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Health Impacts and Economics of Using Dried Manure Solids in the Northeast

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Abstract. Six farms using different types of dried manure solid (DMS) strategies, including a farm that had side-by-side pens using sand and DMS, participated in a study to assess the impact on herd health of using DMS as bedding on dairy farms in the Northeast. Samples of unused and used bedding were taken over the course of a year and analyzed for bacterial content and physical properties. Mastitis and somatic cell count (SCC) records were analyzed in relation to those properties. Although mastitis differed among farm/bedding strategies (FBS), bacteria levels and properties of bedding had no effect on mastitis incidence. Lactation number, stage of lactation and SCC were the significant variables. Decreased levels of *Klebsiella* in the used bedding increased the odds of having an abnormal SCC for one FBS, and decreased moisture and fine particles in the used bedding increased the odds of having an abnormal SCC for a different FBS. For all others, abnormal cell counts were affected only by season, lactation number and milk production. Economic analysis showed a savings of between 1 and 26 cents per hundred weight of milk produced through the use of manure solids as bedding on five farms. This study suggests that properly managed DMS can provide an economic benefit without compromising herd health.

Keywords: dried manure solids, dairy farms, bedding, mastitis, SCC, compost, dairy manure solids, economic benefit

Introduction

Scarcity of bedding has pushed farms to explore different bedding strategies. Use of dried manure solids (DMS) as bedding is being considered by many farms. One of the concerns includes possible elevated levels of environmental pathogens that may negatively affect udder health and milk quality. There are two types of bedding, organic and inorganic.

Organic bedding materials contain nutrients needed for bacterial growth, while inorganic bedding materials do not. However, once any type of bedding becomes soiled (with fecal matter and urine), pathogen growth can be supported. Inorganic bedding, such as sand, may start out with low pathogen concentrations. Some organic bedding materials start out with lower concentrations than others. However, research shows that within 24-48 hours of being in the stall, pathogen levels in all bedding materials rise to similar concentrations (Brimm and Timms, 1989). Composting DMS and the addition of lime to organic bedding materials has been studied (Carroll and Jasper, 1978, Fairchild et al., 1982, Hogan and Smith, 1997 and Hogan, et al., 1999). In all cases, the unused bedding material that was composted or treated with lime had significantly lower pathogen counts than the untreated material, but within 24 hours of being in the stalls, there were little to no significant differences in bacterial counts. Thus the expense of composting DMS prior to bedding may not accomplish a reduction in pathogen exposure. Similarly, the addition of lime to the stalls is not supported by the literature.

Although it is generally thought that greater bacterial populations in the bedding correspond to greater bacterial populations on the teat ends, the literature shows inconsistency regarding this relationship. Several studies show that counts in bedding are correlated with counts on teat ends (Bishop et al., 1981, Fairchild, 1982, Hogan et al., 1999), while others showed no correlation (Hogan et al., 1990, Rendos et al., 1975). Hogan et al., 1990 related that adherence of bedding (due to particle size) had more to do with the difference in teat swab counts than the amount of bacteria in the bedding. Corn cobs adhered more to the teats than newspaper because of fine particle size; cows bedded on corn cobs had higher teat swab counts even though there was no difference in bacterial counts between the two bedding materials.

Researchers have generally stated the rule of thumb that bedding materials should be kept below a maximum bacterial count of 10^6 colony forming units (cfu) per gram of bedding wet weight. This number appears to be based on one study where there were no new cases of coliform mastitis when bedding counts were at 10^4 and 10^5 one summer, but there were several new cases the following summer when bedding counts were at 10^7 cfu/g wet weight (Bramley and Neave, 1975). Bramley and Neave do not claim that 10^6 colony forming units (cfu) per gram of bedding wet weight is a critical level and it represents data from only two summers on one farm. In other studies on the relationship of bedding to mastitis, one study shows a correlation between the number of bacteria in the bedding and mastitis (Hogan et al., 1989) while a number of studies show no correlation (Bramley, 1982, Fairchild et al., 1982). In recycled manure bedding, no correlation existed between the rate of environmental streptococcal intramammary infection during the dry period and streptococcal numbers in bedding by season of the year (Todhunter et al., 1995). Finally, in a recent study on three farms in Iowa using recycled digested manure solids, somatic cell counts at all of the farms have remained the same or decreased with no associated increase in clinical mastitis while using the separated solids (Meyer et al., 2007).

The goals of this study were to determine 1) if different manure systems producing dried manure solids differed in their bacterial content and physical properties, 2) if the bacterial counts in used bedding were correlated with the bacterial counts in unused bedding, 3) if the bacterial counts and physical properties of bedding were correlated with the bacterial counts on teat ends, 4) if the bacterial counts and physical properties of bedding have an impact on udder health, 5) if there was an impact of continued use of DMS on SCC, 6) if bedding type has an impact on lameness, 7) if the bacteria responsible for Johnes disease would remain viable in DMS, and 8) the economic implications of using DMS.

Materials and Methods

Six farms participated in this study based on the fact that they had either been using DMS, or were beginning to use DMS for all or part of their herd. On one farm, a side-by-side trial of sand, drum composted DMS and DMS from a separator were compared using three pens in one barn. A description of the farm bedding strategy (FBS) used for analysis at each farm can be found in Table 1.

Table 1: Description of Bedding Practices at the Six Study Farms

Farm	Bedding Strategy Employed	Farm/Bedding Strategy (FBS)
A	Manure from the stalls is separated, then drum composted for 24 hours. It sits in a pile for one day and is then spread in the stalls over the concrete 3 times per week.	ADrum
B	Manure from the stalls is separated and then put in windrows in a building to compost for about 10 days prior to spreading on mattresses in stalls. Started the study bedding 3 times per week, but after the first sampling, went to 6 days per week.	BWindrow
C	Manure from the stalls is run through a digester, then separated and piled. It is used on mattresses in the stalls right out of the separator in the fresh cow pens. It is re-bedded 3 times per week. As the study progressed, all cows were bedded on DMS.	CDigested
D	Manure from the stalls is separated (in the first month of the study only, it was digested first), piled for approximately 7 days then spread in deep beds 2 times per week. There were some months when stalls were bedded with material directly from the separator.	DSeparated
E	There were 3 bedding treatments at this farm from May 06 through Sept 06, then only 2 from Oct 06 through April 07. Manure from the stalls is separated, then either piled or run through a drum composter with a 3 day retention time and bedded in deep beds 2 times per week. The drum composted bedding was dropped at the end of September. The third bedding is sand in deep beds and bedded once a week	EDrum, ESand, ESeparated
F	Manure from the stalls is separated and piled for about 7 days then spread in deep beds 2 times per week	FSeparated

The six research farms were visited over a period of one year from March 2006 through April 2007. Sampling at Farm E occurred monthly from May 2006 through April 2007;

sampling occurred 8 times (March, May, July, August, September, October, December and February) at the other 5 farms. At each visit, the owner or herdsperson was interviewed to assess changes in bedding, milking or other procedures since the last visit, and farm records were obtained. Also at each visit, quadruplicate samples of used bedding and triplicate samples of unused bedding were taken.

The samples were sent to three different laboratories for analysis. Quality Milk Promotion Services (QMPS), Cornell University Animal Health Diagnostic Center, Ithaca, NY analyzed both the used and unused bedding for the following pathogens on a wet weight basis: environmental *Streptococcus* species, environmental *Staphylococcus* species, *Enterococcus* species, coliform bacteria (including: *Escherichia coli*, *Klebsiella* species, and *Enterobacter* species), *Pseudomonas* species, *Proteus*, *Serratia* species, *Prototheca*, *Corynebacterium* species, other gram negative and gram positive bacteria, and yeast, mold and fungus. The Johnes Laboratory, Cornell University Animal Health Diagnostic Center, Ithaca, NY analyzed only the unused bedding (on a wet weight basis) for the presence of *Mycobacterium Avium paratuberculosis* (MAP) to see if the Johnes disease bacterium was present and thus could potentially be spread through the use of DMS. Brookside Laboratories, New Knoxville, OH, analyzed both the used and the unused bedding for the following properties: % moisture, % organic matter, particle size and volume/density.

The numbers of bacteria found in bedding materials can be reported on a wet weight ("as is"), dry weight or volume basis. Reporting on a wet weight basis has little significance since it will be highly dependent on how moist (heavy) the material is. When comparing bacterial counts within the same type of bedding material, it makes sense to do it on a dry weight basis. For example, dry weights might be used when examining the change in concentrations over time in the same barn using the same bedding. Comparing different materials with very different densities, such as sand and DMS, is challenging since the bedding in a stall of sand will weigh more than a stall with DMS. For the same volume of material, the higher density of sand would result in lower reported dry weight concentrations than a lighter material so the sand would "look cleaner" while the same samples compared using volume based concentrations might show higher concentrations in the sand. Therefore, in this report all bacterial concentrations are reported on a volume basis. The information obtained on volume/density was used to convert the bacterial counts from the wet weight QMPS data to a volume basis.

Teat swab sampling was performed at Farm E three times to assess the bacterial population on the teat ends of cows in the different bedding regimes. Samples were taken on the first 20 cows coming into the milking parlor in each of the three study pens (composted DMS, DMS from the separator, and sand) on September 27, 2006, then in the sand and DMS from the separator pens 2 more times (January 16, 2007 and May 1, 2007). The swabs were taken to QMPS for bacterial analysis.

Teat end scoring (1 to 4) was performed by QMPS trained technicians one time at five of the six farms. It was not performed at Farm A. Teat end scoring is done for two characteristics. The first characteristic is the amount of keratinization, and the second is whether the teat end is cracked or not. The scoring system for keratinization ranges from 0 to 4, with 4 having the most callous tissue and 0 having none. A half point (0.5) is added to each whole number score if cracks are present. For example, a teat with moderate callosity and cracks would be given a score of 2.5, where a teat with high callosity and no cracks would be given a score of 4.0. This was done to determine the health of teat ends at each farm. The health of teat ends is an important determinant of the impact of bacteria on milk quality and cow health. While bedding is not expected to impact teat end health, teat end health may result in differences in the way bedding materials affect SCC and mastitis. Teat end scoring was done to ensure that differences in teat end health between the farms does not account for any differences in clinical mastitis.

The six dairy farms in this study use a computer-based record keeping system called Dairy Comp 305 (Valley Agricultural Software, Tulare, CA). The Dairy Comp 305 files were obtained each time bedding samples were collected to keep track of the cows in each pen that was sampled on each farm. Through this, it was possible to get a count of mastitis incidence, as well as lactation number, days in milk and milk production for the cows in the sampled pens over the study period. Each of the six farms also participated in the NYS Dairy Herd Improvement Program (DHIP), in which trained technicians come to the farm once a month and take milk samples on the whole herd. Milk production is recorded and the samples are analyzed for fat, protein, SCC and linear score (LS). This information can also be found in Dairy Comp 305. This was used to calculate average somatic cell count in the sampled pens over the study period. Farm A discontinued enrollment in DHIP in August 2006, so SCC records from Farm A were not used in this study.

Dr. Robert Everett, Animal Science professor at Cornell University, has access to DHIP records going back to the year 2000. He was able to pull out all of the DHIP records since that time for each of the farms on the study and put them into an excel file. These records include average milk production and linear score (LS) for the whole milking herd at each farm. In addition, he extracted a file with average milk production and linear score for the milking herd at 65 New York State Dairy farms that have a current herd size of between 750 and 2000 cows for the same time period. This data was used to assess the impact of the continuing use of DMS on LS.

Lameness scoring was done twice at Farm E (4/25/07 and 5/22/07) on cows in the pen bedded with DMS from the separator and cows in the pen bedded with sand. Lameness scores are reported on a 1-4 scale. A score of 1 is normal: the cow stands and walks with a flat back, 2 is mildly lame: the cow stands with a flat back and arches when she walks, 3 is moderately lame: the cow stands and walks with an arched back and takes short strides on one or more leg, and 4 is lame: the cow stands and walks with an arched back, and one or more limbs are physically lame or non-weight bearing.

An economic analysis assessing variables affecting the use of using DMS as bedding was performed by A. Edward Staehr, Extension Associate in the Department of Applied Economics and Management at Cornell University. He collected the information related to using DMS as bedding at five of the six farms that participated in the study: The annual cost per hundredweight of milk of using DMS was then calculated based on the information collected.

Statistical analysis was performed using analysis of variance (ANOVA) for multiple comparisons with Tukey corrections, multiple linear regression, logistic regression and/or Poisson regression using the JMP 7.0 statistical package. The analysis was run on a natural log transformation of the bacterial counts, and actual values of all other variables to help normalize the data. All of the analyses were performed with bacterial counts calculated on a volume basis (log cfu/ml).

Results and Discussion

1) Do different manure systems producing dried manure solids differ in their bacterial content and physical properties, and are they different from sand?

Bacterial concentrations in unused bedding: There were no differences in bacterial populations of *Staphylococcus* species, *Enterobacter* and *Proteus* in any unused bedding (Table 2). For the rest of the bacteria analyzed, unused sand bedding had the lowest bacterial populations. Average levels of *E. coli* and *Klebsiella* were very low in all of the unused bedding, with significant differences between populations of these two pathogens occurring only between sand (significantly less) and two or three of the "green" DMS strategies. There was no *E. coli* found in the unused bedding of the drum and windrow composted and sand strategies, and no *Klebsiella* in one of the drum composted and the sand strategies.

Table 2: Average Bacterial Levels (log cfu/ml) in Unused Bedding in each FBS over the Study Period.

Bacteria	ADrum	BWindrow	CDigested	DSeparated	EDrum	ESand	ESeparated	FSeparated
Staph spp	0.0^{a}	0.0^{a}	0.4^{a}	0.5^{a}	0.0^{a}	0.8^{a}	0.8^{a}	0.0^{a}
Enterobacter	0.0^{a}	0.0^{a}	0.0^{a}	0.6^{a}	0.0^{a}	0.0^{a}	0.2^{a}	0.4^{a}
Proteus	0.0^{a}	0.5^{a}	1.4^{a}	1.7^{a}	0.0^{a}	0.0^{a}	0.9^{a}	0.4^{a}
E. coli	0.0^{c}	0.0^{c}	0.5^{bc}	2.7^{ab}	0.0^{bc}	0.0^{c}	0.7^{bc}	3.8^{a}
Klebsiella	0.0^{c}	1.0^{bc}	1.1^{bc}	4.7^{a}	0.6^{bc}	0.0^{c}	3.8^{ab}	3.9^{ab}
Strep spp	7.0^{bc}	7.2^{bc}	12.0^{a}	11.1^{ab}	5.9^{cd}	2.0^{d}	9.9^{abc}	12.5^{a}
G-negative	12.0^{a}	8.6^{ab}	10.7^{ab}	10.8^{a}	6.6^{bc}	3.2^{c}	10.0^{ab}	10.5^{ab}
G-positive	13.7^{a}	12.2^{ab}	12.0^{ab}	12.1^{ab}	10.4^{b}	6.9^{c}	12.6^{ab}	12.9^{ab}
Corynebacterium	0.9^{b}	1.1^{b}	3.9^{ab}	5.5^{a}	0.6^{b}	0.5^{b}	3.7^{ab}	4.3^{ab}
Molds	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	1.6^{a}

Values in each row with different letters are significantly different ($p<0.05$)

Bacterial Concentrations in Used Bedding: In the used bedding, there were no significant differences in the levels of *E. coli*, *Enterobacter* or *Proteus* between any FBS (Table 3). *Streptococcus* levels were significantly higher in the sand strategy used bedding than all other FBS except two. *Klebsiella* (which was absent from the unused bedding in one of the drum composted strategies) was found in significantly higher levels in the used bedding from that strategy than several other FBS. Although sand started out "cleaner", used bedding in the sand FBS had significantly higher levels of the bacteria analyzed (except *Klebsiella*) than at least one, and in many cases, more than one DMS FBS. In all cases (except *Streptococcus*), the three strategies at the side-by-side farm did not differ in bacterial levels, indicating that it is more likely that bacterial levels in used bedding are a result of bacteria in the manure of the cow and how well stalls are cleaned, rather than how "clean" the bedding is when it is put in the stall. In addition, those strategies that started out with "clean" bedding tended to have significantly higher levels of bacteria in used bedding, indicating the bedding may have started out too clean (i.e. no competition from other bacteria).

Table 3: Average Bacterial Levels (log cfu/ml) in Used Bedding in each FBS over the Study Period.

Bacteria	ADrum	BWindrow	CDigested	DSeparated	EDrum	ESand	ESeparated	FSeparated
Staph spp	4.7^{a}	0.8^{ab}	3.4^{ab}	3.3^{ab}	5.4^{a}	3.8^{a}	2.5^{ab}	0.3^{b}
Enterobacter	5.4^{a}	2.2^{a}	3.9^{a}	3.1^{a}	0.6^{a}	3.5^{a}	3.3^{a}	2.4^{a}
Proteus	0.3^{a}	0.0^{a}	0.3^{a}	1.9^{a}	2.0^{a}	0.4^{a}	2.0^{a}	0.6^{a}
E. coli	3.8^{a}	3.2^{a}	6.7^{a}	2.3^{a}	5.8^{a}	5.6^{a}	2.9^{a}	4.3^{a}
Klebsiella	13.7^{a}	9.8^{bcd}	7.4^{d}	12.8^{ab}	12.3^{ab}	10.4^{bcd}	12.8^{ab}	8.7^{cd}
Strep spp	16.7^{b}	16.8^{ab}	16.5^{b}	17.0^{ab}	16.4^{b}	17.4^{a}	16.7^{b}	16.7^{b}
G-negative	12.0^{ab}	13.6^{a}	9.9^{b}	13.6^{a}	12.5^{ab}	13.2^{a}	13.9^{a}	12.7^{ab}
G-positive	16.1^{abc}	15.8^{abc}	14.8^{c}	15.6^{bc}	17.1^{ab}	17.0^{a}	16.1^{abc}	15.1^{c}
Corynebacterium	14.1^{ab}	11.1^{b}	13.2^{ab}	13.1^{ab}	13.4^{ab}	15.2^{a}	15.3^{a}	12.9^{ab}
Molds	0.8^{a}	0.0^{a}	0.8^{a}	0.7^{a}	0.0^{a}	0.0^{a}	0.0^{a}	1.2^{a}

Values in each row with different letters are significantly different ($p<0.05$)

Physical properties of bedding: Bedding (both unused and used) was analyzed for % moisture, % organic matter (OM) and particle size. It has been suggested in the literature that with more moisture and more organic matter, bacterial populations thrive. It has also been suggested that the amount of fine particles in the bedding has an effect on bacterial populations on the teat ends (the finer the material, the more likely it will stick to the teat ends, and therefore there will be a higher population of bacteria on the teat ends). This is hypothesized to, in turn, cause more mastitis. Therefore, particle size was analyzed as % of particles < 2 mm and % of particles < 0.84 mm. ANOVA with multiple comparisons were run on the properties of bedding between each FBS and are presented below.

Unused bedding: As expected, moisture and OM in the unused bedding were significantly lower in the sand bedding strategy (11 and 0.8%, respectively) than any other bedding strategy (69 and 90%, respectively). Fine particles in the unused bedding were expected to be higher in the sand (70%) however one drum composting (74%) and one separated FBS (71%) produced the same amount of particles less then 2mm as in sand bedding. There were significant differences in all of the physical properties between the DMS FBS. Moisture ranged from 64 to 73%, OM from 86 to 93% and the % of particles less than 2 mm and 0.84 mm ranged from 31 to 74% and 6 to 37%, respectively.

These differences may indicate that it is the type and efficiency of the separator being used on the farm that determines the properties of the unused bedding.

Used bedding: As with the unused bedding, moisture and OM in the used bedding were significantly lower in the sand bedding strategy (6 and 3%, respectively) than any other bedding strategy (47 and 83%, respectively). The addition of feces increased the amount of OM in the sand bedding. There was no increase in OM between unused and used bedding in the DMS bedding strategies. Moisture ranged from 29 to 60% in used bedding with higher moisture levels in the bedding strategies that used deep beds than in those that used mattresses. This result is expected since those using mattresses spread the DMS in a 2 - 3" layer on top of the mattresses and thus it dries out. Fine particles were significantly higher in the sand bedding strategy than any other strategy, and tended to be lower in those bedding strategies that used deep beds versus those that used mattresses. DMS in deep beds tends to mat together from the weight of the cow, while the DMS on the mattresses tends to either fall off, or spread out.

2) Are bacterial counts in used bedding correlated to bacterial counts in unused bedding?

Data were analyzed to address the question on whether the cleanliness of the unused bedding has an effect on the bacterial population of the used bedding. That is, will lower bacterial counts in the unused bedding necessarily lead to lower bacterial counts in the used bedding? One would expect that if the bacterial content of the unused bedding determined the levels in the used, it would be the same bacteria (i.e. more *E. coli* in the unused would produce more *E. coli* in the used). However, Table 4 shows that this is only the case for *Staphylococcus*, *Klebsiella* and *Proteus*. *Staphylococcus* levels in used bedding are positively correlated with *Staphylococcus* and *Corynebacterium*, and negatively correlated with *Streptococcus* levels in the unused bedding. That is, one could lower the levels of *Staphylococcus* in used bedding by lowering levels of *Staph* and *Corynebacterium* and increasing levels of *Strep* in the unused bedding. Similarly, decreasing levels of *Klebsiella* and increasing levels of molds in unused bedding would allow for lower levels of *Klebsiella* in used bedding. However, r-square values for both of these indicate that the levels of these bacteria in the used bedding are due only 18 and 29% to the levels of the bacteria in the unused bedding. The best fit (r-square = 0.51) is for levels of gram negative bacteria in the used bedding. In this case, if *Enterobacter* and *Proteus* levels in the unused bedding were increased, then gram negative bacteria in the used bedding would decrease. These data suggest that other factors besides the bacterial level of the unused bedding have an impact on bacterial levels in used bedding.

Table 4: Effect of Bacterial Counts of Unused Bedding (log cfu/ml) on Counts in Used Bedding

Bacteria in Used Bedding (Y)	Multiple Linear Regression Equation (all x variables are in unused bedding)	p-value	r-square
Streptococcus	Y=16.9 – 0.1*g-negative bacteria + 0.1*g-positive bacteria	0.0011	0.1943
Staphylococcus	Y=8.6 – 0.5**Strep* + 0.6**Staph* + 0.3**Coryn*	0.0049	0.1860
E. coli	Y=7.5 - 0.9*molds	0.0372	0.0661
Klebsiella	Y=11.7 + 0.2**Klebsiella* – 1.0*molds	<.0001	0.2928
Enterobacter	Y=5.4 + 0.5**E. coli* – 0.9*molds	0.0080	0.1420
Proteus	Y=2.2 + 0.7**Enterobacter* + 0.4**Proteus* – 0.2**Coryn*	0.0010	0.2286
Gram negative	Y=14.1 – 0.5**Enterobacter* – 0.3**Proteus*	<.0001	0.5138
Gram positive	Y=17.6 – 0.1*g-negative bacteria – 0.1**Coryn*	<.0001	0.2632
Corynebacterium	Y=14.5 – 0.5**Proteus*	0.0392	0.0647
Molds	Y=0.9 + 0.5**E. coli* – 0.6**Enterobacter*	0.0035	0.1645

3) Are bacterial counts in and physical properties of separated DMS and sand correlated with bacterial counts on teat ends and thus, mastitis and SCC?

Teat ends bacterial counts: Comparison of the bacterial population on the teat ends of cows bedded on DMS from the separator and cows bedded on sand at the Farm E showed significant differences only for *Klebsiella*, gram negative and gram positive bacteria (Table 5). Analysis of the bedding properties that caused differences in bacteria on the teat ends yielded variable responses. The percent of fine particles in the used bedding had a significant effect (either by itself or in conjunction with other bedding properties and/or bacteria) on the level of bacteria found on the teat ends for 4 of the 8 bacteria analyzed. However, it did not behave as expected. *Streptococcus*, *Staphylococcus*, *Enterobacter* and *Corynebacterium* levels all decreased when the percent of fine particles increased in the used bedding. Bacterial levels in the used bedding had an affect on several bacterial levels on teat ends, but only in the case of *Klebsiella* were they the same bacteria (i.e. increased *Klebsiella* levels in the bedding caused increased *Klebsiella* levels on teat ends).

Table 5: Average Levels of Bacteria on the Teat Ends of Cows Bedded on DMS and Sand (log cfu)

Bacteria	DMS	Sand
Streptococcus	8.0[a]	7.1[a]
Staphylococcus	4.2[a]	4.0[a]
Escherichia coli	0.5[a]	0.8[a]
Klebsiella	2.1[a]	0.7[b]
Enterobacter	0.4[a]	0.2[a]
Gram negative bacteria	5.9[a]	3.1[b]
Gram positive bacteria	7.1[a]	6.5[b]
Corynebacterium	6.0[a]	5.3[a]
Molds	0.2[a]	0.1[a]

Values in each row with different letters are significantly different ($p<0.05$)

Teat end counts vs SCC: It has been generally accepted that the cell count for "normal" milk is nearly always less than 200,000 cells/ml for cows (2nd lactation or greater). Higher counts are considered abnormal and indicate probable infection. Therefore individual cow SCC was divided into two categories; those cows with less than or equal to 200,000 cells/ml (normal) and those cows with > 200,000 cells/ml (abnormal). There were 18 out of 57 cows (31.5%) in the DMS pen with an abnormal SCC, and 22 out of 60 in the sand pen (36.7%) at Farm E. There was no difference in the number of animals between the two pens. Logistic regression was run to see if the odds of getting an abnormal cell count was different than getting a normal cell count based on pen (sand or DMS bedding), season (fall, winter or summer), lactation (a=2nd, b=3rd or greater) and stage of lactation (early=0 to 60, mid=61 to 200, late=greater than 200 days in milk), as well as the amount of *Streptococcus*, *E. coli*, *Klebsiella*, gram negative bacteria and *Corynebacterium* on the teat ends. All of the indicator variables fell out of the model except the levels of *Streptococcus* and gram negative bacteria on the teat ends. Logistic regression for the log odds of having an abnormal cell count based on the bacterial population on the teat ends showed that the level of *Streptococcus* on the teat ends was positively correlated and the level of gram negative bacteria was negatively correlated. In numbers, the odds of having an abnormal cell count increase 1.6 times for each 1 log cfu of *Streptococcus* on the teat ends, and decrease 1.2 times for each log cfu increase in gram negative bacteria. However, Poisson regression yielded no variables as having a significant effect on the number of animals with abnormal SCC.

Teat end counts vs mastitis: There were 7 cows that got mastitis within one month of when the teat swabs were taken. Two of the seven were in the sand pen and both of them occurred in the winter. The other 5 were in the DMS pen with 1 occurring in the fall, 2 in the winter, and 2 in the spring. Both logistic and Poisson regression failed to show any of the variables as significantly affecting the number of mastitis incidences for these cows.

4) Do bacterial counts and physical properties of bedding have an impact on udder health?

Teat end scores: Mastitis pathogens enter the teat canal through the opening in the teat end. Part of the teat end barrier to the entrance of mastitis pathogens are the keratin cells that line the teat canal. These keratin cells have a sticky or adhesive property that enables them to stop pathogens from completely penetrating the teat canal. If too much keratin is produced, it can form projections, or fronds and/or a ring around the teat opening. If this hyperkeratosis becomes severe, it may be associated with an increase in both non-clinical and clinical mastitis. Teat ends with scores of > 2 would be considered to be at greater risk for entrance of mastitis pathogens. Having greater than 20% of the animals in the herd with teat end scores > 2 can indicate a problem.

Table 6 shows the scores for each FBS. Scores greater than 2.0 ranged between 20.4 and 38.8% of animals within each FBS. The only significant difference between the number of animals at each farm with a score greater than 2 was between CDigested and DSeparated. Therefore, differences in SCC and/or mastitis between the two could be attributed to the roughness and callosity of teat ends at DSeparated. All FBS had greater than 20% of animals with elevated teat end scores. Other variables that were looked at in regard to teat end scores were lactation number and stage of lactation. Heifers were less likely to have scores of > 2, and cows in early lactation were less likely than those in mid, late or extended lactation.

Table 6: Percent of Animals at each FBS with a Teat End Score Greater than 2.0

FBS	% of animals
BWindrow	28.8[ab]
CDigested	20.4[b]
DSeparated	38.8[a]
ESand	35.9[ab]
ESeparated	30.5[ab]
FSeparated	29.5[ab]

Values with different letters are significantly different ($p<0.05$)

Mastitis: Five farms (seven FBS) were included in this analysis since ADrum dropped DHIP. Only three of the FBS had heifers in the study pens, so analysis was run separately for heifers (1st lactation) and cows (2nd lactation or greater). Analysis was performed to see the effect of FBS, season, lactation number (only for cows), stage of lactation and SCC on the incidence of mastitis. The odds of getting mastitis for heifers was significantly affected only by abnormal cell count (those heifers with abnormal cell count, >100,000 cells/ml were more likely to get mastitis), while the odds of getting mastitis for cows was significantly affected by FBS, season and abnormal cell count. Since FBS includes other farm variables besides bedding, Poisson regression was run to see which variables within FBS had an effect on mastitis incidence (Table 7). Bacterial levels and properties of the bedding had no effect on the incidence of mastitis. SCC was a significant variable for all FBS. For CDigested and ESeparated, cell count was the only significant variable. Cows at CDigested with an abnormal cell count were $e^{0.8} = 2.2$, 220% or 1.2 times more likely to have mastitis than those with a normal cell count, and for ESeparated they were 0.8 times more likely. Stage of lactation, milk production and season also had an effect, but not for all FBS. When the three FBS at farm E were analyzed together, type of bedding, or FBS, did not have an effect (Table 7, Farm E results). Instead, the significant variables were cell count (1.7 times more likely for abnormal cell count than normal cell count), the amount of moisture and particles < 0.84 mm in the used bedding, and milk production (positive correlation). When each system within Farm E was run separately, cell count was the predominant significant variable.

Table 7: Poisson Regression Results for the Number of Mastitis Events for Cows within each FBS

Farm/FBS	Predictor Variable	Contrast	Diff in log mean	p-value
BWindrow	Stage of lactation	Early to mid	-1.2	0.0006
		Early to extended	NS	0.3758
		Mid to extended	NS	0.1140
	Cell count	Abnormal to normal	1.0	0.0002
CDigested	Cell count	Abnormal to normal	0.8	0.0035
DSeparated	Cell count	Abnormal to normal	1.8	<.0001
	Milk production		0.05	<.0001
Farm E	Cell count	Abnormal to normal	1.0	<.0001
	Used moisture		0.08	0.0054
	Used fines < 0.84mm		0.06	0.0215
	Milk production		0.04	0.0043
EDrum	Stage of lactation	Mid to late	NS	0.2353
		Mid to extended	-1.7	0.0334
		Late to extended	-2.5	0.0078
	Cell count	Abnormal to normal	1.3	0.0153
ESand	Nothing significant			
ESeparated	Cell count	Abnormal to normal	0.6	0.0126
FSeparated	Season	Spring to summer	1.0	0.0010
		Spring to fall	1.2	0.0003
		Spring to winter	1.1	0.0035
		Summer to fall	NS	
		Summer to winter	0.02	0.0021
		Fall to winter	NS	
	Cell count	Abnormal to normal	0.9	0.0005

SCC: The odds of having an abnormal cell count for cows were affected FBS, season (less likely in the winter), lactation number (greater for those in 3rd or greater lactation than 2nd), and stage of lactation (as the number of days in milk increased, the odds of having an abnormal SCC also increased). The odds of having an abnormal cell count for heifers were affected by FBS and season. As with cows, the number of heifers with abnormal cell count was least in the winter and most in the spring and summer. Since FBS includes other farm variables besides bedding, Poisson regression was run to see which variables within each system had an effect on abnormal cell count (Table 8). The only time bacterial levels had a significant effect on SCC was for the drum composted system at the side-by-side farm, where *Klebsiella* levels in the used bedding had a negative correlation with number of cows with abnormal cell count (i.e. less *Klebsiella* in the used bedding, more cows with abnormal SCC). Bedding properties had an effect only for CDigested where the amount of moisture and the amount of particles < 0.84 mm also had a negative correlation with abnormal SCC. Both of these responses for bedding bacteria and properties are not what would be expected. Otherwise, it was season, lactation number and milk production that had an effect.

Table 8: Poisson Regression Results for the Number of Mastitis Events for Cows within each FBS

Farm/FBS	Predictor Variable	Contrast	Diff in log mean	p-value
BWindrow	Season	Spring to summer	-0.94	0.00272
		Spring to fall	-0.89	0.0309
		Spring to winter	NS	0.8413
		Summer to fall	NS	0.8569
		Summer to winter	0.84	0.0301
		Fall to winter	0.79	0.0342
	Lactation	2nd to 3rd and greater	-0.84	0.0036
CDigested	Lactation	2nd to 3rd and greater	-0.71	0.0034
	Used Moisture		-0.08	0.0016
	Used Fines < 2mm		-0.01	0.0292
DSeparated	Season	Spring to summer	-0.51	0.0374
		Spring to fall	-0.81	0.0005
		Spring to winter	-0.75	0.0043
		Summer to fall	NS	0.0599
		Fall to winter	NS	0.7161
	Milk production		-0.01	0.0292
Farm E	Lactation	2nd to 3rd and greater	-0.59	<.0001
	Milk production		-0.01	0.0310
EDrum	Lactation	2nd to 3rd and greater	-0.93	<.0001
	Milk production		-0.07	0.0005
	Used *Klebsiella*		-0.42	0.0148
ESand	Lactation	2nd to 3rd and greater	-0.51	<.0001
ESeparated	Lactation	2nd to 3rd and greater	-0.51	<.0001
FSeparated	Milk production		-0.03	<.0001

5) Will continued use of DMS have an impact on SCC/LS?

Many producers and veterinarians believe that continued use of DMS as bedding is contributing to increasing SCC on farms. Herds that participate in the Dairy Herd Improvement Program (DHIP) have many years of herd average SCC/LS data available. This information was available from approximately January 1997 through January 2008 for all of the farms in the study except Farm A for which data was available through August 2006. Linear regression of average LS for all farms together and each farm individually was run on all of the data, as well as on the data generated prior to and while using DMS as bedding. This data was run for farm only, not FBS, as the three strategies at the farm using sand could not be separated out in this data set. Two additional farms, not in the study, that are using DMS as bedding also gave permission to access their data. Data was also available from 1997-2008 for 65 NYS dairy farms with comparable herd size, and linear regression over time was run for these 65 farms over the same time period. Data were not available about which of these farms might have been using DMS bedding, but knowledge about NYS practices indicates that this would be a very small percentage.

Looking at the study farms together from 1997 to 2008, linear regression of the data for linear score shows a positive correlation (+ 0.0002/cow/day or 0.07/cow/year) for LS over time for cows bedded on DMS and no significant correlation (no change over time) for those on some other bedding (Figure 1). ANOVA analysis showed the change in LS over time while using DMS was significantly different from the “no change” prior to using DMS on the 6 study farms.

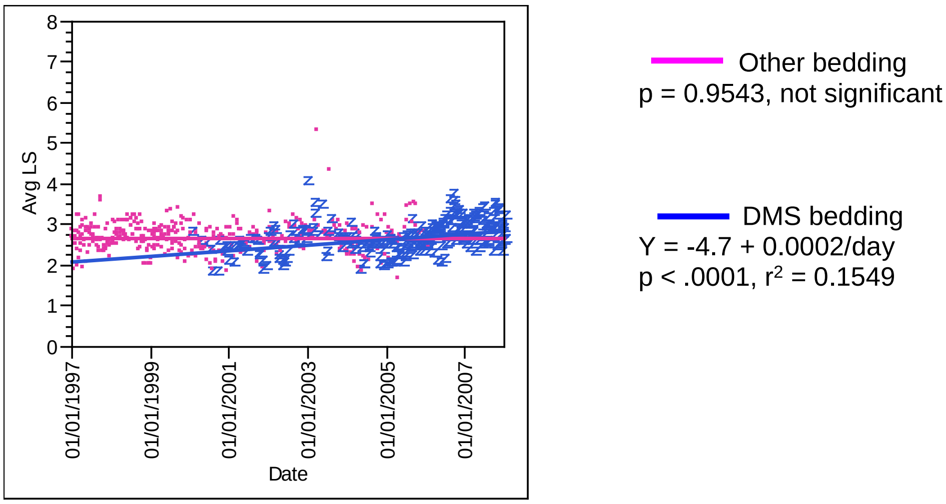

Figure 1: Linear Regression for Average LS per Cow for Study Farms Bedded on DMS or Some Other Bedding

Comparison of the 65 NYS farms and the study farms for the periods in which the study farms were using DMS was made. Both the 65 farms and the six study farms showed an increase in LS between 2000 and 2007 (Figure 2). The 65 NYS farms showed an increase of 0.00002/cow/day (0.007/cow/year), while the six study farms showed an increase of 0.0002/cow/day (0.07/cow/year). ANOVA on these results showed a significant difference in the change in LS over time between the two sets of farms. Therefore, it is possible that continued use of DMS could be increasing LS more than other bedding, but since the dataset for those using DMS is much smaller than those using other bedding, and there is no way to be sure of what type of bedding the other farms are using, no conclusion should be made.

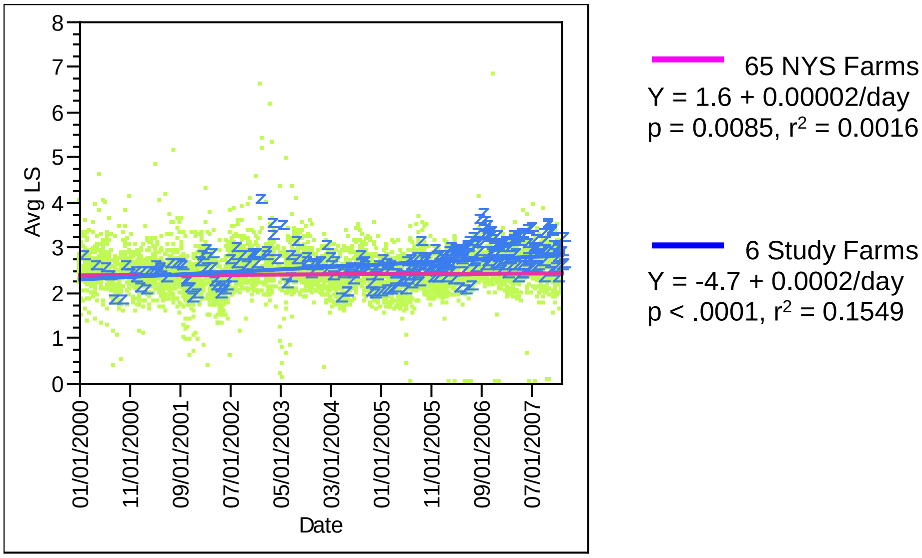

Figure 2: Linear Regression for Average LS per cow for 65 NYS Dairy Farms and 6 Study Farms

In addition, comparison of each individual farm while using DMS, as well as comparison of the additional two farms using DMS (Farms G and H) to the 65 NYS farms, showed only three of eight farms incurring an increase in LS while using DMS, and only two of those were significantly different than the increase in LS that was occurring on the 65 NYS farms during that time period (Table 9). These two farms have been using DMS for approximately 10 years. However, one of the additional farms (not a study farm) has been using DMS for over 15 years with no change in LS over that time period, so changes in SCC/LS may be unrelated to DMS use.

Table 9: Change in LS Over Time for Farms Using DMS in Comparison to 65 NYS Farms in the Same Time Period

Farm	Time Period	Change in LS on Farm	Change in LS on 65 NYS Farms	Are they different?
A	Nov 05 – Aug 06	-0.73/year	+0.29/year	No
B	Apr 04 – Jan 08	+0.15/year	+0.07/year	No
C	May 05 – Jan 08	No change	+0.11/year	No
D	Jan 00 – Jan 08	+0.11/year	+0.01/year	Yes
E	Mar 06 – Jan 08	No change	No change	No
F	Oct 00 – Jan 08	+0.04/year	+0.01/year	Yes
G	Nov 06 – Jan 08	No change	No change	No
H	Jan 97 – Jan 08	No change	-0.01/year	No

6) Does bedding type have an impact on lameness?

Some of the literature has indicated that sand is the best bedding for the health of feet and legs. One of the ways in which foot and leg health is evaluated is through lameness scoring. Twice over the study at Farm E, cows in the sand pen and cows in the pen bedded with DMS from the seperator, were scored. Lameness scores were reported on a 1-4 scale described earlier. Since lameness can also be a function of lactation number (or age), that information was collected as well for the cows that were scored. Lactation number was divided into three categories for the statistical analysis: A = second lactation, B = third lactation and C = fourth and higher.

The analysis showed a significant difference in lameness score by pen (type of bedding) and lactation. The cows in the sand pen had a significantly higher mean lameness score (1.5) than those in the DMS pen (1.3). There was also a significant difference between lactations. Cows in 4th or greater lactation were significantly more lame (1.9) than 3rd lactation cows (1.3), which were significantly lamer than 2nd lactation animals (1.2). Table 10 shows the least square means values for lactation number crossed by pen. Fourth lactation and higher cows in the sand pen (2.1) had significantly higher lameness scores than all other lactation/pen combinations. Also, 4th lactation cows in the DMS pen had significantly higher lameness scores than 3rd lactation cows in the DMS pen, 2nd lactation cows in the sand pen and 2nd lactation cows in the DMS pen. Third lactation cows in the sand pen had significantly higher lameness scores than 2nd lactation cows on sand and 2nd lactation cows on DMS. There were no other significant differences.

Table 10: Mean Lameness Score by Type of Bedding Crossed with Lactation Number for Cows on DMS and Sand

Pen	Lactation	Lameness Score
Sand	2nd	1.2^{d}
DMS	2nd	1.1^{d}
Sand	3rd	1.5^{bc}
DMS	3rd	1.3^{cd}
Sand	4th and greater	2.1^{a}
DMS	4th and greater	1.6^{b}

Values in each column with different letters are significantly different ($p<0.05$)

7) Will the bacterium that is responsible for Johnes disease remain viable in DMS?

There is some concern that since the bacteria responsible for Johnes disease (*Mycobacterium Avium paratuberculosis* –MAP) is shed in the manure, using manure solids as bedding may spread the disease throughout the herd if the bacterium remains viable in the DMS. MAP was found in small numbers in several of the unused bedding sources, including sand. The fact that MAP is not necessarily destroyed by separation, digestion or drum composting means that there could be some potential for the spread of Johnes through the use of DMS if bedding calves with DMS because they might be more inclined to eat it than adult animals.

8) What are the economic implications of DMS?

Economic analysis showed that the cost of using manure solids as bedding produced savings of between 1 and 26 cents per hundredweight (cwt) of milk produced (Table 11). All five farms saved money using DMS through reduced costs of manure hauling and purchased bedding, and one farm was able to make money through the sale of DMS. Total savings, of course, depends on the amount of milk produced. For example, at the farm that showed a savings of 20 cents/cwt, total milk sales for the year were 38,325,000 lbs, saving the farm 383,250 * 0.20 = $76,650 on the cost of producing milk that year.

Table 11: Total Costs and Returns from Using Manure Solids as Bedding on Five Study Farms

	Returns (d) = a + b + c					
Farm	DMS sales (a)	Savings on manure hauling (b)	Savings on purchased bedding (c)	Total fixed and variable expenses (e)	Annual cost to farm = (e – d)	Annual cost per hundredweight of milk
B	$0	$5,490	$57,200	$51,750	-$10,940	-$0.05
C	$0	$8,450	$44,800	$22,236	-$31,014	-$0.08
D	$0	$8,325	$53,082	$59,856	-$1,552	-$0.01
E	$0	$8,425	$156,115	$87,161	-$77,378	-$0.20
F	$15,000	$50,000	$81,600	$79,257	$67,343	-$0.26

Conclusions

This study suggests that properly managed DMS can provide an economic benefit without compromising herd health. As with any bedding, keeping the stalls free of fresh manure and urine will help insure that DMS bedding is properly managed and will provide cows with a clean, comfortable space in which to lie. In addition, one DMS strategy is no better/different than any other in terms of the product produced, so choose a DMS strategy that is affordable and fits into normal farm procedures.

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