The effects of stand-off pad surface materials on the welfare and behaviour of dairy cows over the winter dry period in Canterbury, New Zealand.

A Dissertation
submitted in partial fulfilment
of the requirements for the Degree
of Bachelor of Agricultural Science
with Honours

at
Lincoln University
by
Anna Naivasha Arends

Lincoln University
2016

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Moving dairy cows off pasture to a stand-off area is a common practice used to mitigate nitrate leaching, particularly during winter. From an economic point of view, choice of surface material has large implications for farmers. However, limited data is available on how stand-off pad surface material may affect cow welfare, and compliance with welfare regulations is a priority when choosing a stand-off pad surface material to use. An experiment was conducted over 10 days during winter in Canterbury, New Zealand to investigate the effect of different stand-off pad surface materials on dairy cow feed intake, lying behaviour, cleanliness, lameness and social interaction. In the experiment, 210 Friesian × Jersey, pregnant non-lactating dairy cows were blocked and assigned to three feeding and stand-off treatments: grazed fodder beet *in situ* for 7 hours (8 am to 3 pm) then moved to a stand-off pad with a surface of wood chip (WC), stones 40-60mm (S50) or stones 60-80mm (S70) for 17 hours (3 pm to 8 am). Surface type had no effect on average lying time (9.9 hours ± 1.10), with 85% of cows lying for >8 hours, lameness score (0.043 ± 0.0901) and cleanliness score (0.97 ± 0.0901). There was no difference in the number of interactions per cow over the three treatments however there was a location difference in Dominance Value (DV) which is an indicator of hierarchy determined by aggressive behaviour. Average DV was higher (P=0.05) when cows were on the stand-off pad compared to when they were grazing on the paddock. While current results showed no effect for surface type on cow welfare, all surfaces met minimum welfare requirements. A longer study, covering the whole winter season, is required to confirm these results.

Keywords: stand-off pad, dairy cows, welfare, behaviour, surface material, woodchip, stones, lying, live weight, BCS, social interaction,cleanliness, lameness, fodder beet.

Acknowledgements

I have very much enjoyed my four years at Lincoln University and I appreciate the support that has been provided over my time here.

To my supervisor Prof. Grant Edwards, thank you for sharing with me my passion for the dairy industry and encouraging me to do this honours experiment.

To Racheal Bryant, thank you so much for the guidance, support, constructive criticism, copious amounts of reading and especially time that you have spent with me. I am very grateful for you stepping in to help when it was needed.

To Omar Al-Marashdeh, thank you for all the scientific and statistical help and proof reading. I could not have got through my results without you! Thank you to Aimi Hussein for the help with the social interaction part of the experiment.

Thank you to Helen, Sarah, Jules, Misato, Willem and everyone else from LURDF that was involved in the ADRDS winter trial for all of the logistical and practical support.

Thank you very much to my parents Ester and Geoff for the support they have given me not only over this year but all my time at Lincoln. Your constant support and encouragement means the world to me and you sparked the enthusiasm and passion I have for the dairy industry. My brother Sam, I have loved sharing my last year of university with you, thank you for the laughs and the caring!

A special thank you to my friend and colleague, Annika Coveney, for the team work and time spent together to get our dissertations done! We were a productive and motivated pair and I enjoyed working with you.

Thank you to my flat mates Ella, Georgie, Charlie, Shannon and Naomi and my dear friends Aoife, Ella, Bryony, Hat, Holly and Lucretia for the moral support over the year.

Finally I would like to thank DairyNZ, especially Susan Stokes, for their support over the past years- not only has the financial support been of great significance but the mentoring and networking has been invaluable. I would also like to thank the Harwood Farm Trust, Tararua Federated Farmers, New Zealand Society of Animal Production and the C H Croker Memorial Trust for their generous financial support over my time at Lincoln University.

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Chapter 1

Introduction

1.1 Background

The New Zealand dairy industry is reliant on its pasture-based production system. The effectiveness of this system is due to the temperate climate where grass growth occurs all year round. In addition to the 'grass fed' clean green image perceived by consumers, marketing of New Zealand dairy products depends on better animal welfare practices compared to other countries operating more intensive systems. However, there are growing concerns regarding the environmental and welfare practises of our dairy industry. From an environmental point of view, nitrate leaching of an average of 30-80kgN/ha/annum (Menneer et al., 2004) into groundwater is one of the major concerns, due to its impacts on the quality of drinking water and recreational use of rivers and streams. The majority of nitrate is derived from stock urination, which is exacerbated by high stocking rates and high nitrogen-containing diets. The nitrate leaching risk is particularly high during the winter when plant growth is slow, limiting plant uptake of excess nitrogen, and drainage is high as a result of rainfall. In Canterbury especially, soil types are typically shallow, light and very free draining, instigating an increased susceptibility to nitrate leaching in comparison to other soil types.

To mitigate nitrate leaching from livestock during the winter, an increasingly popular option is to use stand-off pads to gain control over nutrient deposition from urine. The adoption of stand-off pads has increased to the extent that 22% of New Zealand dairy farms had some form of stand-off pad in 2012 (Longhurst et al., 2013), and this is likely to have increased. Benefits of stand-off pads are that they trap effluent, and then allow application of nutrients to occur at a time and place suitable for low leaching potential and are also beneficial in the reduction of pugging damage to soils and the conservation of pastures (Fisher et al., 2003; Schütz & Cox, 2014; Stewart et al., 2002).

However, stand-off pads present a risk to welfare of cows due to lack of space to express normal behaviour. This can lead to health issues, intensification of cow hierarchy and competition, and general cow discomfort including low cleanliness score and disruptive lying behaviour (Dalley et al., 2012). Meeting recommended nutritional (seasonally dependant) and lying (8 hours minimum (DairyNZ, 2014a; New Zealand Government, 2014)) requirements are key influences of welfare status. The behaviour and welfare of dairy cows when using a stand-off pad needs to be more clearly understood.

1.2 Research Objectives

Research objectives of the current study are:

1. To examine and compare the effects of three different stand-off pad surface materials (woodchip (WC), 40-60mm stones (S50) and 60-80mm stones (S70)) on dairy cow welfare – particularly feed intake, lying time, lameness, cow cleanliness and social interaction under a duration controlled grazing system.

2. To observe and compare surface materials in terms of their physical properties such as temperature.

1.3 Hypothesis

The hypothesis for the study is that the cows stood off on wood chip will achieve adequate welfare standards in terms of lying times, lameness, and cleanliness whereas both stone sizes will not achieve adequate welfare standards in terms of lying time and lameness. It is thought that feed intake will be less for both stones sizes compared to the woodchip as cows are likely to make up for lack of lying time on the stones when in the paddock.

Chapter 2

Literature Review

To continue farming sustainably, farmers must consider not just the environmental and financial implications of their practices but the impacts that their management choices have on animal welfare. This literature review discusses how welfare of a dairy cow is defined by indicating crucial welfare aspects such as lying time, live weight and body condition score (BCS), locomotion, cow cleanliness and indicators of stress, as well as how these factors are influenced by different surface materials of stand-off pads. Measuring animal welfare is an important step in order to identify the best available management to meet cow welfare.

2.1 Key Indicators of Welfare

The Code of Welfare for Dairy Cattle, established by the New Zealand Government outlines aspects of a dairy cow's health and welfare which need to be apprehended to (New Zealand Government, 2014). All dairy farms must apply farming systems to meet the minimum standards of animal welfare. Although all standards are essential to ensure high status of animal welfare, there are some standards pivotal to attain an exceptional animal welfare status, particularly those related to feed and water.

Regarding feed, minimal standard no. 2 states:

> *"Dairy cattle of all ages must receive sufficient quantities of food and nutrients to enable each animal to: (i) maintain good health; (ii) meet their physiological requirements; and (iii) minimise metabolic and nutritional disorder"*

Regarding water, minimal standard no. 3 states:

> *"All dairy cattle must have access to a daily supply of drinking water sufficient for their needs and that is not harmful to their health"*

For farm systems that have facilities for cows such as a milking shed, drafting systems, feed pads and, in the current study, stand-off pads, minimum standard no. 7 states:

> *"Farm facilities must be constructed, maintained and operated in a manner that minimises the likelihood of distress or injury to animals"*

In regards to stand-off areas and feed pads, minimum standard no. 8 states:

> *"Dairy cattle must be able to lie down and rest comfortably for sufficient periods to meet their behavioural needs"*

Further, cows standing on a hard surface for a period of 12 hours or more per day for consecutive days are highly susceptible to insufficient lying time, weight loss, lameness, stiffness and agitated behaviour. Therefore, for cows standing on a concrete surface, the recommended practise (New Zealand Government, 2014) is to give them at least one full day on an alternative surface, where they can lie down and rest, every three consecutive days on concrete. In addition, the bedding area should be well drained and covered with dry comfortable material in order to meet the minimum standards of welfare for cows staying on standoff area.

2.1.1 Standing/Lying

What is resting comfortably?

Understanding how a cow stands up and sits down is important when choosing a surface material to have the cows on (Figure 2.1). A large part of defining ‘comfortably resting’ includes how comfortable it is for the cow to physically sit down and stand up – not just the lying itself.

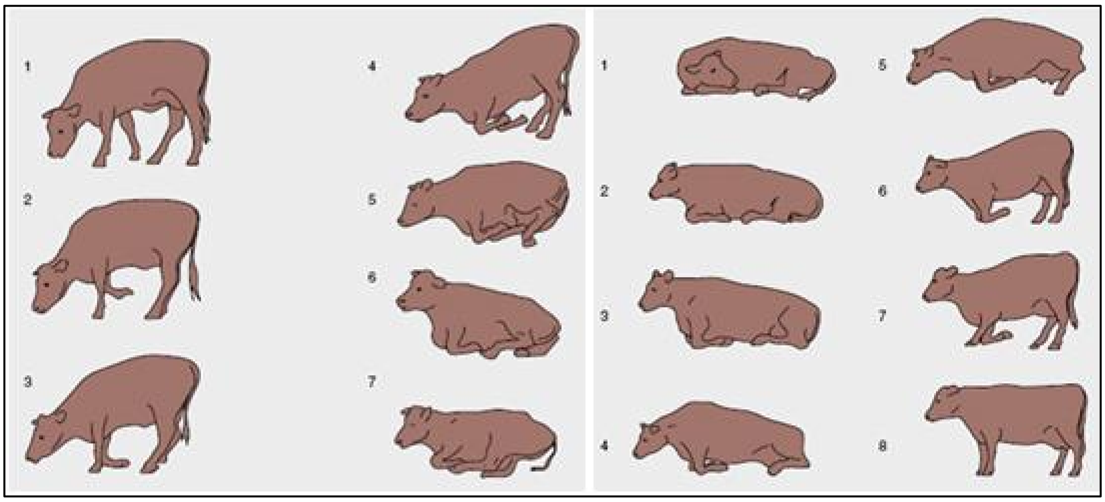

Figure 2.1 The process in which cow sits down (left) and stands up (right) (de Laval, 2007).

If the surface is not comfortable for a cow to perform the task of lying then it will hesitate and avoid sitting down. Each time a cow sits down she puts approximately two thirds of her body weight (400-500kg) on her front knees, and her knees drop freely to the floor from a height of 20-30cm as can be seen in Step 4-6 (Figure 2.1 - left); therefore, it is essential that the ground is comfortable for the cow to land on. In addition, the cow forwards her lunges when standing up; therefore it is important that there is enough room for the cow to do so (Step 4-5, Figure 2.1 – right). Resting comfortably also considers the position of the cow when it is lying. For a cow to comfortably rest, it should have enough space and a surface material that allows her to be in a position of choice (Figure 2.2), as there are four ways that a cow can be lying, as well as both sides to be lying on.

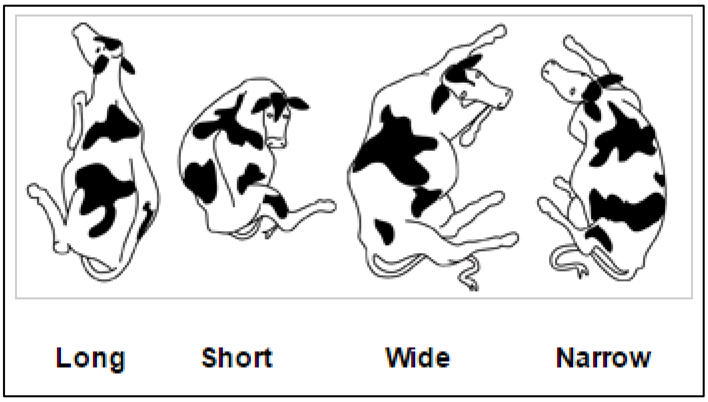

Figure 2.2 Positions cows lie in (de Laval, 2007).

Lying time

Naturally, dairy cows spend a large proportion of their daily time resting (Fregonesi & Leaver, 2001; Jensen et al., 2005; Singh et al., 1993) and it is important that they do so to maintain general health and welfare. Dechamps et al. (1989); Krohn and Munksgaard (1993); Metz (1985) and Ruckebusch (1974) reported that lying occupies approximately 50% of a cow's daily time budget. In New Zealand, cows on pasture spend approximately 10 hours lying per day (Fisher et al., 2008; Schutz et al., 2013) and a minimum lying time of 8 hours per day is recommended for each cow (DairyNZ, 2014a; New Zealand Government, 2014). Under pastoral farming systems and acceptable weather conditions, the lying behaviour of grazing dairy cows is not usually considered to be at risk. However, under farming systems where stand-off pads are used, the stand-off bedding material can strongly impact cows lying behaviour (Fregonesi et al., 2007). A minimum lying time of 8 hours per day are recommended to farmers (DairyNZ, 2014a; New Zealand Government, 2014). In pastoral farming systems, under acceptable weather conditions the lying behaviour of grazing dairy cows is not usually considered to be at risk, however where stand-off pads are used, the surface underfoot strongly influences lying behaviour and is one of the important factors to consider when designing a lying area (Fregonesi et al., 2007).

Several studies reported that cows spend less time lying on hard and or muddy surfaces (Haley et al., 2001; Muller et al., 1996) and prefer lying on soft and well bedded surfaces (Schütz & Cox, 2014; Tucker & Weary, 2004; Tucker et al., 2003; Wagner-Storch et al., 2003). Metz (1985); Munksgaard et al. (2005) and Schütz and Cox (2014) found that cows deprived of lying time due to uncomfortable (hard, cold, wet) stand-off pad surfaces, compensate this lack of resting time while grazing at the paddock. This resulted in less time cows spent grazing and hence reduction in dry matter (DM) intake. When comparing surface materials a common finding is that cows standing off on concrete have the shortest total lying times in comparison to all other surface types (Fisher et al., 2003; Haley et al., 2001; Schütz & Cox, 2014). This is because of the cold, hard surface that discourages cows from lying down as these conditions are uncomfortable. Uncomfortable lying surfaces increases standing time on the stand-off pad and discourage cows to stand up and sit down, resulting in low lying down events per cow per day (Fisher et al., 2003).

Significant differences with regards to lying time and surface materials have been reported by many studies (Fisher et al., 2002; Fregonesi et al., 2007; Haley et al., 2001; Schütz & Cox, 2014; Stewart et al., 2002). In these studies, the surface enabling the greatest lying time was woodchip. Schütz and Cox (2014) compared the lying times of cows standing on concrete with those on rubber mats or wood chip when being stood off for 18 hours and in the paddock for 6 hours per every 24 hours (Table 2.1).

Table 2.1 Lying times of cows standing on concrete, rubber mats (12 or 24mm) and wood chip for 18 hours and grazing for 6 hours (Schutz and Cox, 2014).

	Lying hours/stand-off time (18 hours)	Lying hours/grazing time (6 hours)	Total hours spent lying
Concrete	2.8	1.5	4.4
Wood chip	10.8	0.4	11.2
12mm rubber mats	6.0	0.9	6.9
24mm rubber mats	7.3	0.8	8.1

Similarly Fisher et al. (2003), showed that cows which were stood off on hard surfaces such as concrete had shorter lying times compared with woodchip (Table 2.2). Although cows attempted to compensate by lying down when let out for grazing, they still achieved less than 8 hours total.

Table 2.2 Lying times of cows standing off on either concrete, wood chip, paddock or a laneway for 20-21 hours and grazing for 3 hours (Fisher et al., 2003).

	Lying hours/stand-off time (20-21 hours)	Lying hours/grazing time (3 hours)	Total hours spent lying
Concrete yard	6.5	0.4	6.9
Wood chip pad	12	0	12
Small paddock	6.5	0.3	6.8
Laneway	5.4	0.5	5.9

Cows on woodchip had the greatest lying times in both studies, showing greater than 10hrs lying per day. Interestingly, the experiment with the shorter stand-off times had less total lying times for both the concrete and woodchips. Schütz and Cox (2014) showed the rubber mats had superior lying times than the concrete, but was still 4-5 hours less than that achieved by the woodchips. The 24mm rubber mats had greater lying times than the 12mm. This is in agreement with DairyNZ (2014b) who reported that quality and thickness of rubber mats would affect cow behaviour. Haley et al. (2001) compared concrete and PastureMat mattress flooring (‘PastureMat’ – a rubber filled geotextile mattress designed to mimic a natural pasture). Fisher et al. (2003) and Schütz and Cox (2014) presented similar results to Haley et al. (2001) where total lying time per day on concrete was lower at 10.42 hours compared to 12.25 hours on the PastureMat mattress flooring. These cows were not let out to grazing as they were housed indoors. Both the concrete and mattress flooring had significantly higher lying times than the same surfaces in the other studies. This could be due to the cows being used to these surfaces as they are on them all year round in comparison to New Zealand cows which are generally stood off in winter only, so have shorter transition period to get familiar with the different or new surfaces.

Longhurst et al. (2013) studied the response of animals to different types of wood materials, namely wood chip, post peelings, chipped pallets, bark chip and sawdust, and concluded that cows preferred to lie on dryer surfaces. The coarser materials (bark chip, wood chip and chipped pallets) had a lower bulk density in comparison to sawdust or post peelings and became less compacted over time resulting in better drainage and lower moisture content. In the same study surfaces that were not kept clean or dry by replacing the material after heavy rainfall in June, resulted in insufficient lying times (under 8 hours) as cows chose not to lie down in waterlogged material. The same material that was well managed (replaced/aerated) supplied sufficient lying times of at least 8 hours (Figure 2.3).

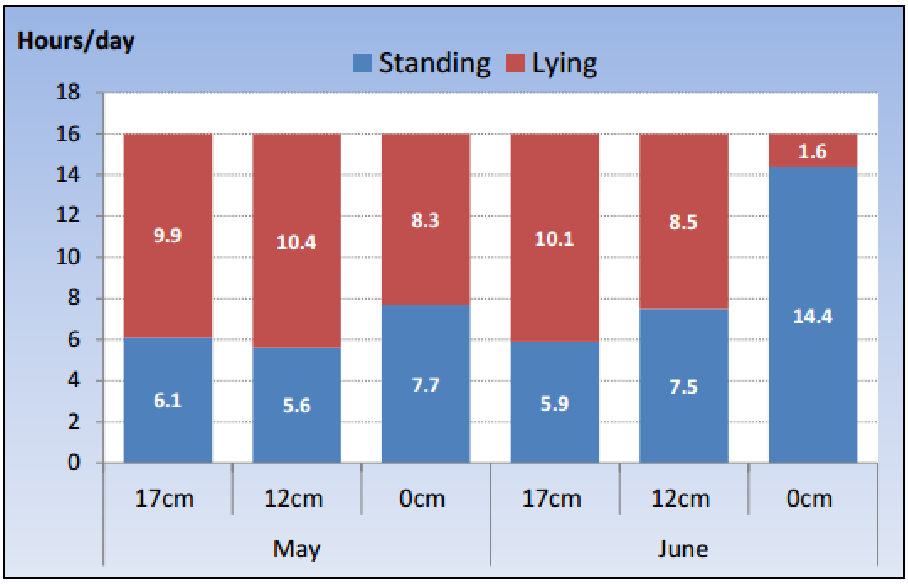

Figure 2.3 Standing and lying times over 16 hours on three pad surfaces during May and June following replacement of different depths of wood chip (Longhurst et al., 2013).

Table 2.3 shows the differences in sample size, experiment duration and the time on the pad for numerous studies. This shows that few cows per experiment were used and therefore limitations to these experiments are likely to be their sample size as well as the use of ‘recovery periods’, as few days standing off may not be enough time to show long term effects of stand-off pads and their different surfaces. Observing frequency may also be a limitation in regards to how accurate the data was at reflecting the overall behaviour of the cows.

Table 2.3 Comparison of studies regarding the sample size and duration of study.

Study	Number of cows	Adaption Period	Experiment duration	Time on pad	Recovery Period	Observing frequency
Fregonesi et al. (2007)	24 (6/group)	5 days	8 days	2 consecutive days 24 hrs/day	2 days	Videoed 24 hrs/2days. Videos scanned every 10 mins.
Fisher et al. (2003)	32 (8/group)	1 week	4 weeks	4 consecutive days, 20-21 hrs/day	3 days	24hr video tapes, then watched for time cows stood and sat.
Haley et al. (2001)	16 (4/group)		12 weeks (3 weeks/ treatment)	Every day, 24 hrs/day	-	4 24hr periods every 3 weeks.
Schutz and Cox (2014)	80 (2 groups)	5 days	7 weeks	4 consecutive days, 18hrs/day	7 days	Immediately before and after each stand off period.
Stewart et al. (2002)	219 (12/farm observed)	N/A	Southland: 4-5 months Waikato: varied (months)	Every day, 24 hrs/day Days weather permitted, 18hrs/day	- -	Once every 10 mins for one 24hr period.

In conclusion, when comparing the effect of surface materials on lying times, wood materials (woodchip, post peelings, bark or sawdust) are recommended over any of the other surfaces that were studied. In addition, it is essential that the type of material used is well drained and kept clean and dry to achieve maximum lying times and hence welfare standards.

2.1.2 Liveweight and body condition score

Gaining BCS over the winter is important to optimise production and reproductive efficiency of cows during lactation. Further, meeting target BCS can help cows to overcome DM intake depression and associated metabolic disorders during the post-partum period (Dewhurst et al., 2000). DairyNZ (2016) recommends the ideal BCS for cows at calving is 5.0 (using a 1-10 scale), and at least 90% of a mixed age herd to be within 4.5-5.5 BCS at calving. It is important that body condition is monitored as over conditioned cows have low intakes both before and after calving compared with cows with normal condition and metabolic disorders are more likely (Dewhurst et al., 2000; Holcomb et al., 2001; Holter et al., 1990). Currently, many cows are failing to reach pre-calving BCS targets in New

Zealand (Dalley et al., 2012) and the use of a stand-off pad may give the ability to manage BCS more effectively. This is because animals are expected to conserve more energy in stand-off areas. Schütz and Cox (2014) however, stated that a stand-off surface that limits lying time means cows may try to compensate by sacrificing grazing time in the paddock for lying, reducing feed intake and hence gain of BCS. Mogensen et al. (1997) suggested excessive standing can adversely affect weight gain in cattle, thought to be due to the increased energetic cost of standing.

There are inconsistent results from previous studies regarding the relationship between live weight gain and surface material. Some studies show that change in live weight is not influenced by surface type or lying time (Schütz & Cox, 2014) however others show it is (Fisher et al., 2003; Webster et al., 2007). Although, incorporating stand-off into a farming system resulted in loss in cows live weight, surface type (concrete, woodchip and rubber mats) had no effect on this loss (Schütz & Cox, 2014) . In contrast, Fisher at al. (2003) reported loss in live weight for cows on concrete compared with live weight gain for those on wood chip and paddock. However, in the later study live weight gain was measured over a short period of four days which is not a sufficient to measure a significant change in live weight gain (Table 2.3). In addition, since cows deprived of lying are likely to compensate for it by choosing lying instead of eating during grazing time (Metz, 1985; Munksgaard et al., 1999). Schütz and Cox (2014) suggested that the loss in live weight could be due to gut fill, as the cows were weighed just before they left the pasture and at the end of the 4 day stand-off period. They also deliberate the possibility that 6 hours on pasture is not sufficient time for cows to meet their daily energy requirements. Webster et al. (2007) reported slower live weight gain in non-lactating dairy cows in winter that were given restricted access to pasture and held on a concrete surface for 18 hours per day over 7 days for two consecutive 14 day periods in comparison to cows with continuous access to pasture. While there are ambiguous results on the effect of stand-off pad surface type on cows live weight, further researches are required for better understanding on how surface material affects live weight.

2.1.3 Locomotion – lameness and gait

Physiological and behavioural signs appear to be indicators of cattle lying down for periods shorter than recommended (8-14 hours) per day (Fisher et al., 2002; Munksgaard et al., 1999; Munksgaard & Simonsen, 1996; Tucker et al., 2007). These include elevated cortisol concentrations, tiredness and increased risk of lameness (Cook et al., 2004; Leonard et al., 1996).

Pain from lameness and hence supressed feed intake can lead to a decrease in BCS and live weight, and milk production during the milking season. In addition, lameness has also been found to contribute to reproductive inefficiency and increases the likelihood of a cow to be culled (Sprecher et al., 1997), resulting in economic loss. The type of surface material strongly influences leg health

(Lombard et al., 2010; Potterton et al., 2011; Rutherford et al., 2008). Stewart et al. (2002) reported that of all dairy farmers reporting health issues in relation to stand-off pads, the main health problem was lameness when using a concrete only pad. Increased standing times on concrete surfaces over extended periods of time have been associated with the development of hoof lesions and laminitis (Colam-Ainsworth et al., 1989; Galindo & Broom, 2000). van Gastelen et al. (2011) found lameness and leg health may be improved by bedding or rubber flooring rather than concrete. Similarly, Hinterhofer et al. (2006) reported that a solid (flat) floor would be the best choice for minimising lameness risk compared to uneven surfaces such as slats or uneven material (sharp, bumpy, curved) which is likely to cause uneven pressure distribution of the foot.

There have been differing results across studies when investigating lameness and surface type. Schütz and Cox (2014) had no cows become severely lame when standing off cows on concrete, wood chip, a laneway or a paddock and this is likely to be due to the access to pasture. Spending time on pasture is beneficial as it is a soft surface for the hoof. As shown in Table 2.3, cows in this study were not on the stand-off surface for enough consecutive days to show an accurate reflection of surface material on lameness.

Cow gait length can be used as in indicator of leg stiffness and soreness, and is calculated by the number of steps taken by the hind limbs to traverse a specified distance (Fisher et al., 2003). Less steps per distance (or a wider stride), is a desired gait in comparison to many small steps. Reduced gait length is often a result of lameness, but not always (Fisher et al., 2003; Sprecher et al., 1997). Cows that spend a lot of time standing on especially hard surfaces are more prone to a lower gait length. Gait score (using a scale of 1-5, 1 being good, 5 being the worst gait score) is an effective system invented by Sprecher et al. (1997) to assess gait. Hernandez-Mendo et al. (2007) found that cows that were normally housed indoors but let to graze on pasture for four weeks had much better gait scores and less lameness than cows that were continuously kept in the stalls for the four weeks (as well as the rest of the year). In this study, cows standing on the pasture improved gait score (on a scale of 1-5 used by Sprecher et al. (1997)) by 0.22 units per week, which totalled to just over 1 unit over the 4 weeks (Figure 2.4).

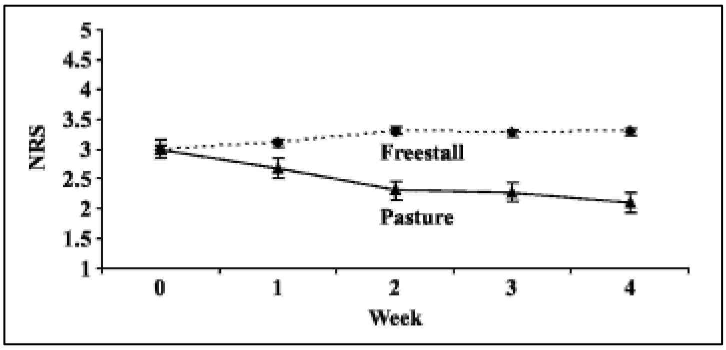

Figure 2.4 Changes in gait score (numerical rating system) for dairy cows kept on pasture or in a free stall barn (Hernandez-Mendo et al., 2003).

Although Schütz and Cox (2014) did not have any of the cows become lame, they did find that surface types influenced gait score after standing off for four days. Gait score deteriorated more for cows on concrete than on the other three surfaces, however there was no significant difference between the other three surfaces. Schütz and Cox (2014) found a similar result for stride length (m/stride) (Figure 2.5).

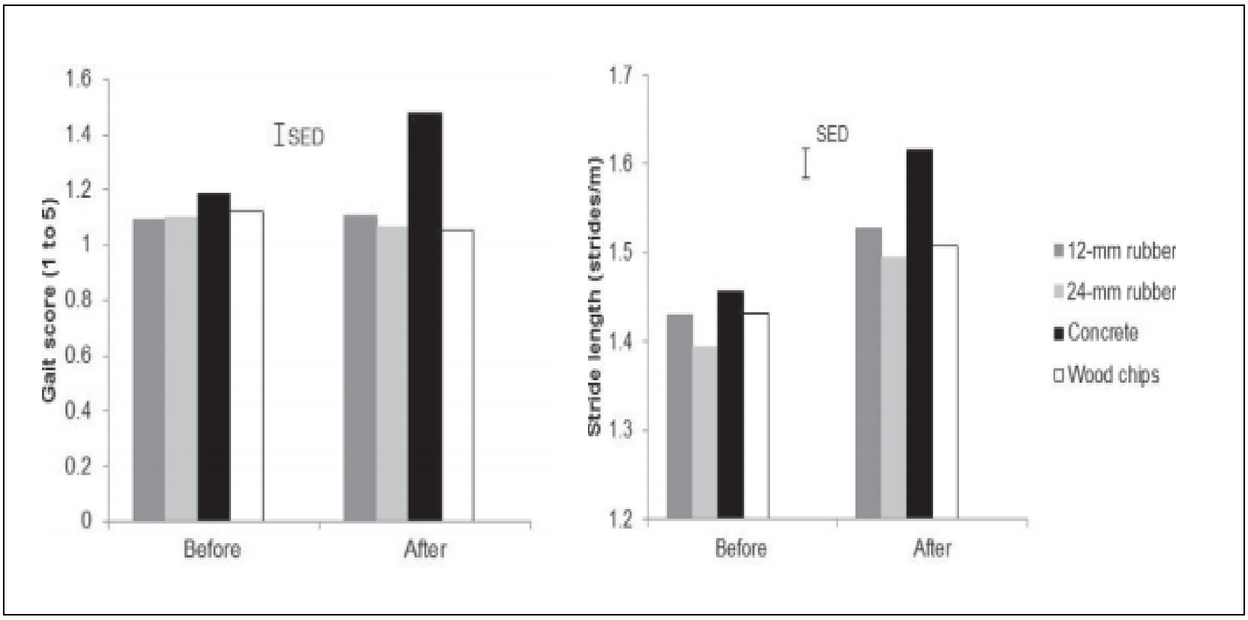

Figure 2.5 Gait score and stride length of dairy cattle before and after a repeated (4 times) 4 days stand off period on a 12mm mat, 24mm mat, concrete or wood chip surface (Schutz and Cox, 2014).

These findings are in agreement with the study of Fisher et al. (2003) who reported that concrete caused a reduction in gait length for cows after being on a stand-off area for four consecutive days. The mean gait length for cows on the concrete yard was less than that for cows on the raceway and small paddock, yet not significantly different than that on the woodchip (Table 2.4). Interestingly, average gait score of the cows on the wood chip and laneway was the same for before and after the stand-off periods.

Table 2.4 Mean gait lengths before and after 4 days stand off for cows on concrete, wood chip, laneway and paddock surfaces (Fisher et al., 2003).

	Mean gait lengths (m)	
	Before	After
Concrete	0.71	0.64
Wood chip	0.66	0.66
Laneway	0.68	0.68
Paddock	0.69	0.68

In conclusion, concrete is considered the worst surface material for susceptibility to lameness, and the longer the cows stayed on a concrete surface, the worse their gait lengths and scores were. A softer surface such as wood chip or pasture is much more desired for a cow's foot health and gait.

2.1.4 Cow Cleanliness

Maintaining cow hygiene and cleanliness may reduce the risk of lameness, skin parasites and infections and udder health problems (DairyNZ, 2016). High stocking densities and long lying times on stand-off pads may increase the risk of cows becoming dirty. For minimal cow dirtiness, bedding should be dry, changed frequently and used in abundance (Ruegg, 2006). Cleanliness is highly related to the type and quality of the surface material and can often be a result of lying behaviour. A cow will voluntarily lie down for longer periods if the surface material is comfortable (dry and soft). If cows have a lying surface that is dirty and wet, they will still lie down but for a shorter times and cow will get dirty. However, an uncomfortable hard surface (such as concrete) will discourage a cow from lying down, which can result in a cleaner cow (Schütz & Cox, 2014).

Stewart et al. (2002) reported mastitis was a major health problem on farms using wood chip pads, due to cows lying on soiled, wet conditions. Remarkably, Fisher et al. (2003) found that even though concrete was washed daily, cows that were standing on it were still dirtier than those on the wood chip surface yet in the experiment by Schütz and Cox (2014), there was no significant difference between the cleanliness of cows on the wood chip or the concrete and this was thought to be due to the very little amount of time cows spent lying on the concrete. Cows stood off on the rubber mats were three times dirtier than the cows on the wood chip, and there was no difference between mats 12mm thick and 24mm thick.

To take the comparison further, Donnison and Ross (2008) compared pine sawdust and bark at a laboratory scale to quantify the retention of bacteria under different amounts of rainfall. This was done by mixing cow dung with two different amounts of water (simulating high and low rainfall), applying to the sawdust or bark, and then counting the amount of bacteria that drained out of the bottom. This study found that sawdust had approximately half the amount of bacteria draining out of the bottom under both rainfall rates. The most notable difference being that more than 80% of the applied E.coli were not recovered from the drainage or the sawdust inferring that sawdust has 'self-cleaning' properties. As other studies have shown wood products are the best material to use for cow cleanliness. If there was a choice as to which product to use, sawdust would be a useful product to use on a stand-off pad to reduce E.coli levels and therefore a reduction in mastitis (Burvenich et al., 1994; Burvenich et al., 2003).

It is greatly important to maintain cow health and cleanliness with the most significant aspect being udder cleanliness and the risk of mastitis which will affect milk production and quality, especially close to calving. The best surface material for this purpose is not entirely clear, as studies have had contrasting findings, however it seems likely that wood products are the best for this purpose, whilst rubber mats and concrete are not recommended. Whichever surface is used, it is important for it to be clean and dry.

2.1.5 Stress factors

As a metric of stress in animals, cortisol is frequently used as it is a steroid hormone which is released in response to stress and low blood-glucose concentration. It is still under debate how cortisol levels can be interpreted as a measure of stress status in dairy cows (Bertoni et al., 2005; Sgorlon et al., 2015). Sapolsky (1992) found an increase in blood cortisol levels to be a common symptom of acute stress; however, Mendoza et al. (2000) states that in a case of chronic stress, blood cortisol is not always high. In a situation where a stand-off pad with a stressful environment is commonly used, it is similarly thought by van Borell (2001) and Smith and Dobson (2002) that animals might adapt to long periods of time under stress therefore resulting in a progressive reduction of blood cortisol. Accurate base levels of cortisol can be hard to establish because cortisol levels in blood can be affected by many factors including daytime, meal, worker operations and blood sampling operations however high base levels have been associated with lower welfare status (Bertoni et al., 2005).

Studies have found relationships between the cortisol levels and floor surface material, as well as the amount of time spent on the stand-off pad. Schütz and Cox (2014) found that cortisol levels decreased for all treatment groups (Table 2.5), emphasizing the points made by van Borell (2001) and Smith and Dobson (2002) regarding stress adaption.

Table 2.5 Percent decrease in cortisol levels of cows standing on concrete, wood chip, 12 and 24mm mats for four days stand-off (Schutz and Cox, 2014).

	Cortisol level decrease (%)
Concrete	27
Wood chip	34
12mm mat	22
24mm mat	45

Although all surfaces resulted in a decrease in cortisol levels, the 12mm rubber mat and the concrete had the smallest decrease. It is emphasised that less lying time probably leads to elevated cortisol, therefore as anticipated, the lying time results and the cortisol level results correlate for this study; concrete was shown to have low lying times and woodchip had high lying times. Results from Fisher et al. (2003) cannot be directly compared as faecal glucocorticoid concentrations are measured (rather than blood cortisol), however both measurements indicate the same response to stress (elevated cortisol relates to elevated stress) and the studies had similar conclusions regarding which surface material had the highest cortisol levels. Fisher et al. (2003) found that the concentrations did not differ for day 1 and 2, but at the end of the stand-off period (day 4) cows on the concrete yard had higher cortisol concentrations than those on the wood chip and in the small paddock (Table 2.6).

Table 2.6 Faecal glucocorticoid metabolite concentrations (ng/g) (means) of cows in response to 4 days of stand-off on a concrete yard, wood chip pad, farm laneway and small paddock (Fisher et al., 2003).

		Concrete yard	Wood chip	Farm laneway	Paddock
Faecal glucocorticoid metabolite (ng/g)	Day 1	8.3	8.2	8.2	8.3
	Day 2	8.2	7.6	8.1	7.6
	Day 4	7.4	6.3	6.9	6.0
	Decrease	11%	23%	16%	28%

Again, the concrete pad had a significantly smaller decrease than that of the wood chip, and also the small paddock.

In conclusion, there are many factors influencing cortisol level, and even if the cortisol level obtained is accurate, it may not be correctly representing the amount of stress the animal is under as cortisol levels may have adapted to stress (yet overall the animal could still be under stress). Thus, it may be just as useful and simpler to use other indicators of stress to make assessment. As lying time is a highly influential indicator of stress (Fisher et al., 2003; Schütz & Cox, 2014), it may be more appropriate and accurate to use lying time or health status (such as lameness or mastitis) to gauge how stressed the animal is.

2.1.6 Social Interaction

The natural behaviour of a single dairy cow will be modified when two cows are within each other's range of perception whether it be visually, by sense of smell, tactile or other. When two or more cows are living in close proximity to each other a pattern of group behaviour exists, and a hierarchy is established. It is important to understand group behaviour and how different environments influence this behaviour as it can be a determinant of individual animals' welfare. Cattle organise themselves into hierarchies according to their willingness and ability to fight scarce resources (Phillips & Rind,

2002) with dominance being associated with higher ranking individuals having supremacy in the distribution of resources (Hussein et al., 2016).

It was hypothesised by Schein and Fohrman (1955) that "the place of each individual in the herd order is determined by the moment of birth", advancing in social scale as older cows are removed from the group and that "the mechanism of order is established somewhere between the late young and early middle group ages". When they are kept in a small area such as intensive housing, the hierarchy is based on competition for space (Potter & Broom, 1987) which is different to a grazing situation, where adequate space is provided and access to the best food forms the hierarchy.

Factors influencing dominance (rank)

Age and Size

Older and larger cows display the most dominance (Phillips & Rind, 2002; Schein & Fohrman, 1955). Age is a good index of seniority (referring to the amount of time a cow has been in the herd) and the experience the animal has being involved in dominance encounters (Hussein et al., 2016). Cow weight is used as an index of strength, Since cows with a heavier weight are more dominant than those with a lighter weight, dominant cows may require more feed intake to satisfy their requirements for maintenance (Phillips & Rind, 2002; Schein & Fohrman, 1955). There is no relation of the cows' BCS and dominance which demonstrates that dominance is primarily related to size of the cow not their level of fat reserves (Rind & Phillips, 1999). The association between age and weight, and rank position are shown (Figure 2.5).

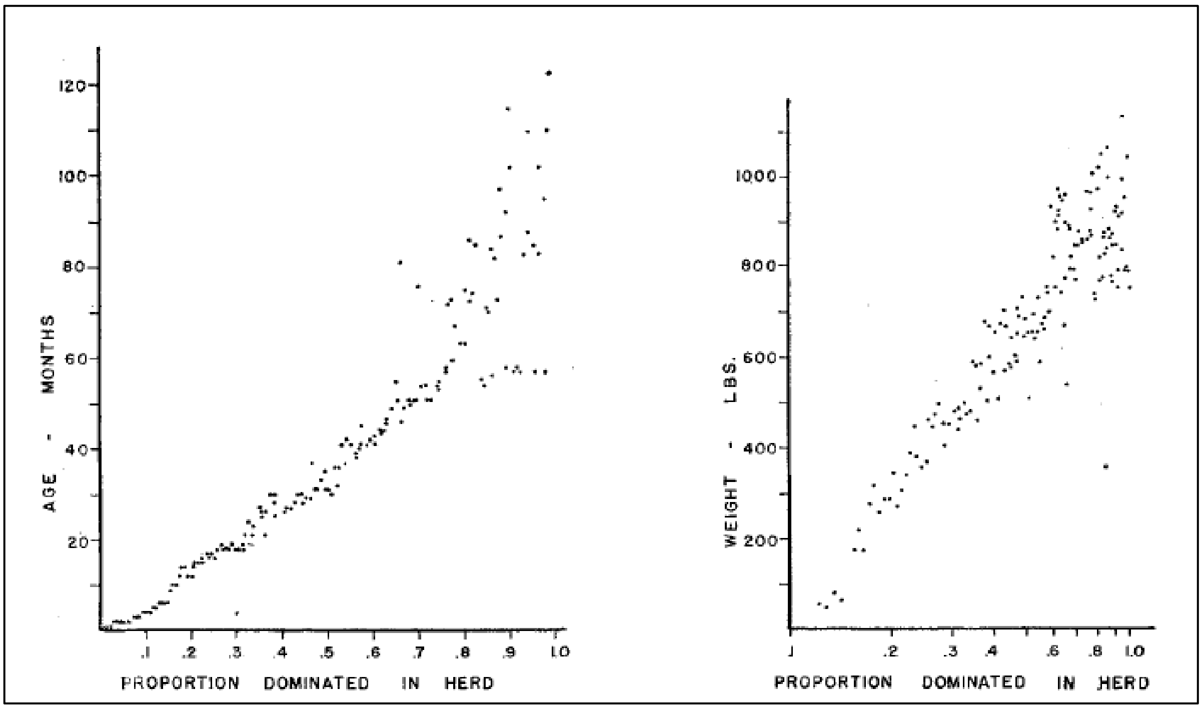

Figure 2.6 The relationship between rank order and age (months) and rank order and weight (lbs) in dairy cows (Schein and Fohrman, 1955).

Feeding Regime

The way in which cows are fed shows different behaviour. When cows are grazed as a group, it is common for rumination of non-grazing cows to be supressed if most other cows are still grazing. Under free group feeding conditions, the higher order animals will get more to eat (Schein & Fohrman, 1955). Ruminants use their dominance more when feeding is ad libitum because available food is diverse, giving choice to the animal (Barroso et al., 2000). The lower ranking cows spend a lot of their allocated grazing time searching for an opening where they can get food. Although not entirely ad libitum, this can be linked to intensive break feeding systems in New Zealand in winter such as fodder beet breaks or even a row of silage that has been fed out in the paddock.

The influence of space on social interaction

Space is a factor of large significance when determining social interaction and aggressive behaviour. Natural instinct encourages cows to stay together for protection, therefore there is an optimum inter-individual distance for grazing cows, determined by group size (Rind & Phillips, 1999). In a case of ad libitum feeding, forage is usually adequately available however space is normally restricted. This causes the subordinate cows to feed away from the from the dominant cows as providing supplement will cause an increase in aggression between the cattle (Clutton-Brock et al., 1976). Feeding allocation and space availability interact to cause an effect on aggression. Regarding aggression when feed is not a factor, such as in a stand-off pad environment, the main reason for aggression between cows is fighting for space (Potter & Broom, 1987). Dominant cows have greater opportunity to obtain basic resources such as space and food in comparison to subordinate cows. This is of significance in a system incorporating a stand-off pad as cows are in a confined area of space for many hours a day over long periods of time such as winter.

2.2 Conclusion

- The welfare of a dairy cow is greatly important when managing a herd, and needs to be carefully monitored especially when using a stand-off pad.

- Cows lying down behaviour, cleanliness, lameness and gait score are strongly influenced by stand-off pad surface material and time spent on stand-off pad.

- There are numerous options of surfaces to use for stand-off including concrete, wood chip, sawdust, rubber mats, raceways or paddocks.

- Concrete is the least desired surface in nearly all aspects of welfare reviewed and is not recommended to be used as a stand-off pad surface material.

- Although there was not one surface material that was unanimously determined the favourite when considering each aspect of animal welfare separately, the wood chip had the greatest results.

- More effort is still required in order to identify the low cost options of stand-off pad surface material that meet cow welfare requirements.

Chapter 3

Materials and Methods

3.1 Experimental Site and Design

The experiment was carried out at Ashley Dene Research and Development Station, (43°39’ S, 172°21’ E.) Canterbury, New Zealand between 18th July and 5th August 2016. All procedures were approved by Lincoln University Animal Ethics Committee. The experimental area consists of a combination of soil types, Lismore stony silt loam, Lowcliff stony silt loam and Ashley Dene deep fine sandy loam. Lismore stony silt loam has excessive drainage with water holding capacity (WHC) of 70-100 mm/m of soil. It is a very light soil as stones are found at a depth of 450-750mm. Lowcliff stony silt loam are imperfectly drained with WHC of 100-120 mm/m of soil and stone depth of 450-900mm. Ashley Dene deep fine sandy loam is moderately to well drained with WHC of 100-160 mm/m of soil. Stones are reached at a depth of over 900 mm (McLenaghan & Webb, 2012).

A total of 210 late gestation Friesian x Jersey crossbred dairy cows were blocked into 3 groups of 70 based on calving date (25/08/2016± 15.2 days; mean ± SE), live weight (462.7 ± 3.06kg), age (3.5 ± 0.1yrs) and body condition score (4.5± 0.04 BCS) and randomly assigned into one of three stand-off treatments: cows grazed fodder beet in situ for 7 hours (8 am to 3 pm) before being returned to stay on a standoff area (17 hours) with a surface of woodchip (WC); cows grazed fodder beet in situ for 7 hours (8 am to 3 pm) before being returned to stay on a standoff area (17 hours) with a surface of small stones (40-60 mm; S5o); cows grazed fodder beet in situ for 7 hours (8 am to 3 pm) before being returned to stay on a standoff area (17 hours) with a surface of big stones (60-80 mm; S70). All groups were offered 4 kg/cow/day of grass silage before being allocated to 8kg/cow/day of fodder beet. Cows had unlimited access to water while on the paddock or stand-off area.

The experimental site was composed of 8ha of fodder beet grazing area and 0.56ha of stand-off area (Appendix A.1). The stand-off area was subdivided into five partitions of 0.112ha separated by dual wire electric fence; however, in the current study, three partitions, one each treatment, were used at an area of 0.336ha (Lane 2, 3 and 5) (Appendix A.2). The stand-off pads were lined with high density polyethylene (HDPE) liner with BIDIM® nonwoven needle-punched continuous filament polyester geotextile A24 filter fabric over and under the HDPE liner. This was covered with sub bedding base material consisting of 5cm of compacted angular graded gravel 40mm in diameter (AP40) and approved drainage aggregate was used for the top layer of the sub bedding. The bedding (surface) material (WC, S50 and S70) was put down at a depth of 40cm. At the lowest point of the sub bedding material, two 110mm NEXUSFLO™ subsoil polyethylene punched pipes were installed for drainage purposes (Appendix A.2).

3.2 Management

Cows were transitioned onto the fodder beet crop from 7 June 2016 over 14 days, increasing the crop offered by 0.5 to 2 kg DM per cow per day and adjusting pasture and supplement allowances to meet daily energy requirements. Cows were intended to transition onto the stand-off areas shortly after transition onto their crop diets in June. However, delay in construction of the stand-off area resulted in a late commencement date for the experiment on 18 July 2016.

Cows were offered an area of 10m^2/cow while on the stand-off pads, exceeding the space recommendation of 5.0m^2/cow by DairyNZ (2014) for medium- long term use of a stand-off pad to ensure space was not a limitation. This area was adjusted daily as number of cows per group declined due to calving. Treatments were assigned randomly to graze fodder beet on three separate paddocks with an area of 3.0ha, 2.0ha and 3.0ha for the WC, S50 and S70 respectively. Fodder beet allowance and the yield of fodder beet per unit of area determined the area allocated per cow to graze daily. However, the daily breaks were not back fenced so the area of paddock per cow increased each day

Initially there was no transition onto the stand-off areas, cows were removed from the paddock onto the stand-off at 3:00pm and remained on the stand-off until 8:00am the following day (n = 17 hours). Three days after commencement of the experiment, a transition period onto the stand-off areas was necessary as feed intake difficulties arose. Previously, cows had been used to being on the paddock for 24 hours of the day, meaning they had all day to eat the allocated feed. For the first two days of the experiment, the cows did not consume all of the fodder beet offered to them in the limited grazing hours provided. This then lead to them compensating the next day by gorging on the fodder beet allocated as well as what was left from the previous two breaks. As a result moderate acidosis occurred and cows were then transitioned onto the stand-off pads by altering the feed allocation to 5kg grass silage and 7kg Fodderbeet as well as altering the hours on the paddock from 8:00am to 5:30pm. Feed and grazing time allocation was adjusted over 4 days to reach the original allocations.

3.3 Measurements

3.3.1 Animal

Hunger/feeding

Fodder beet Intake

Yield cuts were taken two times per paddock over the duration of the experiment. At each paddock, the area of fodder beet needed for the next week was visually estimated, and from this area three cuts were taken from near the sides and middle of the break to represent the whole area. Each cut consisted of sampling two rows × 2 m length of fodder beet. All fodder beet in this area were extracted from the ground and had the bulb and leaf separated. The leaf and bulb fresh weight were then weighed separately. Near the cut site, a single plant was taken as a subsample to the laboratory to use to calculate leaf, bulb and total dry weight (DW), dry matter percentage (DM) and nutritive value. Fodder beet was washed and then three sections from both ends and the middle of the bulb were taken to act as a representative of the bulb. They were cut into pieces, thoroughly mixed and then a subsample was processed into pieces less than 5mm in diameter using a food processor. This was weighed and then freeze dried (Model E.D.5.3, Cuddon Ltd, NZ,) for 48 hours to determine DM content. The dried samples were then ground to 1mm (ZM200, Retsch GmbH, Haan, Germany) and stored for chemical composition analysis. Chemical composition was determined using near-infrared spectroscopy (NIRS) using a FOSS NIRSystems 5000, (Foss Ltd, Maryland, USA) spectrophotometer. Metabolisable energy (ME) was calculated as MJME/kg DM = 0.16 x DOMD (CSIRO, 2007).

Fodder beet Utilisation

Utilisation was determined using pre and post grazing cuts. Pre grazing information was used to determine the amount of fodder beet available pre grazing. Post grazing, two 2m long rows were randomly chosen to be sampled. The same process was undergone as described in the section above. The difference between the pre grazing and post grazing weight represented DM intake what was left over, and therefore the percent of fodder beet utilised. Utilisation percent was calculated as pre mass –post mass/pre mass x 100.

Grass silage (supplement) intake and utilisation

Grass silage was fed out in a long row by a wagon. Immediately following the silage being fed out and 0- 30 minutes before the cows were allowed the silage, quadrat samples were taken. Six 1m^2 quadrat measurements were randomly taken along the row of silage. The amount of silage within each quadrat was weighed and then returned to the ground. Each sample area was marked so that the same process could be repeated once the cows had returned to the stand-off pads and had finished eating. The difference in weight was used to calculate the supplement utilisation. A large handful of silage was taken at each time of sampling to determine DW, DM and chemical composition. For DW, the silage sample was cleaned and weighed. It was then dried in the oven for 24-48 hours and reweighed for DW and DM determination. The sample was then ground into particles less than 1mm and was scanned to determine NIRS.

AfiAct Pedometer Validation

AfiAct (Waikato Milking Systems) pedometers were fitted to each cow immediately above the rear fetlock joint. For validation, 20-25 cows were randomly selected and observed for lying down and standing, at 5 minute intervals, for a minimum of 2 consecutive hours per day. This happened over 5 days during one week before the start of the experiment. The visual observations recorded were plotted against data recorded by the AfiAct pedometers, resulting in a correlation coefficient of r^2=0.96. This strong correlation between the visual observations and AfiAct recorded data is in agreement with the strong correlation (r^2=>0.99) observed by Borchers et al. (2016), suggesting AfiAct pedometers as a reliable technology to measure lying down activity of cows.

Behaviour

AfiAct pedometers were used to record total lying hours per cow. Data was retrieved daily.

Social interaction and aggression was observed twice daily, twice per week between 8:30am and 10:30am in the paddock (whilst the cows were grazing) and between 3:30pm and 5:30pm on the stand-off pad. Methods developed by Schein and Fohrman (1955) and Phillips and Rind (2002) were used. An interaction was defined as any type of behaviour that involved two or more cows. Interactions were categorised into one of four categories; bunting, pushing, mounting and allo-grooming. The cow that performed the interaction was awarded a 'win' and scored accordingly, and receiving cow awarded a 'loss' and scored accordingly (Table 3.1). A chart developed by Schein and Fohrman (1955) was used to calculate the amount of points a cow accumulated and how many interactions she was involved in and points awarded was taken from Phillips and Rind (2002) (Table 3.1). From this information, cows were given a number of average interactions and a Dominance Value (DV).

Table 3.1 Description of types and scores of cow interactions (Phillips and Rind, 2002).

Interaction	Identification	Points awarded
Bunting	A cow using her head to bunt other cows away from her or the food she was eating.	4
Pushing	A cow using her body to push another cow or to push in between cows.	3
Mounting	A cow mounts another cow from behind.	2
Allo-grooming	A cow licking, scratching or resting their head on another cow.	1

Lameness

Lameness was determined by visually observing 20 randomly selected cows per treatment group as they were actively walking in the paddock (usually to and from the water trough) or when on the race walking to the paddock in the morning. This was repeated twice weekly using the scoring system developed by DairyNZ (http://www.dairynz.co.nz/animal/cow-health/lameness/lameness-scoring/). In this scoring system cows were scaled from 0 (no lameness) to 3 (very lame).

3.3.2 Surface Effects

Cleanliness score

Cleanliness score was determined by visually observing 20 cows randomly selected per treatment group whilst in the paddock. This occurred twice weekly using the scoring system by DairyNZ (Appendix B) which rates cows on a scale of 0, 1 or 2 (0 being very clean and 2 being very dirty).

Pad temperature.

Temperature of each stand-off surface was measured remotely using laser-spot infrared light. Measurements were taken daily between 8-10 am using a FLIR MR77 moisture meter.

3.4 Statistical Analysis

All analyses were conducted using GenStat 16. The lying down, cleanliness and lameness measurements were analysed using one-way ANOVA with stand-off surface as treatment and observation day as replicate. The DV data of each cow were averaged across the observation days and analysed using two-way ANOVA with stand-off surface and location as treatments with cow as replicate. Results were declared significant at $P < 0.05$.Due to there being only one sampling day for each paddock for feed nutritive value and intake and utilisation no statistical analysis could be performed on this data.

Chapter 4

Results

4.1 Climatic Conditions

Daily rainfall and air temperatures for the study period are shown in Figure 4.1. Precipitation in both June and July (17.8mm and 13.8) was well below the 31 year monthly total precipitation averages, (57.2mm and 57.8mm respectively) (NIWA, 2007). The low rainfall resulted in soil which was relatively dry, compared to typical conditions, before the experiment as well as for the duration of the experiment. Mean air temperature during June and July was 6.9°C and 5.3°C; very similar to the 31 year average temperatures of 6.7°C and 6.1°C.

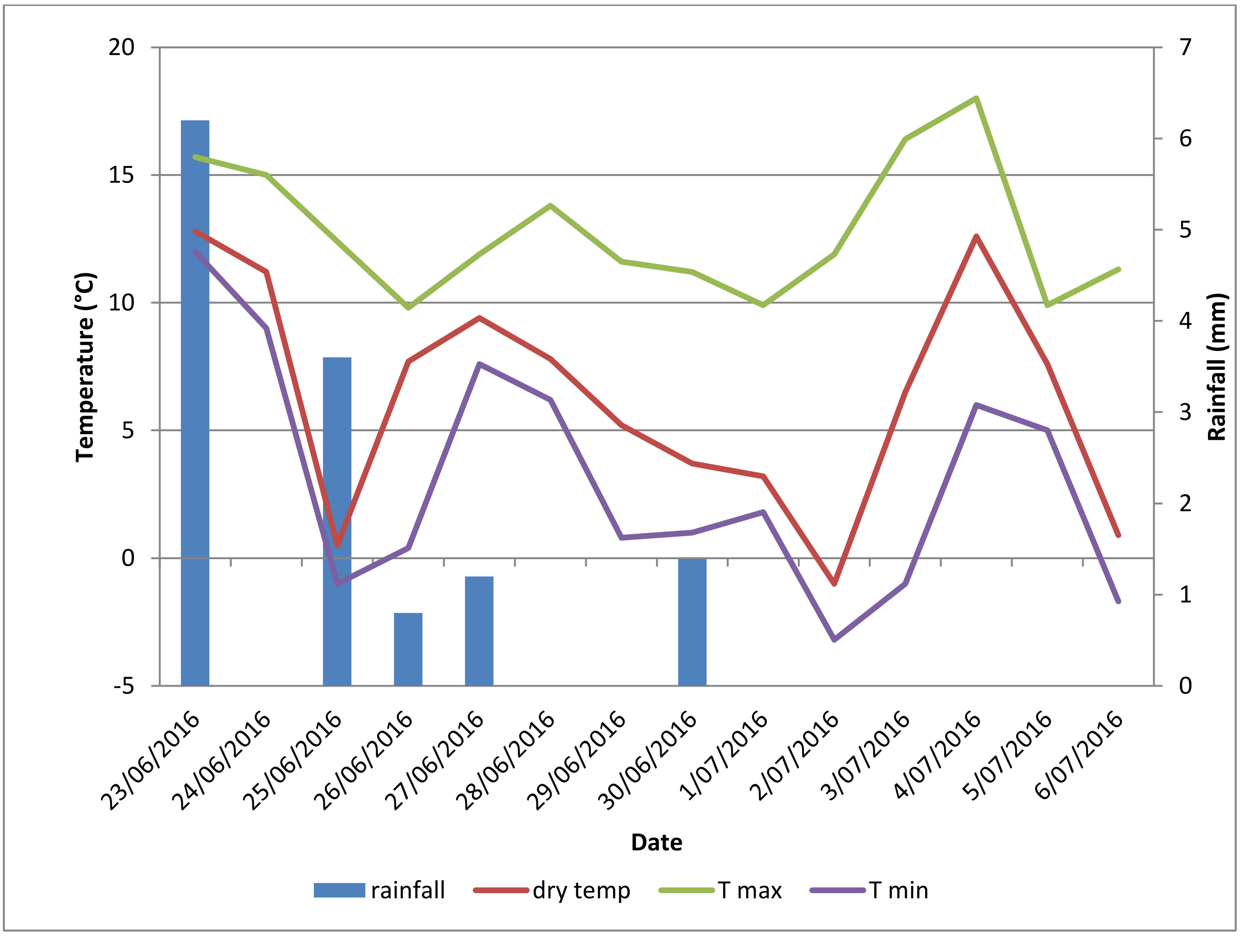

Figure 4.1 Total daily rainfall, max temperature, minimum temperature and dry temperature from 23/6/16 to 6/7/16 taken from NIWA weather station at Broadfields, Lincoln (11.2km from Ashley Dene).

4.2 Surface material description

Surface temperatures of the stand-off materials are presented in Figure 4.2. Variation in temperature of surface materials was related to the air temperature. The mean temperature for WC, S50 and S70 were 1.67± 0.9, 0.67± 1.1 and 0.67± 0.8 °C respectively. There was no surface material that had more extreme temperature changes than any of the others.

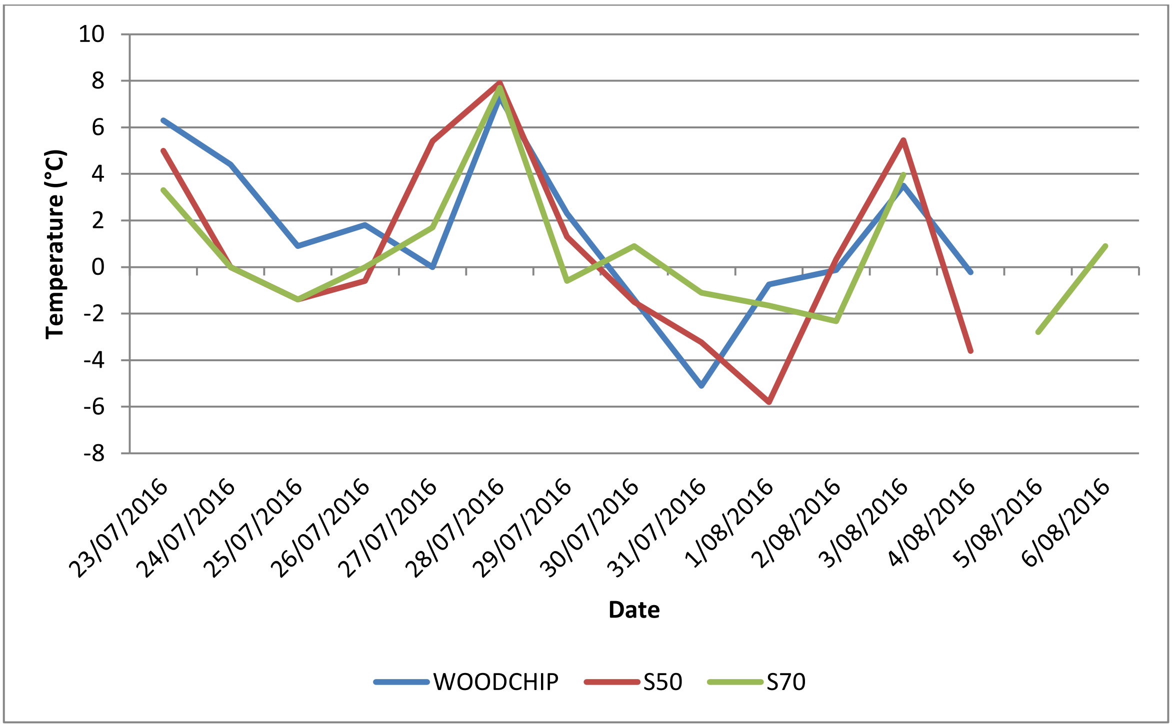

Figure 4.2 Average daily surface material temperature of area of stand-off pad where cows were between 8:30am and 10:30am each day of wood chip, S50 and S70 for the duration the cows were on the stand-off pads from 23/07/2016 to 6/08/2016.

4.3 Nutritive value and utilisation

Nutritive composition of crop and supplement are presented in Table 4.1. When components of the diet were combined, total crude protein and metabolisable energy over the available diet were and 13.11% and 11.76 MJ ME/kgDM respectively.

Table 4.1 Nutritive value of fodder beet (leaf and bulb) and supplement (barely and lucerne silage) made available to the cows.

	Fodder beet		**Supplement**	
	Bulb	**Leaf**	**Barley**	**Lucerne**
% of diet	40.6	26.0	23.7	9.6
Dry matter (% FW)	9.7	14.1	50.2	50.2
Organic matter (% DM)	98.5	86.6	89.5	90.5
Neutral detergent fibre (%DM)	14.2	30.6	47.3	53.7
Acid detergent fibre (%DM)	11.7	13.7	23.9	40.7
Crude protein (% DM)	8.57	20.35	13.14	12.92
Water soluble carbohydrates (% DM)	79.3	27.78	11.22	7.44
DOMD[1]	96.63	53.49	64.09	47.59
Metabolisable energy (MJ/kg DM)	12.74	12.43	10.85	8.25

[1] DOMD is the digestible organic matter in the dry matter (% of DM)

Herbage mass, utilisation and intake of crop and supplement are presented in Table 4.2. Utilisation of both the fodder beet and supplement was over 90% for all treatments. Fodder beet intake differed by a maximum of 400g per cow over the three treatments and 570g per cow over the three treatments for the supplement.

Table 4.2 Utilisation and intake of fodder beet offered over three different treatments (WC, S50 and S70) on 2/08/2016 and supplement on 28/07/2016 (S50 and S70) and 29/07/2016 (WC).

	Treatment		
	WC	**S50**	**S70**
Pre mass (t DM/ha)	17.8	12.4	22.6
Post mass (t DM/ha)	1.47	0.18	0.28
Utilisation of fodder beet (%)	92	99	99
Utilisation of supplement (%)	93	94	97
Intake of fodder beet (kg DM/cow)	6.40	6.80	6.75
Intake of supplement (kg DM/cow)	3.76	4.33	4.22

4.4 Animal behaviour

4.4.1 Lameness and cleanliness

Table 4.3 shows there was no difference (P=0.756) of lameness between the treatments with a mean of 0.043 ± 0.0481.

There was no difference between the treatments in cleanliness of cows (P=0.268) with a mean of 0.97 ± 0.0901.

Table 4.3 Lameness and cleanliness scores for cows standing on WC, S50 and S70.

	WC	S50	S70	P value	SEM
Lameness score	0.067	0.048	0.015	0.756	0.0481
Cleanliness score	0.833	1.033	1.036	0.268	0.0901

4.4.2 Lying

The average lying hours for each treatment is presented in Table 4.4. The percentage of cows lying for more or fewer than 8 hours is presented in Table 4.4 and Figure 4.3. There was no effect of surface material on lying time. The percentage of cows lying for less than 5 hours was 2.01 ± 1.69% (P=0.299). The percentage of cows lying between 5 and 8 hours was 12.1 ± 6.84% (P=0.57). The percentage of cows lying more than 8 hours was 85.9 ± 7.33% (P=0.447).

Table 4.4 Average lying hours per day and % of cows lying for < 5 hours, >5 but <8 hours and >8 hours.

	WC	S50	S70	P value	SEM
Average lying hours	10.3	9.6	9.8	0.368	1.10
% cows lying < 5 hours	0	2.24	3.78	0.299	1.69
% cows lying > 5 but < 8 hours	6.0	15.2	15.0	0.568	6.84
% cows lying > 8 hours	93.6	82.6	81.5	0.447	7.33

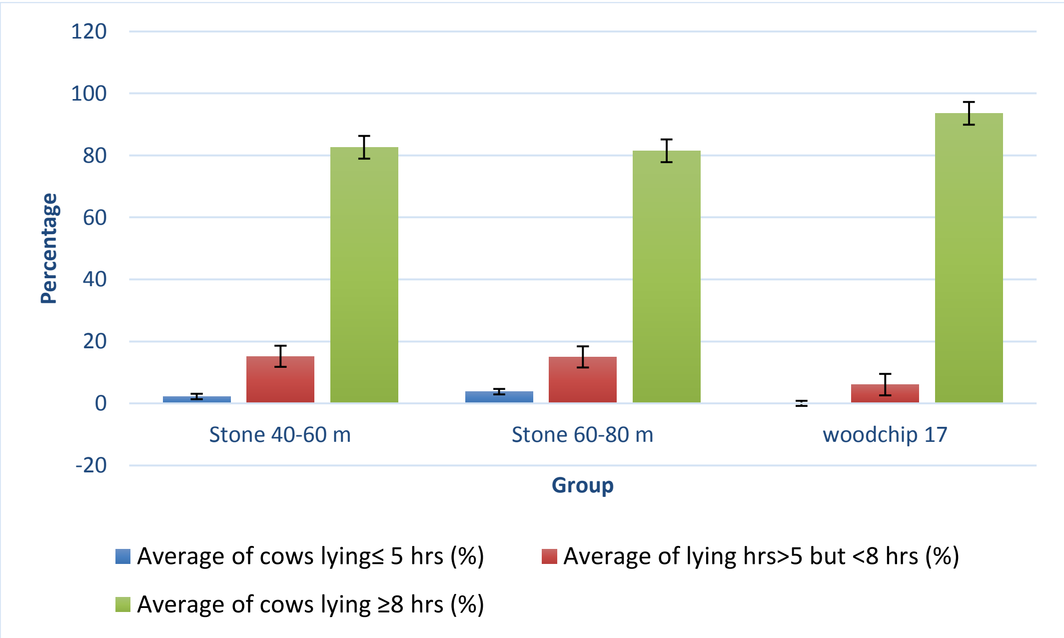

Figure 4.3 Percentage of cows per treatment lying for <5 hours, >5 but <8 hours and >8 hours.

4.4.3 Social Interaction

There was a large proportion of the allo-grooming (licking and scratching) interactions due to lice infestation on the neck and shoulders of cows. The number of interactions and DV are presented in Table 4.5. There was no difference in DV between material types (P=0.45). However, there was an effect of location where expression of dominance (DV) was greater on the stand-off compared with the paddock locations (P=0.050). There was no interaction between material and location (P=0.249).

Table 4.5 Average number of interactions and dominance values (DV) whilst on the paddock and whilst standing on the stand-off pad for cows wintered on either WC, S50 or S70.

	Interactions/cow	Average DV
Paddock		
Wood chip	4.47	39.0
S50	3.46	43.6
S70	6.03	38.3
Stand off		
Wood chip	2.72	41.9
S50	1.87	44.9
S70	1.62	50.5
SEM	-	3.68
P value		
Material	0.55	0.45
Location	0.00	0.05
M x L	0.01	0.25

P values for transformed data, actual means presented.

Total number of interactions per cow were the same across stand-off pad treatments (3.39 ± 0.32 interactions/cow. P=0.55). There was an interactions between location and stand-off treatment (P=<0.001) which showed that there were generally fewer interactions on the stand-off pad than the paddock. However for cows on S70 the increase in the number of interactions was more pronounced than on the other stand-off treatments (Figure 4.4).

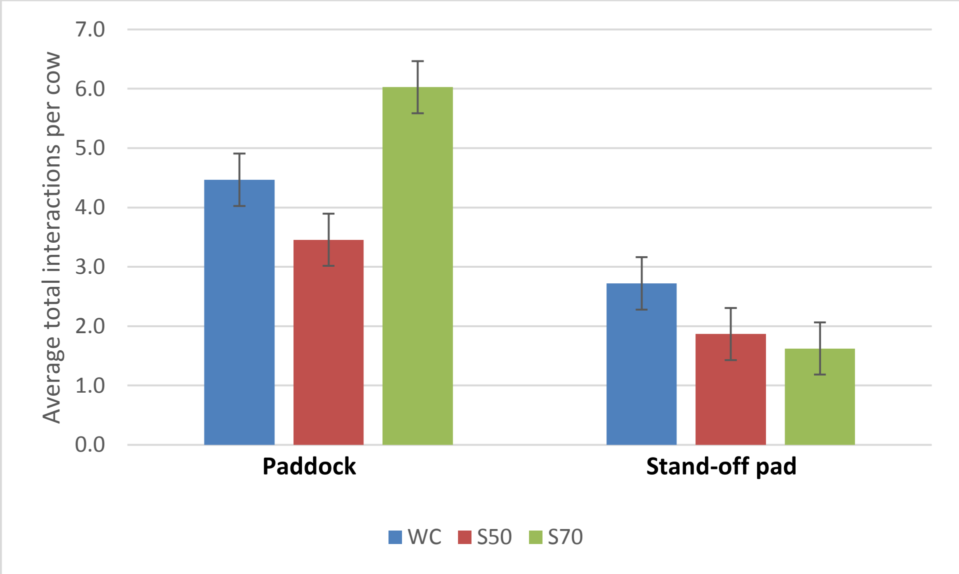

Figure 4.4 **Average total interactions per cow grazing in the morning on the paddock 8:30am to 10:30am and in the afternoon whilst standing on the pad 3:30pm to 5:30pm.**

4.5 General Observations

During the measurement period general observations of cow behaviour were noted which did not have an obvious metric to quantify what was visually apparent. Cows on the S50 and S70 treatments were very hesitant to enter the stand-off pad, once on the pad they moved very little (such as standing in the corner for hours before spreading out). It looked as if the cows on the stones had uncomfortable footing and pressure was unevenly distributed over the hoof (Figure 4.5).

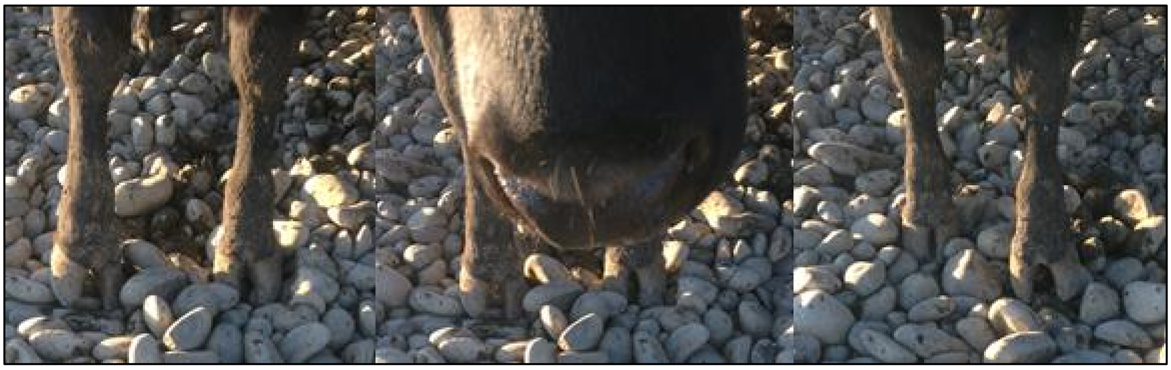

Figure 4.5 **Hoof placement on stones showing possible uneven pressure distribution and hoof angle.**

Chapter 5

Discussion

There is little information on the impact of stand-off surface materials on cow welfare. From an economic point of view, choice of surface material has large implications for farmers. However, compliance with welfare regulations is the first priority. Therefore the purpose of the current study was to compare the effects of different stand-off pad surface materials on dairy cow welfare whilst under a duration controlled grazing system.

5.1 Nutritional requirements

The nutritional value of the diet consumed by the cows under duration controlled grazing met pregnant cow nutritional requirements of 94 MJ ME per day (8.6kgDM per day) outlined by Rattray et al. (2007), as the cows were offered a total of 8kgDM fodder beet and 4kgDM supplement per day comprising 13.11% CP and 11.76 MJ ME/kgDM (Table 4.1). Utilisation of the fodder beet for the WC, S50 and S70 was high (>85%) at 92, 99 and 99% respectively (Table 4.2). Little comparable data are available on DM utilisation of fodder beet. When comparing to Edwards et al. (2014) which measured the DM utilisation of fodder beet, the current study found similar utilisation percentages to their 99.6%. As the nutritive data could not be statistically analysed, it is difficult to say whether the 7% utilisation difference between the WC and S(50 and 70) was significant or not, but Edwards et al. (2014) reported an 8.36% difference in utilisation as significantly different. High levels of DM utilisation were also apparent in the current study for the combined barley and lucerne supplement offered of 93, 94 and 97% for WC, S50 and S70 respectively. This is higher than utilisation levels estimated by Edwards et al. (2014) of 51, 65 and 86% for barley straw, oat silage and grass baleage respectively.

High utilisation levels may have been found in the current study due to the weather being dryer than average over winter (Figure 4.1) meaning the ground was also dry. It could also be due to the use of the stand-off pad, where cows may have felt deprived of feed over the 17 hours they were on the stand-off pad and therefore gorged when they were let to graze. There are few studies that have focused on duration controlled grazing of fodder beet with dry cows in winter. However, Jenkinson et al. (2014) reported that when grazing fodder beet and kale, utilisation in the first 6 hours of grazing was on average 83%, and was >90% for fodder beet. Therefore 7 hours of grazing time allocated for the current study should have been adequate for consumption of available feed.

Although nutritional requirements were met, the time frame of the current study limits the implications of the results for BCS gain. While we can assume that adequate BCS and live weight would have been maintained as a result of the diet consumed, the experiment only went for 10 days and therefore there was not enough time to show differences in BCS or live weight gain. Similar limitations were reported by Fisher et al. (2003); Schütz and Cox (2014) and Webster et al. (2007) which all acknowledged that their results regarding live weight gain and BCS were not reliable due to the short duration of the study and the small differences (a mere few kilograms) in weight.

5.2 Animal behaviour

5.2.1 Lying Time

There was no effect of surface material on lying time. The average lying time was 9.9 hours per day (Table 4.4) which exceeds the recommended 8 hours (DairyNZ, 2014a; New Zealand Government, 2014). This finding is similar to that of Fisher et al. (2003) and Schütz and Cox (2014) which found that cows in NZ dairy farming systems lie for approximately 10 hours per day. On average, 2% of cows lay down for less than 5 hours, 12% lay down for 5-8 hours and 86% lay down for more than 8 hours (Figure 4.3). As stated by Ruegg (2006) harder, colder surfaces can discourage lying, therefore it was expected that cows would lie for less on the stones than on the woodchip. Although S50 and S70 had very hard surfaces, they were not dramatically colder than the WC, as all three surface materials temperatures were directly related to air temperature (Figure 4.1, 4.2). Average lying hours of 9.6 and 9.8 on S50 and S70 respectively reported by the current trial is an exceptional result compared to Schutz and Cox (2014) which found on average cows lied for only 4.4 hours/day when stood off on concrete (which has many similar properties to stones) for 18 hours per day. Similarly, Fisher et al. (2003) found a 40% reduction in lying when they were on concrete rather than woodchip. Although there is little data available on the effects of stones as a surface material, our results contrast that of Fisher et al. (2003) and Schutz and Cox (2014) which found differences in lying times between hard (eg concrete)and soft (eg woodchip) surfaces where as we did not.

A possible reason for 14% of cows lying for less than 8 hours could be due to the reliability of the AfiAct pedometers. Not all cows had 24 hours of data recorded per day. Due to this, cows with a minimum of 20 hours data were used to minimise incomplete data sets yet 4 hours of unknown activity could have up to 4 hours of unrecorded lying time. If this study was carried out again, identifying what times in the day cows allocated their lying to would be of interest (and therefore did any cows compensate for lying deprivation on the pad in the allocated grazing time). It would also be beneficial to better understand the behaviour of the cows that lied for less than 5 hours, for example, were these cows subordinate cows that were deprived of lying time by disruption by dominant cows as discussed by Galindo and Broom (2000).

5.2.2 Lameness

No difference in lameness resulted over the trial. Again, the lack of effect of surface type could be attributed to the length of the trial. Use of the stand-off pad for 10 days did not show effects of lameness, however if the trial had gone on longer it would have been interesting to see if any lameness developed. It was noted cows on stoned appeared to have pressure unevenly distributed over the hoof, with the claws of the hoof being widely spread and hoof placement was on an angle (Figure 4.5). Cook (2003) reported a greater incidence of lameness in cows housed on hard floors and a greater incidence of claw lesions. Although Cook (2003) was comparing flat concrete to concrete slatted floor, it found that specific points of high stress at the point of contact on the edge of slats and the end of the standing area. This is similar to the edges of the stones. Prolonged periods of time with the hoof walking on these uneven and hard conditions may have led to laminitis and claw lesions causing severe lameness and inadequate welfare status (Hinterhofer et al., 2006). However, this is speculation and cannot be proven by the current study.

5.2.3 Cleanliness

There was no difference in cleanliness over the three treatments. Ruegg (2006) explains that for minimum cow dirtiness bedding should be dry, changed frequently and used in abundance. Due to the winters below average rainfall, the bedding was kept dry. The short 10 day duration of the trial could also mean that there was not enough time for moisture to build up from urine and rainfall. The construction of the pads with the use of gravel and sand under the surface material reduces water absorption and meant that they were well drained so any potential excess moisture would have rapidly drained. A thick surface material depth of 40cm meant there was abundant material to be turned over, particularly for the WC. Harder surfaces have often been found to discourage lying (Fisher et al., 2003; Reugg, 2006; Schutz and Cox, 2014) and therefore result in cleaner cows however there was no difference in lying times over the treatments so in the current study there was no relationship between lying time, surface material and cleanliness. A difference may have been present if the trial was repeated under wet and prolonged weather conditions.

5.2.4 Social Interaction

No other studies have investigated the effect stand-off pads have on cow social interaction and hierarchy, however some research has been done on the effects of social interaction and grazing (Hussein et al., 2016; Phillips & Rind, 2002; Schein & Fohrman, 1955). DV was significantly higher when cows were on the stand-off pad than when on the paddock grazing (Figure 4.4). This is unexpected as a higher number of interactions as well as more aggressive behaviour was observed on the paddock when grazing (such as bunting and pushing compared to allo-grooming). The results may not accurately reflect common behaviour of cows when standing off because of the lice infestation. This caused excess levels of allo-grooming whilst standing on the pad, that although was still recorded as an ‘interaction’, it may not have been an attempt to assert dominance at all, instead likely to purely be an action to relieve itchiness. Interaction observations only occurred for 2 hours per location, for 2 days per mob so a longer observation period as well as more days may have resulted in more accurate data as Hussein et al. (2014) recorded animals for 5 hours per day for 12 weeks. Time constraints and the lice infestation are key limitations to the social interaction data.

In the paddock, there was a significant difference in DV between all treatments. S70 had the highest average DV, and WC the least. It is unknown as to why this could be. Possibly their hesitation to move around whilst on the stone pads meant they did not undergo aggressive behaviour (minimal interactions per cow as shown in Table 4.5) to establish a hierarchy so therefore they had to compensate for it in the paddock.

Dairy NZ (2014) recommends for medium- long term use of a stand-off pad (more than 3 consecutive days, more than 12 hours per day) that 5.0m^2 of space per cow should be allowed. The construction of the stand-off pads in the current study allowed 10m^2 per cow therefore space was not a scare resource. As there was no food available on the pad, there was limited need for competition of resources and therefore the uncertainty of the higher DV value when standing off.

5.3 Practical Implications

The prime reason for the use of stand-off pads is to protect pasture from damage in autumn and winter and to reduce nitrate leaching. Although the objectives of the current study focussed on cow welfare, there are some practical implications regarding the results of the experiment.

- Both stone sizes gave an acceptable animal welfare standard. This means stones may be a viable choice of surface material for farmers.

- Because the cows were off the paddock for two thirds of the day, it means the stand-off pad captured two thirds of the urine, and therefore achieved its purpose of nitrate leaching reduction (likely to be around 60%). A feasible option for farmers who have limited capital to invest in a stand-off pad large enough for all of their cows would be to rotationally stand-off their cows, which would dramatically reduce nitrate leaching.

- Future work comparing the costs of different surface materials over time would be beneficial to farmers.

5.4 Conclusion

Based on the results of this short term study key welfare aspects including feed intake, lying time, lameness and cleanliness were similar over all three surfaces. All surfaces reached minimum welfare requirements under a duration controlled grazing system in winter in Canterbury.

Appendix A

Experimental Site

A.1 Map

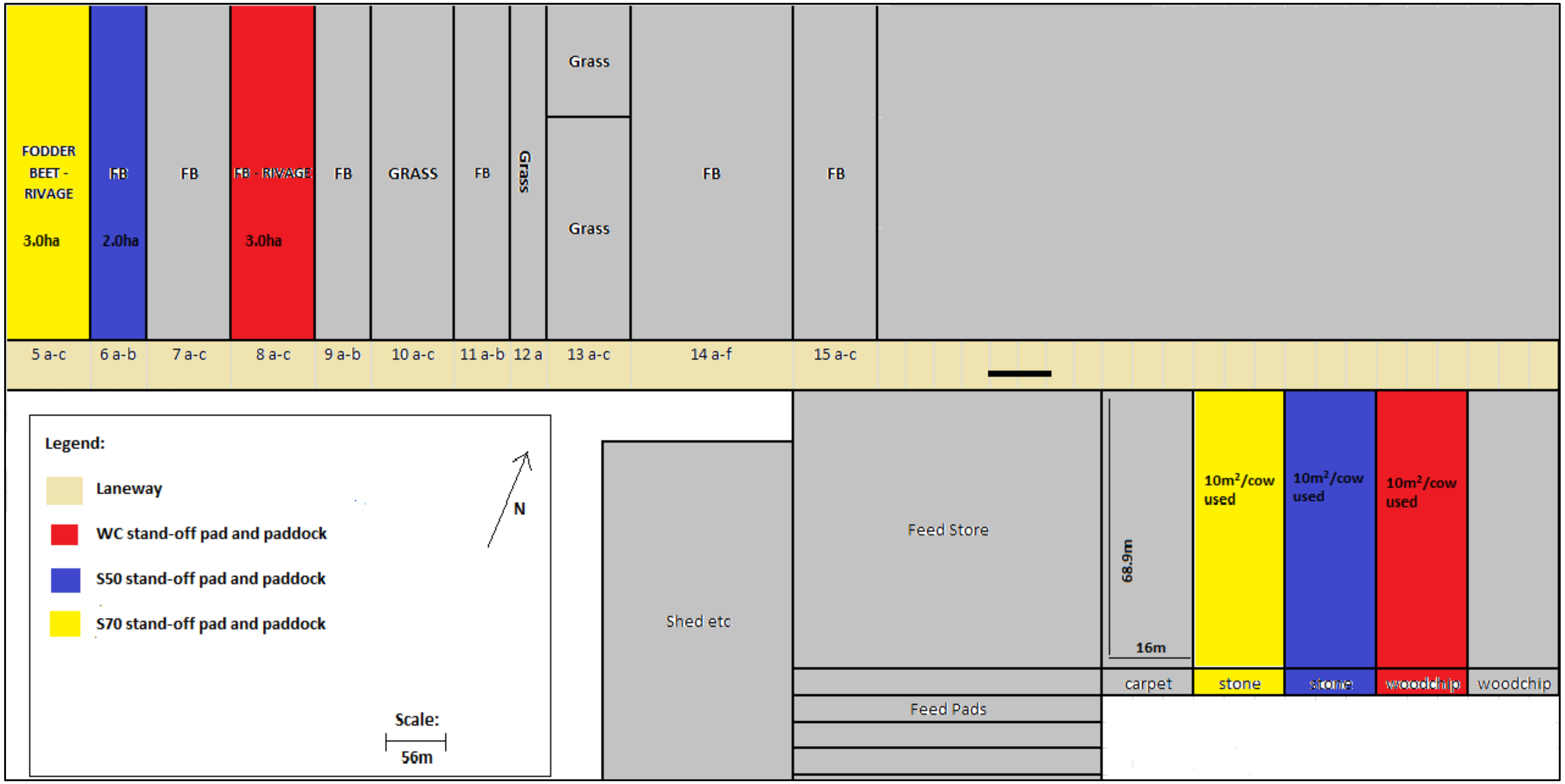

Figure A.1 Map of the experimental site at Ashley Dene Research Development Station.

A.2 Stand-off pad specs

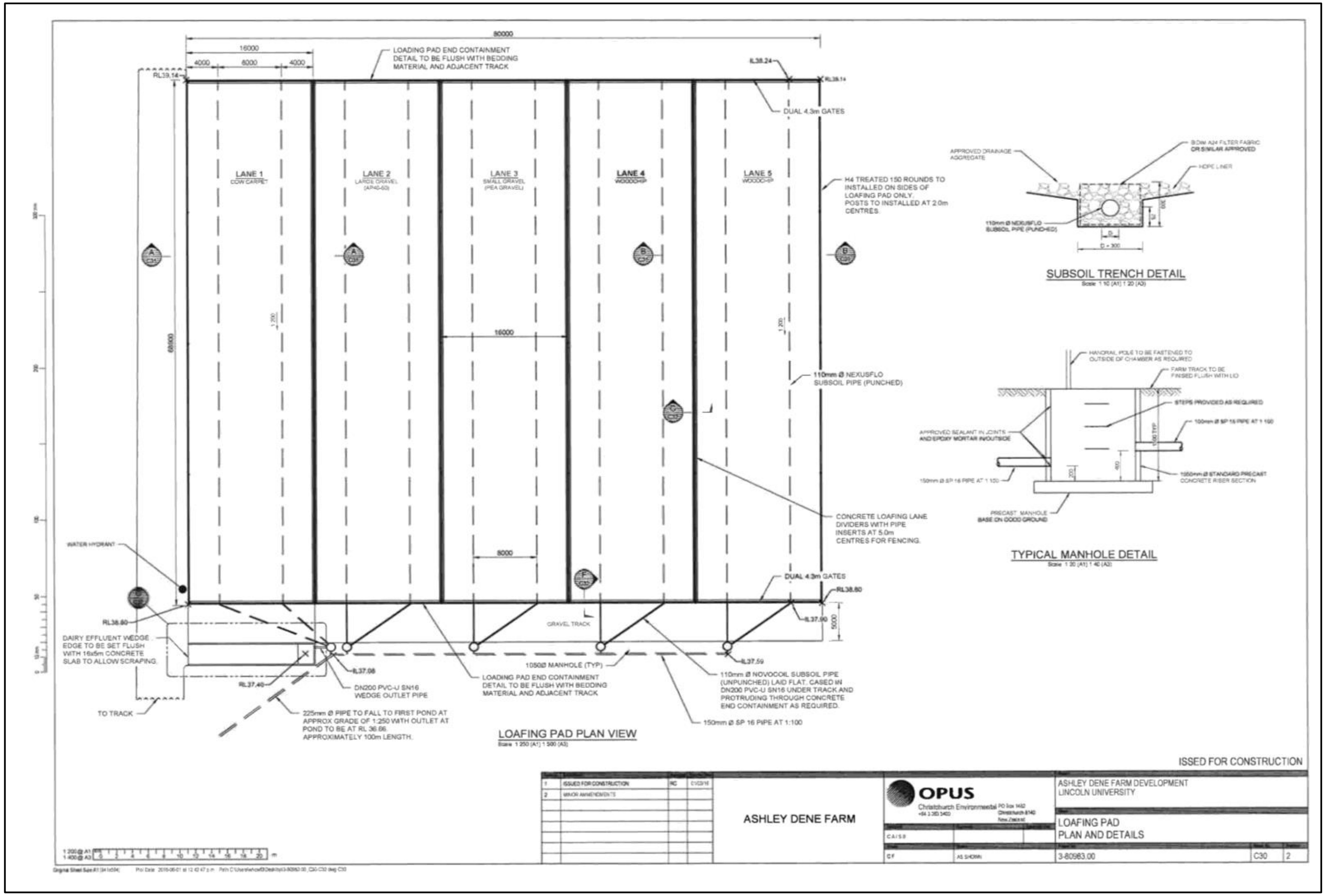

Figure A.2.1 Birds eye view of the stand-off pad site with construction detail.

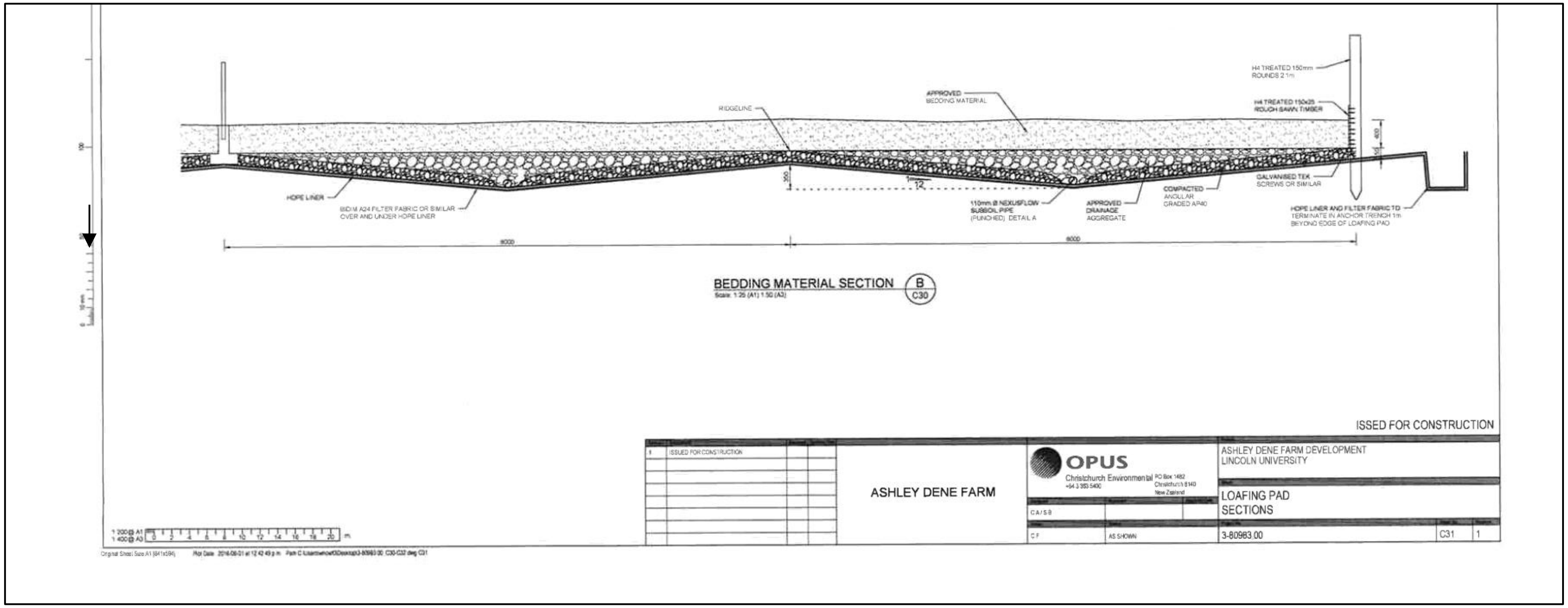

Figure A.2.2 Cross section view of stand-off pad with construction detail.

Appendix B

Cleanliness Scoring

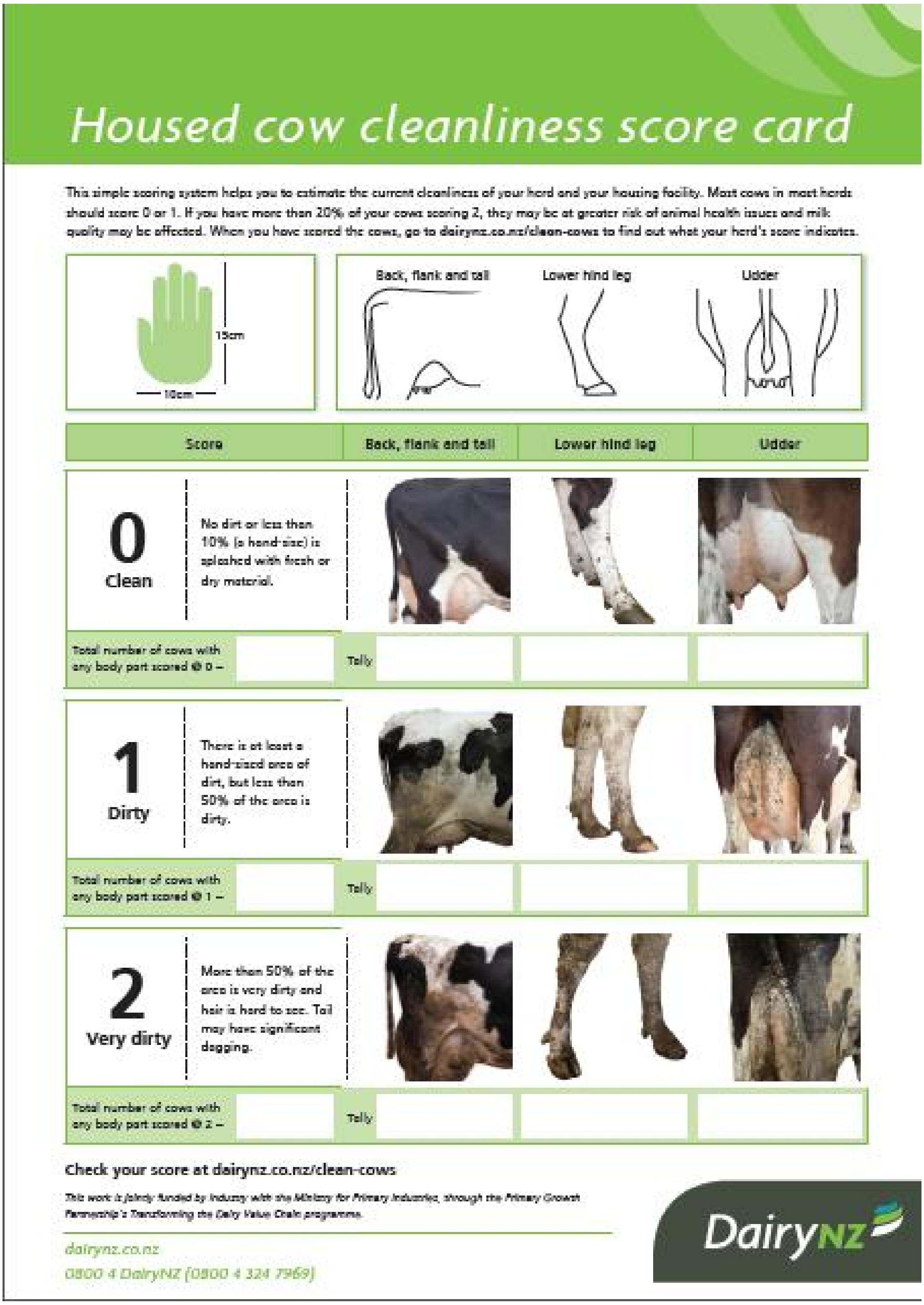

Figure A.3 **Cow cleanliness score sheet used for cleanliness scoring (DairyNZ, 2016).**

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