2012. Restricted maximum likelihood (REML) estimation of variance components in the mixed model. Technometrics 18: 31-38.

Di Grigoli A, Todaro M, Di Miceli G, Alicata ML, Cascone G, Bonanno A 2009. Milk production and physiological traits of ewes and goats housed indoor or grazing at different daily timing in summer. Italian Journal of Animal Science 8: 616-618.

Færevik G, Anderson LL, Bøe KE 2005. Preference for sheep of different types of pen flooring. Applied Animal Behaviour Science 90: 265-276.

Ganskopp DC, Johnson DD 2007. GPS error in studies addressing animal movements and activities. Rangeland Ecology & Management 60: 350-358.

Gordon GDH, Cockram MS 1995. A comparison of wooden slats and straw bedding on the behaviour of sheep. Animal Welfare 4: 131-134.

Haenlein GFW 2007. About the evolution of goat and sheep milk production. Small Ruminant Research 68: 3-6.

Litherland AJ, Woodward SJR, Stevens DR, McDougal DB, Boom CJ, Knight TL, Lambert MG 2002. Seasonal variation in pasture quality on New Zealand sheep and beef farms. Proceedings of the New Zealand Society of Animal Production 62: 138-142.

Morand-Fehr P, Fedele V, Decandia M, Le Frileux Y 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. Small Ruminant Research 68: 20-34.

Nicol AM, Brookes IM 2007. The metabolisable energy requirements of grazing livestock. In Occasional Publication New Zealand Society of Animal Production 14: 151-172.

Osuji PO 1974. The physiology of eating and the energy expenditure of the ruminant at pasture. Journal of Range Management 27: 437-443.

Peterson SW, Prichard C 2015. The sheep dairy industry in New Zealand: a review. Proceedings of the New Zealand Society of Animal Production 75: 119-126.

Pollard J, Cox N, Hogan N, Huddart F, Webster J, Chaya W, Paterson R, Wigbolus L 2004. Behavioural and physiological responses of sheep to shade. MAF Policy Project FMA 123, MAF, Wellington.

Schütz KE 2011. Heat stress in farm animals. Proceedings of the New Zealand Society of Animal Production 71: 178-202.

Sevi A, Casamassima D, Pulina G, Pazzona A 2009. Factors of welfare reduction in dairy sheep and goats. Italian Journal of Animal Science 8: 81-101.

Swain DL, Friend MA, Bishop-Hurley G, Handcock R, Wark T 2011. Tracking livestock using global positioning systems – are we still lost? Animal Production Science 51: 167-175.