Evaluating loafing surfaces for off-paddock facilities on New Zealand dairy farms

PC Beukes[1]*, B Dela Rue[1], D Dalley[1] and D McCall[1]

[1]*DairyNZ Ltd., Private Bag 3221, Hamilton 3240, New Zealand*

**Corresponding author:* Email: pierre.beukes@dairynz.co.nz

Abstract

Off-paddock wintering facilities need loafing surfaces that meet animal welfare requirements. Our objectives were to establish relationships between dairy cow behaviour and firmness (comfort) and traction (non-slip) across four different loafing surfaces. The four surfaces were post peelings (woodchip), a 50 mm shredded rubber playground surface with 6 mm geotextile overlay (NUMAT), a 25 mm rubber and plastic chip sports turf underlay with 6 mm geotextile overlay (Tiger Turf), and 25 mm × 1 m^2 interlocking rubber matting (NUMAT). Average daily cow lying times were 11.5, 11.0, 10.5 and 8.0 hours/day for post peelings, shredded rubber, rubber/plastic chip, and rubber matting, respectively. A Clegg hammer impact soil tester (2.25 kg) used for mechanical measures of firmness (comfort) showed a strong negative curvilinear relationship with lying times. A Rotational Traction Tester for measuring traction (non-slip) indicated the least to most slippery surface was post peelings followed by shredded rubber, rubber/plastic chip, and finally, rubber matting, which aligned with anecdotal observations of slipping events. Threshold values for these mechanical tests are proposed that will help with evaluating innovative surfaces for cow comfort without the need for animal trials.

Keywords: cow comfort; lying times; off-paddock wintering; cow behaviour

Introduction

Heavy soils common in the Southland region of New Zealand are prone to pugging when wet. This is problematic for farmers wintering cows on forage brassica crops grazed *in situ* due to the environmental implications (e.g., surface run-off and nutrient leaching), animal welfare concerns (e.g., lack of dry and comfortable lying surfaces), and resulting poor public perception (Beukes et al. 2011). A survey of existing options for wintering cows found that many current off-paddock structures do not meet animal welfare requirements for sustainable dairy farming into the future (Dalley 2014). Therefore, there is a need to develop off-paddock wintering facilities that will provide affordable alternative options to farmers and help to address these issues.

A major challenge in designing innovative off-paddock wintering facilities is ensuring satisfactory cow welfare. A key welfare concern is the suitability of the loafing surface provided in a wintering facility. Cow lying time, cleanliness, and lameness are important animal-based indicators of welfare on different loafing surfaces that have been investigated in grazing dairy cows wintered off-paddock (Schutz & Cox 2014, Schutz et al. 2015, Al-Marashdeh et al. 2019). Few studies have investigated surface suitability using other resource-based indicators such as slipperiness or traction, durability, cleanability, ease of effluent handling, and disposal of used surface materials. The gold standard for assessing an animal's welfare state is through the use of direct, animal-based measures. Therefore, the suitability of alternative surface materials for cow comfort is typically investigated through cow behaviour. However, it has also been recognised that ethical research practices should aim to improve the welfare of animals used in science through the principles of the three R's (Replacement, Reduction, Refinement; Animal research and the 3 Rs | NZ Government (mpi.govt.nz)). As a result, there is a need to consider the development of alternative methods to assess cow comfort as it relates to different loafing surfaces. Comparison of cow behaviour such as lying time (e.g., the gold standard) with mechanical tests may provide a low-cost 'fatal flaw' evaluation, which can be used to screen out unsuitable surface materials that do not need to be evaluated using animal trials.

Therefore, the objectives of this study were to 1) investigate four different loafing surfaces and establish relationships between dairy cow behaviour and mechanical tests for firmness (comfort) and traction (non-slip) and, 2) based on the mechanical tests establish guidelines for the suitability of different loafing surfaces from a cow comfort perspective.

Materials and methods

The indoor Calan gate barn at DairyNZ's Lye Farm, Newstead, Hamilton was selected for the wintering surfaces trial to reduce the potential confounding effects of weather conditions on cow behaviour in an outdoor setting. The barn was divided into four areas of 56 m^2 with four cows allocated to each area provided 14 m^2/cow, giving cows ample room to express their typical behaviours. The trial received animal ethics approval (AE APPLICATION 15435).

Alternative loafing surface options that could be evaluated generally fit into three broad categories: 1) Rubber matting, which is currently used for cows standing for short durations in collecting yards and on feed pads, 2) Pour-in-place surfaces such as playground, recycled rubber surfaces with a durable top layer, 3) Loose-fill composting bedding such as woodchip, low quality wool, or inorganic products including sand, recycled rubber chip, and synthetic mulch. Four surfaces were selected to provide an industry-relevant range in firmness (comfort) for comparative assessment of animal behaviour, correlated with mechanical tests. The choice of surfaces also provided an opportunity to assess different materials for suitability, particularly in traction and cleanability. The surfaces selected were, 1) 300 mm deep post peelings, 2) 50 mm thick pour-in-place underlay (SustainPor from NUMAT) with a durable 6 mm geotextile top surface (Cow Carpet, NUMAT) glued on top, 3) 25 mm pour-in-place underlay (Ecocept supplied by Tiger Turf) with Cow Carpet glued on top and, 4) 23 mm interlocking rubber matting (Double Stud from NUMAT). The post peelings are similar to dry woodchip that is widely regarded as the ‘gold standard’ for cow comfort in loose-housed systems. Ecocept is a 50:50 mix of recycled rubber and plastic chip bonded with a resin. SustainPor is a shredded recycled rubber material bonded with a resin. Cow Carpet was selected as the durable layer due to a close similarity to a geotextile product used successfully in a previous study (Al-Marashdeh et al. 2019).

Experimental design

The trial consisted of two phases, firstly a comparison of lying behaviour of cows kept on one of the four surfaces, followed by a surface preference test where cows could choose between two surfaces.

Phase 1. A total of 32 non-lactating (>21 days from planned calving date) cows were enrolled and fitted with leg-mounted IceQube activity meters (IceRobotics, Scotland) to measure lying time and lying bouts. All cows then spent three days on pasture before the trial so that their pre-trial lying behaviour could be recorded. Lying behaviour immediately post-trial was also recorded for two days to establish if there was compensatory lying time as a potential consequence of restricted resting time on any of the surfaces. Cows entered the barn for the trial period in two cohorts, one day apart. The first cohort of 16 cows was randomly selected and assigned to the four loafing areas (four cows per area) within the barn for a duration of 72 hours, with *ad libitum* access to clean water and pasture silage at feeding stations. The procedure for cohort 1 was repeated for cohort 2.

The surfaces were cleaned daily with faeces removed by scraping. The post peelings were turned over with a pitchfork and topped up with approximately 150 mm of fresh post peelings between cohorts in phase 1.

Phase 2. The gates separating the two surfaces on each side of the barn were removed giving cows access to either the post peelings and rubber matting on one side, or the two pour-in-place surfaces on the other. The 32 cows from phase 1 were randomised into eight groups of four animals. Four cows were assigned to each side of the barn for a 24 hour period where they had access to two surfaces (8 cows in total with 28 m^2/cow). The cows were observed visually every 10 minutes throughout the 24 hour period, recording cow location and if they were standing or lying to determine surface preference. This was repeated three times over three consecutive days for different groups of 8 cows with the surfaces cleaned between the groups, following the cleaning procedure described for phase 1.

Mechanical testing of surfaces for firmness and traction

A review of literature and discussions with international experts did not identify any widely accepted standard tests to assess the firmness (comfort) or traction of loafing surfaces. A Portable Friction Tester used to measure traction on road markings has been trialled in a previous study (Telezhenko & Bergsten 2005) to measure the dynamic coefficient of friction for surfaces used in indoor housing facilities. It was reported that the device may underestimate friction on compressible materials due to insufficient weight.

Wider investigation found that the sports turf industry uses devices for measuring the performance of sport surfaces, in particular surface firmness and traction that have potential for similar use on cow loafing surfaces. Two test devices were trialled in the current project. For comfort we used the Turf Clegg hammer (2.25 kg), an accelerometer-based device used internationally to measure the firmness of sports fields and playing surfaces.

For measuring traction, we used a Rotational Resistance (Traction) Tester that simulates the grip of football boots on sports fields (FIFA 2015). The device measures the torque (Nm) required to rotate the base 45 degrees under a load of 40 kg. The FIFA approved base consists of a circle of football boot studs, however, we found during testing that this base was unsuitable for loafing surfaces. An experimental base was constructed for this project where the studs were replaced with large size EVA foam hoof pads (Shoof NZ) that are commonly used for treating lameness in dairy cows.

At the end of phase 2 the surfaces were cleaned as before and the barriers between the surfaces were replaced. Four cows were kept on each surface for 24 hours to replicate the soiling of surfaces as in phase 1. At the end of the 24 hours all four surfaces were tested for firmness and traction. Surface firmness was measured using the Turf Clegg hammer by taking four consecutive readings at 20 selected sites per surface, following a double V pattern across the surface.

The Rotation Traction testing device, fitted with EVA foam pads on the base, was used to assess the traction of each surface. Twenty sites were tested once along a double V pattern on each surface using the 40 kg weight on the base plate. A preliminary test was conducted to assess whether the Rotation Traction device with the standard 40 kg weight was sufficient to adequately compare surfaces. For this purpose, 10 sites on three surfaces were tested with 40, 60 and 80 kg weights on the base plate of the device. No difference was found in the comparative performance of each surface at each weight, which means that the standard weight of 40 kg can be used in the future.

Data analysis

For firmness measurement, the fourth Turf Clegg hammer reading per site was taken as the representative reading (acceleration in Gmax), in accordance with recommended practice for use of the device. Lower values indicate a less firm and higher values a firmer surface. Data were summarised by calculating the mean, median and 75th percentile per surface to account for surface variation, with the 75th percentile representing the higher end of firmness for a surface. For traction, the mean, median and 25th percentiles were calculated to show the lower end (more slippery) of the variability for each surface.

Behaviour data for phase 1 was analysed for average lying time, number of lying bouts, average duration of a lying bout, and proportion of cow-days with less than 8 and less than 10 hours lying time by pooling the data for cohorts 1 and 2. The data for both cohorts showed an exceptionally low number of lying hours for the first day on the surfaces, probably due to cows being unfamiliar with the barn and surface conditions. This anomaly justified not using the data for the first day and only analysing data for the last two days on the surfaces. The data for cohort 1 and 2 were also pooled when analysed for potential compensatory lying.

The surface preference data from phase 2 of the trial was assessed using the observations at 10 min intervals. To calculate total standing and lying times over the 24 hour periods, an assumption was made that the behaviour (standing or lying) remained the same during the interval between the observations. The data were summarised over the four replicates with mean standing and lying time per cow calculated.

Results

Lying behaviour – phase 1

Average lying time was the highest on the post peelings with 11.5±0.41 hours/day and the lowest on the rubber matting with 8.1±0.49 hours/day (mean±SD). The two pour-in-place surfaces with Cow Carpet were intermediate with 10 to 11 hours lying time per day (Fig. 1).

The number of lying bouts per day were significantly (ANOVA, P<0.001) lower on the rubber matting (7±0.5) compared with the two pour-in-place surfaces (both 12± 0.8), with post peelings intermediate at around 9±0.7 bouts per day. Lying hours and number of bouts were used to calculate average bout length with cows on post peelings and rubber matting achieving 1.2 to 1.4 hours/bout and the two pour-in-place surfaces 0.8 to 1 hours/bout. The rubber matting did not achieve the target of 10 hours lying time per day as the minimum requirement for animal welfare (MPI 2019). The inadequacy of the rubber matting as a loafing surface was further emphasised by clear compensatory lying by both cohorts on the day they were taken off the rubber mats, with a large increase in lying time compared to the previous days (results not reported).

Preference test – phase 2

There was a strong preference for lying on softer post peelings compared with the rubber matting. The cows spent 96% of their collective lying time, estimated at 10.5 hours/cow, on this surface. This surface preference is consistent with the large difference in surface firmness, 193 Gmax for the rubber matting versus 35 Gmax for the post peelings.

There was a slight preference for lying on softer shredded rubber (SustainPor, NUMAT). The cows spent 55% of their estimated 9.2 hour of total mean lying time on SustainPor. Three cows (out of 16) spent all their lying time on the rubber and plastic chip (Ecocept, Tiger Turf), and three cows spent all their lying time on SustainPor. The results suggest that surfaces with a firmness reading

Figure 1 Lying time per day for cows (n = 8) kept indoors on four different surfaces over two full days (16 cow-days per surface). Median is horizontal black line and mean is the solid diamond.

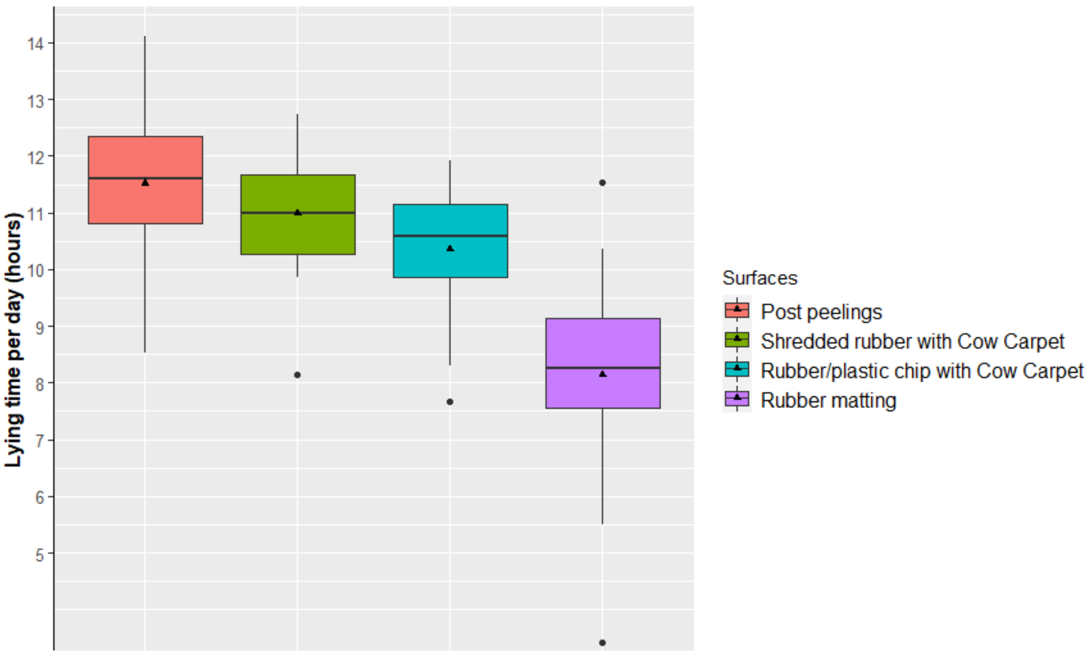
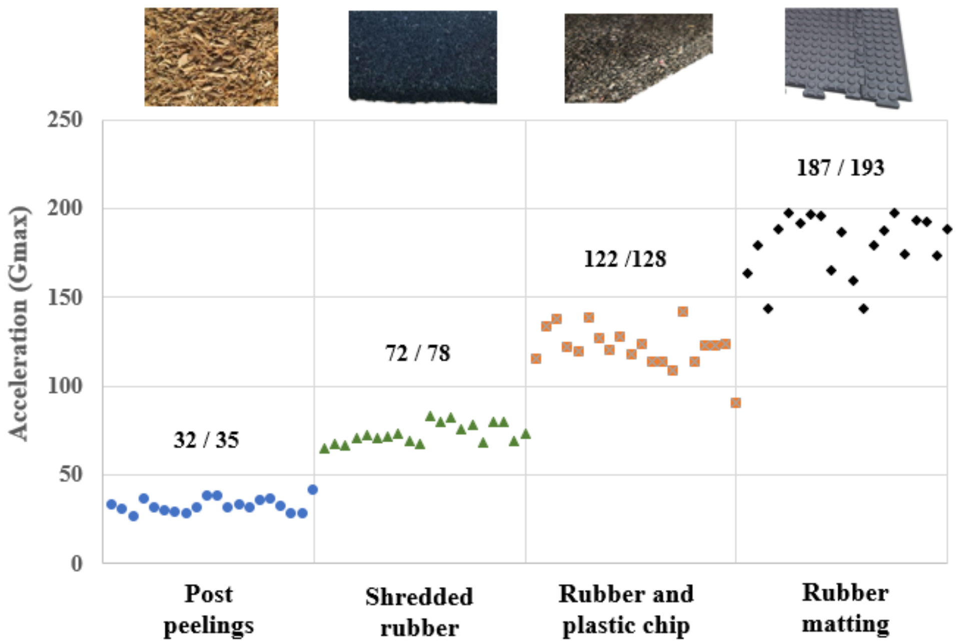


Figure 2 Results for firmness (acceleration in Gmax) using the Turf Clegg Hammer (2.25 kg) for four loafing surfaces. Individual data points and the value of the median and 75th percentile is presented.



of around 140 Gmax or less may be suitable from a cow comfort perspective.

Mechanical tests

Firmness. The Turf Clegg hammer results (Fig. 2) show a clear range from the least firm post peelings to the firmest rubber matting, with the two pour-in-place surfaces intermediate. The variability observed in the rubber matting is due to thicker rubber around the joins between mats, whereas variability in the pour-in-place surfaces is probably due to mix density or the laying process. The results in Fig. 2 can be put into context by comparing them with results for additional surfaces (values in Gmax); woodchip for calf pens – 49, soft condition paddock – 58, 25 mm rubber mix (SustainPor, NUMAT) – 104, 30 mm Comfy Cow interlocking rubber matting – 140, 25 mm Kura (NUMAT) interlocking rubber matting – 182.

Traction. The post peelings was the least slippery while the rubber matting was the most slippery surface, with the two pour-in-place surfaces intermediate (Fig. 3). The variability in the pour-in-place surfaces is the result of measurements being taken on freshly deposited dung. Older dung patches tended to dry out fairly quickly due to good drainage of these surfaces. The traction readings align with visual observations of the surfaces, where the rubber matting was the wettest surface and more slippery than the others. A 25^{th} percentile reading of <10 Nm may be a useful threshold for unsuitable traction.

Discussion

Cow lying time threshold

Cow lying time (hours/day) is a commonly used metric to determine the relative welfare of animals under different conditions. New Zealand's dairy cattle code of welfare states that 'when dairy cattle are well fed, have suitable soft lying surfaces and space available and are not exposed to adverse environmental conditions, they should be able to lie for 10-12 hours each day to meet their behavioural needs' (MPI 2019).

The average lying times of between 8 and 11.5 hours/day for the four surfaces in this study are consistent with the results from previous studies. Al-Marashdeh et al. (2017) found no effect of surface on lying time (average 10.1 hours/day) across three surfaces, woodchip, 70 mm round-stone and 50 mm round-stone. However, they found that lying time on a geotextile carpet (11.6 hours/day) was significantly greater than on woodchip (10.8 hours/day). In another study Al-Marashdeh et al. (2019) found that surface type significantly affected lying times with most lying time on 40-60 mm stone (9.5 hours/day), followed by carpet (8.8 hours/day), with least on sand (7.6 hours/day). The control cows in the paddock had lying times of 8.1 hours/day and those on woodchip 8.4 hours/day. Although the stone had the highest average lying time, Al-Marashdeh et al. (2019) rated the stone surface as a less-suitable surface because the number of lying bouts were much lower and each bout much longer compared with the other surfaces suggesting that cows found standing up and sitting down on the stone surface difficult. Our results appear to support this hypothesis, the lowest number of lying bouts were recorded on the firmest surface, the rubber matting, potentially indicating discomfort or difficulty when getting up and down.

Our expert panel agreed that a threshold of 10 hours/day (median) lying time would be a suitable minimum threshold for pre-calving lying time. This threshold is

Figure 3 Results for traction (Torque in Nm) using the Rotation Traction testing device for four loafing surfaces. Individual data points and the value of the median and 25th percentile is presented.

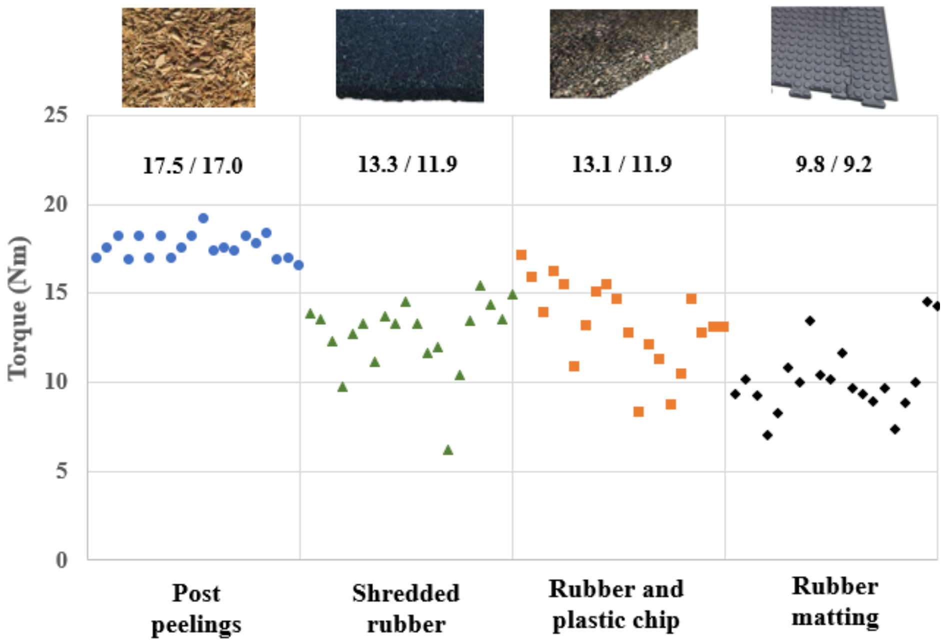
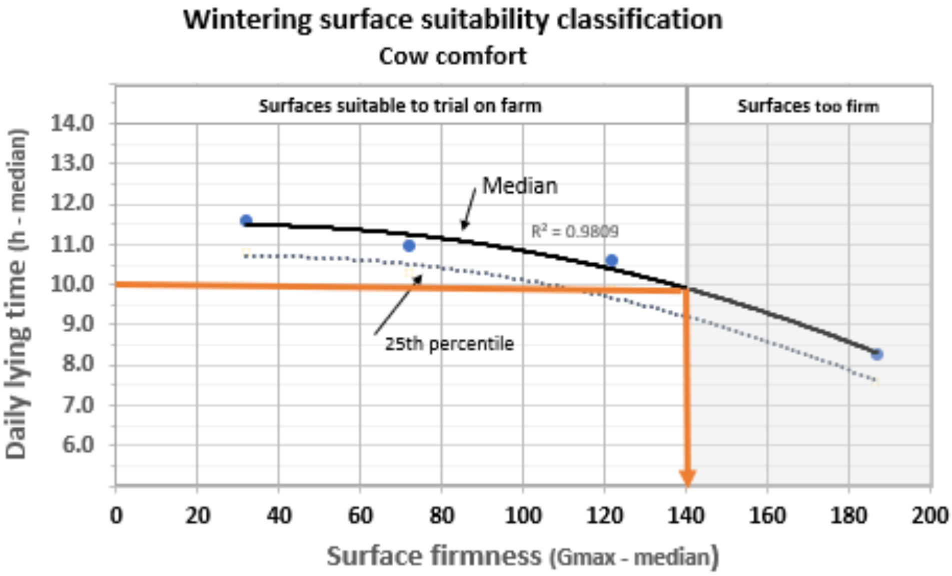


Figure 4 The relationship between surface firmness as measured with a Turf Clegg hammer (Gmax units) and median cow lying time (hours/day) for four loafing surfaces. The solid black line is the best fit for the median, with the dotted black line the best-fit for the 25[th] percentile of the data points. The orange lines are indicative of a cut-off point for surface firmness that will allow median lying times of 10 hours/day or more.



supported by previous studies which showed >10 hours/day lying time by non-lactating cows in winter when they have access to comfortable lying surfaces (e.g. Schütz & Cox 2014, Schütz et al. 2015, 2019). A surface firmness corresponding to 10 hours/day lying time in our study would probably result in the majority (~75%) of cows getting at least 8 hours/day lying time under farm conditions.

From our results we propose a non-linear relationship between the surface firmness and cow lying time (Fig. 4). A curvilinear regression appears to be a very good fit with our data (R^2=0.98 compared with R^2=0.90 for linear). A median lying time of 10 hours/day corresponds to a surface firmness measurement of 140 Gmax (median) (Fig. 4). Based on our threshold of 10 hours/day lying time, post peelings (point 1) and two pour-in-place surfaces (points 2 and 3) would be suitable loafing surfaces. Surfaces firmer than 140 Gmax (point 4) could be suitable for feeding areas in off-paddock infrastructure, but only when used together with an appropriate loafing surface where cows can meet their lying requirements.

Surface traction guideline

Traction on a surface can be affected by the design and maintenance e.g., slope, permeability, cleaning routines.

Our study compared the surfaces under the same physical and environmental conditions and effluent loading. As a guide to suitability, we consider surfaces to be too slippery when the 25th percentile torque value using the Rotational Traction Tester is less than 10 Nm (See Fig. 3). This is based on visual observations and anecdotal reports during our study and not a detailed examination of cow movements on the surfaces. Although most slipping was observed on the rubber matting, some slipping occurred on the two pour-in-place surfaces, especially on wet dung patches. Further testing of surfaces in a farm environment where slipping is observed would be useful to reinforce our findings.

Conclusion

We evaluated two performance criteria for surface materials for wintering cows on off-paddock facilities using surface performance measurement tools. A relationship between surface firmness (a proxy for comfort) and cow lying time was established, with a threshold for suitable daily cow lying time corresponding to a firmness value (<140 Gmax) for covered loafing surfaces. A guideline for surface traction requirements using a modified Rotational Traction Tester has been proposed. It provides comparative differences between surfaces consistent with anecdotal observations and will provide an initial means of screening out unsuitable surface materials. It is proposed that suitable surfaces should have a 25th percentile torque value greater than 10 Nm to minimise the risk of slipping. Field studies in commercial environments are required to validate this proposed threshold. Future research will test performance, cleanability and durability of suitable products under field conditions.

Acknowledgements

This work was funded by the Sustainable Farming Fund (project S3F-20020) and New Zealand dairy farmers through DairyNZ Inc. Thanks to the Lye Farm team led by Caitlyn Dawbin for running the trial. Thanks to Tiger Turf for donating the Ecocept surface.

References

Al-Marashdeh O, Cameron KC, Bryant RH, Box L, Arends A, Coveney A, Chrystal J, Edwards GR 2017. Stand-off pad wintering system: effect of surface types on cow comfort and urination behaviour. Proceedings of the New Zealand Society of Animal Production 77: 137-142.

Al-Marashdeh O, Cameron KC, Bryant RH, Chen A, McGowan B, Gillé-Perrier C, Carey P, Chrystal J, Hodge S, Edwards GR 2019. Effects of surface type in an uncovered stand-off pad system on comfort and welfare of non-lactating dairy cows during winter. Applied Animal Behaviour Science 211: 17-24.

Beukes PC, Gregorini P, Romera AJ, Dalley DE 2011. The profitability and risk of dairy cow wintering strategies in the Southland region of New Zealand. Agricultural Systems 104: 541-550.

Dalley DE 2014. Achieving wintering system performance targets. DairyNZ Technical Series, April 2014.

FIFA 2015. Quality Programme for Football Turf. Handbook of Test Methods. Edition V3.1 (16.03.2020). http://quality.fifa.com/media/1238/fqp-handbook-of-test-methods-2015-v31-w-cover.pdf. [accessed 5 July 2022].

Ministry for Primary Industries 2019. Code of Welfare: Dairy Cattle. Version 2019. https://www.mpi.govt.nz/dmsdocument/46024-Code-of-Welfare-Dairy-cattle [accessed 15 July 2022].

Schütz KE, Cave VM, Cox NR, Huddart FJ, Tucker CB 2019. Effects of 3 surface types on dairy cattle behavior, preference, and hygiene. Journal of Dairy Science 102: 1530-1541. doi:10.3168/jds.2018-14792.

Schütz KE, Cox NR 2014. Effects of short-term repeated exposure to different flooring surfaces on the behavior and physiology of dairy cattle. Journal of Dairy Science 97(5): 2753-2762.

Schütz KE, Huddart FJ, Sutherland MA, Stewart M, Cox NR 2015. Effects of space allowance on the behavior and physiology of cattle temporarily managed on rubber mats. Journal of Dairy Science 98(9): 6226-6235.

Telezhenko E, Bergsten C 2005. Influence of floor type on the locomotion of dairy cows. Applied Animal Behaviour Science, 93(3-4): 183-197. https://doi.org/10.1016/j.applanim.2004.11.021.