EVALUATION OF PHYSICAL, CHEMICAL AND MICROBIAL CHARACTERISTICS OF STAND-OFF PAD MATERIALS DURING WINTER USE AND RELATIONSHIP WITH COW BEHAVIOUR

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Abstract

Stand-off pads are used by New Zealand dairy farmers to protect susceptible soils from treading damage during the wet winter season. Large gaps in information still remain as to what are the best carbon materials for using on stand-off pads.

This project investigated the physical, chemical and microbial characteristics of stand-off pad materials so that recommendations could be made as to the best materials to use. Eight stand-off pads in Northland, Waikato, Otago and Southland were sampled that used different materials (wood chips, post peelings, chipped pallets, bark chip and sawdust). Cow behaviour was also measured (using activity meters) to ascertain which material achieved acceptable lying times on.

Key findings were that the bulk density of materials increased with stock usage. The coarser materials (bark and wood chip) appeared to perform better than the finer materials like post peelings. As particle size decreased and bulk density increased, compaction increased which may impede drainage. Chemical concentrations increased with stock usage, particularly nitrogen, phosphorus and potassium. The carbon/nitrogen ratio decreased rapidly from 300-600 to <100 during wintering. *Escherichia coli* concentrations were high (6.5×10^4-1.0×10^8 per 100g) in pad materials after stock use, similar to those found in fresh faeces. Cow lying times were found to be at least eight hours on pad surfaces except when pad surfaces were badly deteriorated and water logged.

Background

Stand-off pads are now commonly being used by New Zealand dairy farmers. A 2011 survey of Waikato farmers found that 22% of farms had stand-off pads (WRC 2012). Similar numbers have been found throughout NZ for Fonterra suppliers (Murray Pedley, Fonterra, pers. comm.). The main aim of these pads is to protect susceptible soils from treading damage by stock during the wet winter season. The implications of pugged pastures and likely environmental consequences have been previously summarised (Longhurst & Luo, 2007). A secondary benefit of using stand-off pads is that when cows are withheld from pastures during high-risk periods the volume of urinary-N excreted onto pastures is greatly reduced resulting in lower amounts of nitrate-N leached and N_2O emissions.

Dexcel (2005) reported that cows can be withheld from pasture for up to 18-20 hours/day on a regular basis but require a larger area per cow (8 m^2) when resting on a stand-off pad.

Few studies on stand-off pads have been conducted in NZ. A recent Northland study (Wynn *et al*., 2011) investigated surface management of a post peelings surface over a six-week period on cow welfare. The effect of mechanical aeration via ripping once or twice per week was compared against no aeration. Measurements of cow locomotion, cow cleanliness, teat surface bacterial contamination and lying behaviour patterns found cow lameness <2% across treatments, similar dirtiness scores and bacterial counts. Cow lying times were not significantly different although where the pad surface had been ripped twice per week a higher number of lying bouts was observed.

In 2011, a DairyNZ study (unpublished) examined the state of two woodchip pads in the Waikato for their chemical and microbial content throughout the profile at the end of the wintering period. The large variation in nutrient concentrations and microbial populations found prompted the need for an enlarged study.

Aim

The objective of this study was to identify the most suitable carbon-based materials for quality bedding in terms of providing greater cow comfort, nutrient retention, and materials longevity.

Methods

This project investigated the physical (dry matter, bulk density, particle distribution), chemical (nitrogen, carbon, phosphorus, potassium) and microbial (*Escherichia coli*) characteristics of stand-off pad materials. Stand-off pads in the Waikato (4) and Northland (1) were the main focus of this study. An additional sampling was also collected from pads in Otago and Southland that were part of the DairyNZ Southern Wintering Project that used different bedding materials (sawdust and bark chips). Site details are summarised in Table 1.

Table 1. Stand-off pad site details.

Site	Pad size (m^2)	No. pads	Type of surface material	Depth of surface material (cm)	No. samplings	Rainfall (mm)
Hamilton	1,035[1]	3	Wood chip	17/12/0[1]	3	311
Tokanui	1,980	2	Post peelings	30	3	405
Hautapu	2,000	2	Post peelings	50	3	444
Taupiri	770	1	Chipped pallets	27	1	230
Hikurangi	3,200	2	Post peelings	100	4	537

[1] Stand-off pad divided into three treatments (345m^2) based on re-surfacing of wood chip material: Pad A – 17cm; Pad B – 12cm; Pad C – no new material (i.e., original material from previous season)

Drainage samples were also collected from pads when there was flow and analysed for nutrient concentrations, pH, electrical conductivity (EC) and sodium absorption ratio (SAR). All physical and microbial measurements were undertaken at AgResearch Ruakura, chemical analysis were performed by ARL, Napier Lying behaviour patterns were measured at North Island sites using Ice Tag® activity meters on 10-20 randomly selected cows. The activity meters were attached to the cows' back right leg above the fetlock. The data was downloaded and lying and standing times were matched to times when cows were either on the pad or in a paddock.

Results and Discussion

Physical measurements

A summary of bulk density (BD) measurements of stand-off pad materials shows that there was an increase in BD both from the original material and over time (Table 2). The main exception to this was at the Hikurangi site where fresh material was added to the pad on several occasions and the pad was mechanically ripped once to decrease material compaction and improve drainage. The increase in BD was supported by particle distribution analysis (data not presented) that showed that the post peelings in particular broke down quickly into smaller particle sizes which lead to compaction. Compaction of the pad material at the surface layer favours the formation of muck when combined with heavy rainfall.

Sampling dates varied between sites, generally the first sampling represented the period 4-6 weeks into the wintering period whereas the third sampling occurred after 10-12 weeks.

Table 2: Bulk density (t/m^3) of dried stand-off pad materials for 0-30cm depth.

Site (material)	Original BD	First sampling	Third sampling
Hamilton (wood chip)	0.15	0.19	0.20
Tokanui (post peelings)	0.08	0.12	0.13
Hautapu (post peelings)	0.07	0.09	0.13
Taupiri (chipped pallets)	0.20	0.20	-
Hikurangi (post peelings) [1]	0.07	0.12	0.11

[1] Stand-off pad had top 20cm removed in July and the additions of ~10cm in June, July and August. This pad was also mechanically aerated using a ripping implement to ~20cm in late August.

Chemical measurements

An overview of the mean chemical composition of pad materials for 0-30cm depth over the wintering period from the different sites is summarised in Table 3.

Table 3: Summary of mean nutrient concentrations (% w/w) of stand-off pad materials at the 0-30cm depth during the wintering period[1].

Stand-off pad Material	Wood chip	Bark chip	Post peelings	Sawdust	Chipped pallets
Number of samples	10	12	40	6	6
Dry matter %	26	30	30	27	30
pH	7.1	8.2	7.5	7.9	7.7
Total nitrogen	0.26	0.26	0.18	0.15	0.20
Total carbon	11.9	17.7	13.9	13.0	12.1
C/N ratio	48	62	99	121	69
Phosphorus	0.05	0.06	0.04	0.03	0.07
Potassium	0.18	0.33	0.15	0.17	0.23
Sulphur	0.04	0.05	0.03	0.02	0.04
Calcium	0.14	0.16	0.15	0.08	0.14
Magnesium	0.05	0.05	0.06	0.04	0.04
Sodium	0.01	0.14	0.02	0.03	0.02

[1] Note that these are the mean concentrations found for 0-30cm depth and not necessarily the concentrations at the end of the wintering period.

Pad materials averaged 29% DM across sites and ranged between 21-40%. Initial carbon-based materials had a pH <6. However, with stock usage the pad pH became alkaline. Nitrogen concentrations averaged 0.21% (range 0.15-0.30%). The coarser pad materials (wood chip and bark chip) appear to have higher N and P concentrations. Pad materials originally had high carbon/nitrogen (C/N) ratios (300-600) however this decreased rapidly with stock usage. C/N ratios averaged 80 but by the end of the wintering period the C/N ratio was more likely to be closer to 30-40. The bark chips are likely to take the longest time to breakdown.

Microbial measurements

The microbial composition from the different stand-off pads sites and treatments are presented in Table 4.. Once stock started using the pads *E. coli* concentrations increased significantly from 10^1-10^2 and ranged from 6.5 x 10^4 to 1.0 x 10^8 *E. coli* per 100g wet material. Mean *E. coli* concentrations for the North Island sites are presented in Table 4. *E. coli* concentrations after pad use are similar to concentrations observed in fresh faeces (Luo *et al*., 2008; Donnison & Ross, 2008).

Pad temperatures were also measured and no relationship with *E. coli* concentrations was found. Pad temperatures were influenced by moisture content of pad materials. The lowest pad temperatures were found at the Hamilton site with no replacement wood chip. By late June this treatment had become waterlogged and pad temperatures had dropped to 11^{o}C (Photo 1).

Table 4: Mean pad temperatures ($\pm$ standard deviation) and mean *E. coli* concentrations in used pad materials at stand-off sites.

Site (material)	Pad temperature (^{o}C)	*E. coli* (per 100g wet material)
Hamilton (17cm wood chip)	18.1 $\pm$2.6	2.00 x 10^{6}
Hamilton (12cm wood chip)	17.3 $\pm$3.9	2.40 x 10^{7}
Hamilton (0cm wood chip)	14.0 $\pm$3.1	1.90 x 10^{7}
Tokanui (post peelings)	18.4 $\pm$1.3	3.95 x 10^{7}
Hautapu (post peelings)	16.0 $\pm$2.4	1.40 x 10^{5}
Hikurangi (post peelings)	20.3 $\pm$4.4	3.66 x 10^{7}

Wynn *et al.*, (2011) commented that while coliform mastitis, and *E. coli* mastitis in particular, is relatively uncommon in conventional spring calving pasture grazing systems in NZ, high numbers of coliform bacteria were isolated from the post peelings pad (the same Hikurangi site used in the current study) and from the cow teats of stock using the pad. The recommended practice for safeguarding against coliform mastitis when using stand-off pads would be to ensure that teat sealing of udders is carried out when cows are dried off.

Stand-off pad drainage

While there are limited data available on nutrient concentrations in pad drainage it is clear that once stock used the stand-off pads there was a large increase in leached nutrients. In particular there was a ten-fold increase in potassium (K) concentrations leached after stock use (Table 5). These K concentrations are considerably higher than those normally found in farm dairy effluent.

Table 5: Mean chemical composition of drainage flowing from the stand-off pads.

Stock	N	P	K	S	Ca	Mg	Na	SAR [1]	EC [2]	pH
usage	mg/L							ratio	mS/m	
Before	70	10	190	10	110	40	100	1.0	105	7.3
During	325	10	1275	80	170	130	200	1.9	590	7.5

[1] SAR = sodium absorption ratio; [2] EC = electrical conductivity (mS/m) at 25^{o} C

Stocking densities

The main factor affecting the longevity of pad materials is stock density over winter. Table 6 summarises data from the North Island sites and shows that the average stocking density allocations exceeded the recommended area of $5m^2$ per cow (Dexcel, 2005). However, farmer observations were that the pads were subjected to heavy usage at the beginning of the standing-off period, when peak cow numbers were more likely, and that the number of days at peak cow numbers was also an important determinant of pad longevity.

Table 6: Summary of stocking densities on North Island stand-off pad sites.

North Island	Area allocation			Stocking density
Sites	Average m^2/cow	Peak m^2/cow	Peak cow days	Cow hours/m^2
Hamilton (17cm)	11.1	10.1	28	53
Hamilton (12cm)	14.1	10.1	18	57
Hamilton (0cm)	14.3	10.1	12	152[1]
Tokanui	13.5	6.9	1	58
Hikurangi	8.6	5.3	4	258
Hautapu	11.0	5.0	10	106
Taupiri	5.2	4.9	36	141

[1] 2011 winter plus 2012 winter

The smallest area observed for peak cow usage was 4.9 m^2/cow at Taupiri over 36 days when the pad held maximum stock numbers. Dexcel's (2005) recommended that the long-term pad area allocation of 5 m^2 per cow for 12 hours/day for more than three days in a row be increased to 8 m^2/cow for situations where stock are held permanently off pasture. However, it appears that these past recommendations should be revisited as a combination of larger cows and number of days at peak density is also going to impact on pad longevity. Interestingly, UK experience tends towards larger per area per cow and a deeper layer of bedding material. Irish research found that as the area per cow increased from 6 to 12 m^2 the frequency of cleaning (removing the top 10 cm) decreased from 10 to 2 occasions (Hickey & French, 2002).

Cow behaviour

While the activity meters were used at five sites there were only two sites where data were captured over consecutive months. At the Hamilton site, where the pad was divided into three surface treatments, data were captured from cows that had spent 16 hours/day on each pad in May and again in June. Cow lying times exceeded 8 hours/day in mid-May and late-June on the pad surfaces that had received wood chips (Figure 1). By mid-June the site had received 300 mm rainfall and where woodchips had not been replaced, the cows chose not to lie down due to the waterlogged state of the pad's surface (Figure 1, Photo 1).

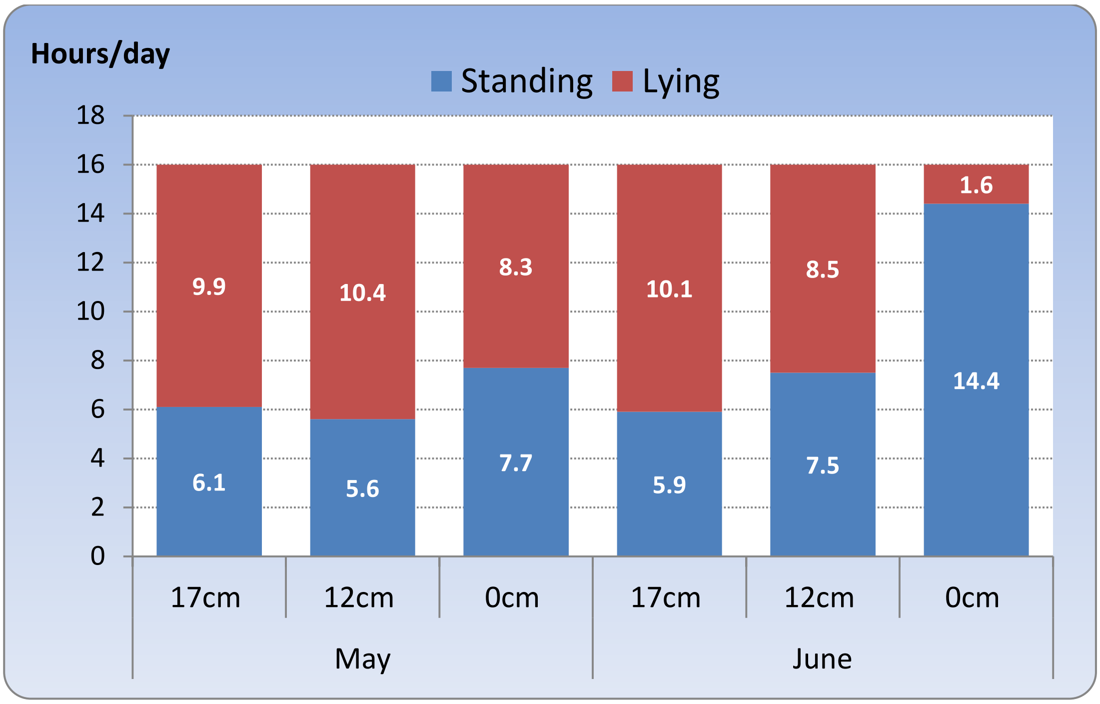

Figure 1: Standing and lying times over 16 hours on three pad surfaces during May and June following replacement of different depths of wood chip. The remaining eight hours were spent on pasture.

Photo 1: Pad surface with no replacement wood chips where cows chose not to lay.

At the Hikurangi site cow behaviour data showed that during each of the three measurement periods (June, July, August) lying times exceeded 9 hours/day (Figure 2). These lying times were remarkable considering the intensity of pad usage and demonstrates that with proactive management (removal and/or addition of new material) that the cows coped well and will lie down for the required resting time.

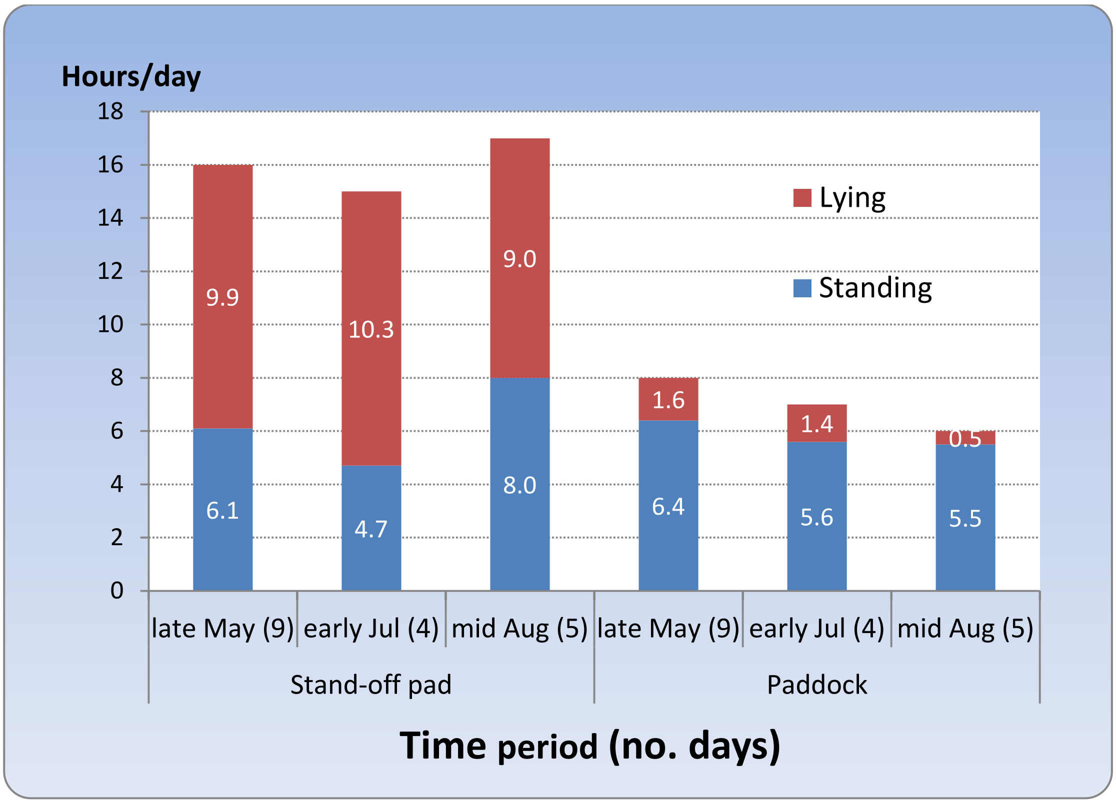

Figure 2: Cow behaviour as measured on three occasions at Hikurangi pad. Note that for 2 hours in July and 1 hour in August it could not be determined where the location and/or position of cows were so this time has not been included.

Other issues identified

Obtaining a cheap source of good quality carbon-material continues to be problematic, an issue identified by Longhurst *et al.,* (2006). The escalating price of soft surface carbon materials has increased steadily to $20-25/m^3 (Phil Manson, TD Haulage Ltd, pers. comm.). Material supply shortages are another issue that has caught out farmers who did not plan early enough to have pad bedding on farm well before winter. When the wintering period arrived, many farmers were still waiting for delivery of pad materials.

Conclusions

It is accepted that holding cows on stand-off pads is an effective measure for protecting pasture and soils from treading damage. Many different materials are used for pad surfaces however source of supply and affordability present an on-going issue. Using coarser materials (bark chip, wood chip or chipped pallets), if available, is likely to result in prolonged pad life compared to finer materials (post peelings, sawdust).

Pads not only accumulate nutrients with time but also microbial contaminants. To avoid risk of mastitis infection, teat sealing on dried cows should be considered.

Managing pads early on in the winter has been identified as an area that greatly impacts on the pads overall performance. Options such as splitting herds to avoid whole herd impact should be considered. If unavoidable, holding back some fresh bedding material to refresh the pad surface may be another management option. Stocking densities greater than 75-100 cow hours/m^2 are likely to require proactive pad management by either removal and/or additions of fresh pad material.

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