Waste Wallboard and Wood Fiber for Use as an Alternative Dairy Bedding Material

Final Report for Resource Recovery Fund Board

September 13, 2013

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Funding provided by:

Resource Recovery Fund Board (RRFB) Nova Scotia
Truro, Nova Scotia

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Summary

Competition for wood products in Nova Scotia has increased the cost and availability of wood residue for animal bedding. Most dairy farms utilize straw, sawdust and wood shavings for bedding material. The dairy industry has been exploring alternative materials for bedding such as sand and peat. Waste wallboard and wood fiber are viewed as problematic materials that need increased diversion options from landfills. Using waste wood-wallboard fiber as an alternative bedding material may not only provide an economic alternative for the dairy industry, it can also provide recycled gypsum for improved soil health when applied to agricultural fields.

A bedding alternative must be at least as good as traditional bedding materials, be free of contaminants, be economical and cannot compromise udder health and milk quality. The waste product (75% wood fiber: 25% wallboard) was tested in comparison to kiln dried shavings and sawdust to ensure it is safe to livestock and the environment in two dairy barn systems; Compost dairy barn and Freestall barn. Testing included bacterial populations on bedding and cow teats, heavy metals, organic contaminants, cow comfort (length of lying time), hock health, cow cleanliness, odor, absorbency, ease of handling, nutrient value when applied to agricultural fields, and economic comparison to traditional bedding. An agriculture awareness program of the alternative bedding was also implemented.

Cyanide, asbestos, TCDD, PCB and organochlorine pesticides were not detected in either pre or post-commercial wood-wallboard fiber bedding. All other organic contaminant levels detected were far below levels of concern and wood-wallboard fiber tested similar to kiln dried shavings and sawdust.

Heavy metal testing for all three bedding materials tested below the Canadian Food Inspection Agency (CFIA) regulated maximum metal levels for products that are sold to be applied to agricultural land. The wood-wallboard bedding had the highest level of metals but was far below CFIA maximum allowable levels. Other metals were tested but there are no maximum allowable levels. The kiln dried shavings had the highest metal levels but tested at low levels.

Hydrogen sulfide and Formaldehyde gases were tested in both barns and during agitation of the manure pit. Neither gas was detected in either the Compost dairy barn or the Freestall barn.

The wood-wallboard bedding provides approximately 6 % sulfur, 10% calcium and 30% organic matter. Maritime soils are low in sulfur and calcium. The wood-wallboard bedding provided a higher soil amendment value than the other two beddings.

The total absorbency of the wood wallboard is higher than that for shavings or sawdust. It starts out at low moisture content and can absorb more moisture than sawdust or shavings on a volume basis. Kiln dried shavings are similar to wood wallboard, usually less than 18% while sawdust is usually between 40-60%. Low moisture content is important for restricting bacteria growth and absorbing animal waste

Restricting bacteria growth is one of the most important aspects of bedding material. Bacteria count readings of more than 1,000,000 colony-forming units per ml (cfu/ml), referring to “total coliform count”, is seen as a tipping point of increased risk of new infections. The project tested for total coliforms, Klebsiella and Streptococcus.

August typically has the highest bacteria tests due to hot humid conditions. The Compost dairy barn, showed no difference between wood-wallboard bedding and kiln dried shavings for bacteria counts. At day 14, the bacteria counts were 11,025 for dried kiln shavings and 49,627 for wood-wallboard. Both were below the threshold levels. In the Freestall barn, at day 14, the bacteria counts were 14 million for sawdust and 497,649 for wood-wallboard bedding. Not only was there a significantly large difference in bacterial counts between the bedding but the wood-wallboard bedding was low for the month of August.

Average of bacteria tests in bedding for the year mostly showed that wood-wallboard counts initially started out higher but, after use, the dry kiln shavings and sawdust quickly caught up and in the case of sawdust surpassed bacteria levels.

As with the bedding bacteria counts, a total coliform reading of more than 1,000,000 in teat sampling is seen as a tipping point of increased risk of new infections. The average tests for the year in the compost dairy barn showed the bacterial burden at the teat end was not different for either the wood-wallboard or the kiln dried shavings. In the Freestall barn, the bacterial burden at the teat ends was very low for all categories, but was greater for the streptococci in the wood-wallboard bedding group. Regarding teat end bacteria counts, generally there were no differences and levels were fairly low.

Cow cleanliness is a key management tool for dairy farms. There is a correlation between cow cleanliness and mastitis control. The udder hygiene scoring chart assesses each cow and the goal is to have at least 80% of the cows in the first two scoring categories. In the Compost dairy barn, the high group was bedded on kiln dried shavings and the low group was bedded on wood-wallboard. All readings from wood-wallboard bedding scored better than the kiln dried shavings bedding. In the Freestall barn, after the initial reading, which was above the preferred reading of less than 20%, the scores dropped into the recommended range and remained there for the remainder of the project.

Hock appearance scoring is a method to measure the cow comfort of the bedding and bedding surface. The hock appearance scores of the Compost dairy barn were all in the preferred range of less than 20%. Initially, the wood-wallboard group had a better rating then the group bedded on kiln dried shavings, but by the end of the trial all hock scores were in the excellent range. The hock appearance scores in the Freestall barn varied during the trial. The scores ended where they started in the trial. The trend would indicate that the wood-wallboard bedding is similar to the traditional sawdust bedding used by most dairy farmers.

Cow standing and lying behavior was assessed using HOBO dataloggers, which record timed data for leg position. The lying times were quite good in both barns. In the Compost dairy barn, there was a small difference in lying time between the kiln dried shavings (13.8 hrs) and the wood-wallboard bedding (12.1 hrs). For the Freestall barn the lying time was 13.7 hours regardless of bedding type. The cows were comfortable on all three bedding types.

The wood-wallboard bedding is a more economical product than the kiln dried shavings and sawdust. Based on current pricing, it costs 30% less than sawdust and 20% less than kiln dried shavings based on the same cubic meters of product. As competition for traditional wood residues increase, the savings will be even higher.

The project indicates that udder health and milk quality are not compromised and that waste wood-wallboard fiber can be diverted from the landfill to provide a safe economically viable alternative bedding material. Overall, the wood-wallboard bedding has shown to be in most cases, equivalent or superior to the traditional kiln dried wood shavings and sawdust.

Introduction

Potential Impact of Waste Wallboard and Wood Fiber on Waste Diversion to Agriculture

The Nova Scotia Solid Waste-Resource Management Strategy is committed to diverting waste material from the landfill to the production of value-added products.

Waste wallboard and wood fiber, which includes clean, painted, plywood, MDF, particle board, etc, are viewed as problematic materials that need increased diversion options. Disposal of waste wallboard at landfills can lead to anaerobic conditions which allow bacteria to release hydrogen sulfide gases. Even low concentrations of these gases are noxious. Wood fiber takes a lot of space at the land fill, up to 4 m^3 per tonne as compared to 0.8 m^3 per tonne of asphalt shingles.

The 2006 C&D Debris Management Study by Dillon Consulting Limited indicated that there is 50,000 tonnes of wallboard and 100,000 tonnes of wood fiber waste in Nova Scotia. This represents over 75% of the C&D waste stream therefore finding a valuable alternative use for these materials would significantly impact the diversion of waste per capita goals of Nova Scotia.

The principle ingredient of wallboard is gypsum (calcium sulfate) that is pressed between two sheets of paper. It is usually comprised of 92% gypsum, 7% paper and less than 1% impurities or additives.

Using natural gypsum for a soil amendment is not a new idea to agriculture but the use of recycled gypsum from new construction waste wallboard has only been recently considered. There have been good results with land application of natural gypsum therefore the application of ground waste wallboard should provide similar results.

There has been some work on using natural gypsum for agricultural bedding. Research conducted by the University of Wisconsin found that gypsum improved barn air quality by tying up ammonia in manure, stayed in suspension in slurry tanks and pits and did not compromise manure pumps. Wallboard can work successfully as a bulking agent, absorbing excess moisture, reducing odor and adding calcium, sulfur, and carbon to the bedding mixture.

There has been limited use of clean pre-consumer wallboard for bedding but there has been no research on using waste wood fiber or post-consumer wallboard as components of dairy bedding materials.

A number of Nova Scotia dairy farmers have used natural gypsum for bedding but a significant disadvantage is that it gets hard and clumpy when wet which causes handling problems. Waste wallboard is bulkier which improves cow comfort and may address those problems.

Using waste wood-wallboard fiber as bedding material may not only provide an economical alternative for the dairy industry, but will also provide recycled gypsum for improved soil health when the bedding/manure material is applied to agricultural fields.

The use of waste wood-wallboard fiber for an alternative dairy bedding material can have a considerable impact on the Strategy to reduce waste per person in Nova Scotia. According to The RRFB Research and Development Program Guidelines, Nova Scotia Waste Information, diversion of 5,000 tonnes is rated as high and may have an impact of 5.5 kg/person or more on waste diversion.

Using waste wood-wallboard fiber as an alternative bedding material has a potential to divert over 90,000 tonnes of C&D waste from regional disposal sites across the province each year. This equates to the space of 48 soccer fields piled 1 meter high or 5 soccer fields piled 10 meters high.

The demand in the agricultural industry for wood-wallboard fiber bedding should provide economic opportunities for the newly created value-added product. This includes manufacturing of the product and required transportation from various C&D Municipal landfills.

There are approximately 243 dairy farms in Nova Scotia that could potentially utilize wood-wallboard fiber as a bedding alternative. The wood-wallboard fiber can also be used in the beef, sheep and horse industries.

Gypsum Use in Agriculture

Farmers have had good results with the application of natural gypsum as a soil amendment. Gypsum has many benefits when applied to the soil. It:

- provides calcium to the crop. Maritime soils are non-calcareous therefore most agricultural soils are deficient in calcium. Calcium is very important for many plant processes. Gypsum contains approximately 21% calcium.

  The Nova Scotia Department of Agriculture Laboratory (NSDA) recommends an optimum soil calcium level of 5610 kg/ha. Based on over 74,000 soil test results from across the province from 1999-2008, no soil tests were at the recommended level. The median soil test was 2360 kg/ha which means that 50% of the soil tests are at less than one half the recommended level.

- provides sulfur to the crop. Sulfur is very important for root growth, seed production, improving shoot and root growth and density, resistance to cold, reduction in disease susceptibility, increases forage protein levels and helps with shallow root systems. Gypsum contains approximately 15% sulfur.

  Historically sulfur was not applied to land, as pollution has contributed to high sulfur levels in the soil. Over the past few years, industry has been cleaning up their air pollutants therefore Maritime soil test levels have dramatically decreased and it is affecting crop yield and quality. Most soil tests since 2008 are below the optimum soil levels of 40 kg/ha therefore sulfur is now added to fertilizer mixes.

- provides boron to the crop. Maritime soils are very low in soil boron levels with most testing at 0.5 ppm or less. Crops require from 1-3 ppm for optimum growth therefore boron is regularly added to fertilizer mixtures.

Gypsum can also improve soil structure and health. It:

- improves soil structure by keeping the soil loose and helping particles form small soil clusters with air pockets.
- helps the soil dry out more quickly after a rain.
- reduces soil erosion and helps to prevent crusting
- binds organic matter to clay to provide stability to soil aggregates
- increases soil microorganism "health".
- improves nutrient availability to the crop i.e. zinc, phosphorus and potassium.
- can reduce amount of nitrogen gas lost from urea fertilizers.

Over 80% of Nova Scotia soils have below optimum pH levels for crop production. Although gypsum does not increase soil pH, it does provide many benefits to overcome acidic soil problems.

Nova Scotia Dairy Industry

Competition for wood products in Nova Scotia has increased the cost and availability of wood residue for animal bedding. Most dairy farms utilize straw, sawdust and wood shavings for bedding material. The dairy industry has been exploring alternative materials for bedding such as sand and peat. The Dairy Industry has been exploring alternative materials for bedding such as sand and peat moss. Alternative bedding materials cannot compromise udder health and milk quality. A new bedding product must be at least as good as existing bedding materials. As Nova Scotia continues to explore biomass production for energy, these wood products will be even more difficult to access for use as bedding materials.

Bedding can be made of organic or inorganic materials. Organic bedding materials are usually plant by-products such as straw, hay, wood shavings, composted manure, sawdust, etc. They usually work with available manure handling systems. The disadvantage of these materials is that they support the growth of bacteria in moist conditions. Straw can promote the increase of fly populations and long cut straw and hay does not work with some manure handling systems. There has been cow hock problems associated with the use of straw and shavings due to poor cushioning. Currently, sawdust is the primary choice by dairy farmers.

Inorganic materials do not support the growth of bacteria (at least until mixed with organic material) but can be difficult to integrate into typical manure handling equipment. An example of inorganic bedding is sand. Sand is easy to store outside and is a dry product. It can be expensive, very heavy to handle for disposal and difficult to clean out of manure storages.

Barn housing design affects bedding options. There are several dairy housing systems used in Nova Scotia with the majority of farms using Freestall housing. There has been a growing interest in compost dairy barns which offers loose housing. This system has shown good cow comfort and freedom of movement.

Freestall System. A Freestall system allows the cows to move freely from their resting and eating areas. The resting areas are comprised of stalls where they can rest and lie down. A Freestall must be comfortable, clean and prevent injuries. The stalls need to allow room to enter and exit, lie down and stretch. Most stalls have cushioning mats but still require bedding to maintain clean and dry conditions.

Compost Dairy Barn (CDB). A CDB generally has a center concrete feed alley with a bedding pack on either side of the alley. The cows can stand on the concrete on either side of the feed alley for feeding and then move onto the bedding pack for rest. The pack is aerated twice a day to enhance microbial activity and freshen the pack surface. This is done with a cultivator on the back of a tractor which incorporates the manure on the surface into the bedding pack material. A CDB may have lower bacteria counts because of the drying and heating of the compost. Bedding material is added to pack when it becomes too moist. Bedding material is usually removed once per year and applied onto farm fields.

Bedding Criteria

The choice of dairy bedding should meet a number of criteria for optimum animal comfort and farmer ease of use. These include:

- **Restrict bacteria** – restricting bacteria growth is one of the most important aspects of good bedding material. Cows require clean, dry, low-bacteria bedding. Bacteria counts should be lower than 5,000 colony-forming units per ml (cfu/ml) of bedding. If counts are above 1 million, there is higher probability of disease incidence.

  Mastitis is the most common and costly disease of dairy cows. High bacteria levels in bedding materials lead to high bacteria levels on teat surfaces. This can increase the incidence of mastitis, reduce production, affect milk quality, etc. Mastitis is the inflammation of mammary gland tissue which can be potentially fatal. White blood cells are released into the mammary gland as a response to invasion of bacteria through the teat. The gland is damaged by the bacterial toxins. Symptoms include swelling, high temperature, hardness and pain. Milk from the infected cows have a high somatic cell count and cannot be used for human consumption. This condition occurs in all lactating mammals including humans.

- **Absorbency factor** – a primary function of bedding is to absorb moisture from manure and urine production. It should be absorbent and long lasting. Particle size can affect its absorbency factor and its ability to harbor bacteria. Sawdust is usually 50% moisture, while wallboard has about 17% moisture. The drier wallboard and wood fiber could decrease conditions such as hoof problems due to lower moisture content.

- **Access and cost of material –** bedding should be easily accessible throughout the year and be cost effective.

- **Storage –** depending on the farm storage capacity, bedding may be stored inside or outdoors. If it has to be stored outdoors, it should be able to shed water and not lose its absorbency factor.

- **Ease of handling** – bedding should be easy to handle for application in the barn, removal and disposal of soiled bedding. It should easily integrate into current manure handling systems. For a liquid manure system, it should be able to mix into manure slurry. Bedding should be labor efficient.

- **Cow comfort –** a soft dry comfortable resting area for cows is very important for health and performance. Cows can rest 12-14 hours per day, spread throughout several resting periods. Bedding must provide nonabrasive cushioning for all points of contact for hocks, knees, hips, and udders. Good footing is also important to reduce injuries. The longer the lying down time in a dry location, the better the milk production and life of the animal.

Important Considerations for Successful Implementation of a Wood-Wallboard Bedding Program:

- Waste wood-wallboard fiber must be free of screws, nails and other contaminants. This is usually not a problem with new pre-commercial wall board but may be difficult to ensure no contaminants from renovation and dismantling projects. Some products may have additives that may not be approved for use by Agriculture or Environment.

- If using engineered wood and post-consumer wallboard, then contaminants cannot exceed regulatory levels.

- It is essential that udder health and milk quality is not compromised through the use of alternative bedding materials.

- Farmers are unwilling to pay for a product that doesn’t perform better or at least as good as current bedding options.

- Farmer education programs must be implemented for successful uptake by the industry. This should include presentations to farm groups, development of factsheet and tours at the project farms. Information should include safety of the product, BMP for use of the product, comparison of product to other current practices (which includes absorbency, bacterial information and economics) and nutrient value when applied to farm fields.

  Also, as part of the education process, awareness needs to be increased on shared stewardship on material re-use. Using the alternative bedding will not only benefit the Agricultural and Construction Industries but also the Nova Scotia Community through meeting waste diversion goals.

Testing Results

Mixture and Particle Size

Absorbency of waste wood-wallboard fiber is an important criteria for dairy bedding. Particle size can have an effect on both absorbency and bacterial growth. Larger particles support less bacterial growth but smaller particles are more absorbent.

Mixtures of waste wood-wallboard fiber were produced: 25:75, 50:50, 75:25. The participating farmers reviewed the mixtures and determined that the 75 (wood fiber): 25 (wallboard) mixture was best suited for their farms. This was the product that was initially produced and sent to the farms in May.

After using the waste wood-wallboard bedding, it was determined that the wood fiber particle size was too large for cow comfort and hock health. Product shipments were delayed until particle size was decreased to meet bedding standards.

New product with smaller wood fiber particle size was shipped from July, 2012- April, 2013. The 75:25 mixture continues to be used in the Freestall barn. This mixture did not work for the compost dairy barn. The composting process was affected by reduced temperature and aeration in the pack. The mixture was changed to 100% wood fiber towards the end of the project for the Compost dairy barn. This still did not improve the composting process.

Moisture content was 7.2% pre-commercial and 16.9% post-commercial.

Substances of Concern

Organic Contaminants

Due to potential concerns on post consumer products, metals and organic contaminants (flame retardant, asbestos, pentachlorophenol, organochlorines, etc) laboratory testing was conducted on pre and post consumer wood fiber and wallboard. Twenty-three organochlorine pesticides, 36 flame retardants, PCBs, and 60 dioxins and furans were tested as well as cyanide and asbestos.

Table 1 – Organic Contaminants Testing on Pre and Post Commercial Waste Wood-Wallboard Fiber

		Pre-Commercial	Post Commercial
Other			
Cyanide		0	0
Asbestos		0	0
Pentachlorophenol (SVOC)		0	0
Organochlorine Pesticides			
a-Chlordane (Hfx 2012-03)	µg/kg	0	0
Aldrin (Hfx 2012-03)	µg/kg	0	0
g-Chlordane (Hfx 2012-03)	µg/kg	0	0
o,p'-DDT (Hfx 2012-03)	µg/kg	0	0
Polybrominated Dephenylethers (PBDE's) - Flame Retardants			
2,6-Dibromodiphenylether (Hfx 04-2012)	pg/g	0	0
2,4,4'-Tribromodiphenylether (Hfx 04-2012)	pg/g	5.9	190
2,3,3',4,4',5-Hexabromodiphenylether (Hfx 04-2012)	pg/g	0	0
2,2',3',4,4',6,6'-Heptabromodiphenylether	pg/g	0	0
Polychlorinated Biphenols (Total PCB's)			
Total PCBs	mg/kg	0	0
Dioxins & Furans (Soil, WHO 2005)			
2,3,7,8-Tetra CDD	ng/kg	0.4	0
Total Tetrachlorodibenzodioxins	ng/kg	3.2	0.8
Total PCDDs	ng/kg	92000	159
Total PCDFs	ng/kg	5060	24.8
2,3,7,8-Tetra CDD (TEF 1.0)	TEQ	0.435	0
1,2,3,7,8,9-Hexa CDF (TEF 0.1)	TEQ	0.828	0

*See the Appendix for the full list of testing results.

Cyanide, asbestos and organochlorine pesticides were not detected in either pre or post-commercial wood-wallboard fiber mixture.

Dioxin and Furans are general terms used for hundreds of chemicals that persist in the environment. Sources of dioxins and furans in Canada include fuel burning, electrical power generation, tobacco smoke and burning of plastics. 2,3,7,8-TetraCDD (TCDD) is considered as one of the most toxic dioxin compound.

There are no Canadian national standard level for levels of dioxins and furans in compost or other products used in agriculture. Compost studies in Quebec and Nova Scotia showed an average of 9.7 ng I-TEQ/kg with a range of 1-31. Quebec C2 has a dioxin and furan quality standard of 50 ng TEQ/kg for any residuals applied on agricultural land. USEPA uses 300 ng TEQ/kg as the risk based criteria.

The post commercial waste wallboard and wood fiber tested at 0 TEQ for TCDD. It also tested 0 for PCB’s. All other levels detected were far below levels of concern.

Heavy Metals

The Canadian Food Inspection Agency (CFIA) regulates maximum metal levels for products that are sold to be applied to agricultural land. The metals include arsenic, copper, molybdenum, cadmium, cobalt, mercury, nickel, lead, selenium, zinc and chromium. These metals were tested in the waste wood-wallboard fiber, kiln dried shavings and sawdust bedding.

Other metal tests included aluminum, antimony, barium, beryllium, bismuth, iron, lithium, magnesium, manganese, rubidium, silver, sodium, strontium, tellurium, thallium, tin, uranium and vanadium. There are no maximum allowable levels for these metals in agricultural products.

Chloride was also tested as it was identified as a possible concern if applied at high rates. Chloride is a plant nutrient; chlorine is the toxic form. Chloride is an important micronutrient. It is important in the opening and closing of stomata, balancing potassium ion concentrations, photosynthesis and other crop processes.

The chloride levels in the Compost dairy barn were higher than the Freestall barn with an average of 5324 ppm for kiln dried shavings and 5864 ppm for wood-wallboard fiber. In the Freestall barn, sawdust had an average of 2120 ppm and wood-wallboard fiber had an average of 1428 ppm. These are not high levels. In comparison, potassium chloride (0-0-60) which is typically used by dairy farmers, contains 50-60% chloride.

CFIA Maximum Allowable Levels for Agricultural Applications

A CFIA metal scan was conducted on the pre and post commercial product. Testing was also conducted quarterly on waste wood-wallboard fiber (WW), sawdust (SD) and kiln dried sawdust (KDS). Samples were taken from various stalls therefore they also included manure. All tests were far below maximum allowable levels.

Table 2 – CFIA Maximum Allowable Metal Levels Comparison between Bedding Products

Trace Metals Analysis	CFIA Max Levels	Pre-Commercial WW	Post-Comerical WW	Compost Dairy Barn WW Average	Compost Dairy Barn KDS Average	Freestall WW Average	Freestall SD Average
Concentration (mg/kg)							
Arsenic	**75**	0	7	18	0	42	0
Cadmium	**20**	0	0	0	0	0	0
Chromium	**1100**	0	16	25	6	56	3
Cobalt	**150**	0	1	1	2	1	0
Copper	**850**	3	19	88	38	143	85
Lead	**500**	4	42	32	3	109	5
Mercury	**5**	0	0	0	0	0	0
Molybdenum	**20**	0	0	0	0	0	0
Nickel	**180**	0	0	3	5	2	0
Selenium	**14**	2	1	0	0	0	0
Zinc	**1850**	18	63	164	106	110	56

*The bedding material also included manure.

The wood-wallboard bedding had the highest level of metals but was far below CFIA maximum allowable levels.

Other Metals

There are no maximum allowable levels for the following trace metals for agricultural application of materials. The CCME soil quality guidelines are used for soil suitable for use in contaminated sites and are not intended for maximum allowable levels in agricultural products. This is for information only.

Table 3 – Other Metal Level Comparison between Bedding Products

Trace Metals Analysis	CCME Soil Quality Quidelines - Agriculture*	Pre-Commercial WW	Post-Comerical WW	Compost Dairy Barn WW Average	Compost Dairy Barn KDS Average	Freestall WW Average	Free stall SD Average
Concentration (mg/kg)							
Aluminum	**NA**	423	818	817	1783	471	1127
Antimony	**20**	0	0	0	0	0	0
Barium	**750**	11	47	38	41	34	37
Beryllium	**4**	0	0	0	0	0	0
Bismuth	**NA**	0	0	0	0	0	0
Iron	**NA**	648	1310	1277	3673	1115	2394
Lithium	**NA**	0	0	0	3	0	0
Manganese	**NA**	39	87	288	410	156	283
Rubidium	**NA**	2	2	13	14	5	10
Silver	**20**	0	0	0	0	0	0
Sodium	**NA**	182	706	5086	4026	1585	2806
Strontium	**NA**	128	357	59	31	103	67
Tellurium	**NA**	0	0	0	0	0	0
Thallium	**1**	0	0	0	0	0	0
Tin	**5**	0	0	3	2	2	2
Uranium	**23**	0	0	1	1	0	0
Vanadium	**130**	0	7	0	2	0	1

***Canadian environmental quality guidelines for the protection of environmental and human health. Maximum soil levels – most metals do not have maximum soil levels.**
WW – waste wallboard/wood fiber, KDS – kiln dried sawdust, SD – sawdust. The bedding material also includes manure.

Overall, the kiln dried shavings had the highest metal levels but all were at low levels.

Gases

The disposal of waste wallboard at landfills can lead to anaerobic conditions which allow bacteria to release noxious hydrogen sulfide gases. It is important to test for the potential release of hydrogen sulfide in bedding due to direct animal exposure. Low levels can lead to irritation of respiratory systems. Hydrogen sulfide gas levels were tested with the Crowcon Tetra Channel Gas Monitor. Hydrogen sulfide gas was not detectable in either the Compost dairy barn or the Freestall barn.

Formaldehyde gas (released from resins used to manufacture wood products) could also potentially have an adverse affect on livestock health in an enclosed area. Typically there aren't problems in well ventilated areas (most barns are well ventilated). Formaldehyde gas levels were tested with s RKI Instrument Model FP-30 Formaldehyde Gas Detector. Formaldehyde gas was not detectable in either the Compost dairy barn or the Freestall barn.

Hydrogen Sulfide gas was also tested when the Freestall barn manure pit was agitated. Hydrogen sulfide was not detected.

Agricultural Soil Application Value

Waste wood-wallboard fiber (WW), sawdust (SD) and kiln dried sawdust (KDS) was tested for agricultural soil amendment value.

Table 4 – Agricultural Soil Application Value between Bedding Products

Ag Soil Value	Pre-Commercial WW	Post-Comerical WW	Compost Dairy Barn WW Average	Compost Dairy Barn KDS Average	Freestall WW Average	Freestall SD Average
Concentration (mg/kg) unless stated						
Boron	22	27	16	13	18	5
Calcium	82000	103000	27175	14225	35675	6592
Magnesium	665	3030	4131	4044	1512	767
Phosphorus	165	87	5454	5429	175	1315
Potassium	481	550	14013	13493	3245	4179
Sulfur	74700	59700	13003	5006	25013	6807
Ammonia (as N) (ug/g)	7	<5	27	18	133	87
Kjeldahl Nitrogen	0	0	12565	13865	2752	5024
Moisture (%)	7	17	60	57	30	36
Neutralizing Value (% as $CaCO_3$)	3	5	4	4	3	1
pH (units)	5	7	8	9	7	7
Total Solids (%)	93	83	40	43	70	65
Organic Matter (%)	ND	ND	78	74	82	95
Total Organic Carbon (%)	31	32	30	23	26	32

The wood-wallboard bedding material has a significant amount of calcium and sulfur. It provides approximately 6 % sulfur and 10% calcium which are important nutrients for crop production. Maritime soils are low in sulfur and calcium. Current practices include adding sulfur to fertilizer recommendations and applying calcitic lime. It also had higher nitrogen levels. Previous studies have indicated that gypsum can capture ammonium nitrogen which reduces odor.

There is little neutralizing value which is to be expected as gypsum does not neutralize soil. There is approximately 30% total organic carbon which will provide about 52 % organic matter. Manure provides the remainder of the organic matter when applied to the soil. Micro-organisms in the soil will breakdown the organic carbon and use it as an energy source which improves soil health. Organic matter can improve nutrient availability to the crop.

Optimum bedding has low moisture content for maximum absorbency. A goal of the project was to have moisture levels below 30%. Sawdust can have moisture content levels between 40-60% which is much higher than the wood-wallboard bedding at 17%. The moisture content increased as manure and urine was mixed with the bedding. The Compost dairy barn had significantly higher moisture content than in the Freestall. Overall, the wood-wallboard bedding provided a high soil amendment value.

Pathogenic Bacteria Counts

Restricting bacteria growth is one of the most important aspects of bedding material. Cows need clean, dry, low-bacteria bedding. High bacteria levels in bedding materials lead to high bacteria levels on teat surfaces. This can increase the incidence of mastitis. Mastitis continues to be the number one disease of the dairy cow and can have a major negative effect on the economics of a dairy farm.

Bacteria counts should be lower than 5,000 colony-forming units per ml (cfu/ml) of bedding. If total coliform counts are above 1 million, the bedding material puts the cows at risk.

Many research trials for the past 20 years have demonstrated that the quality of bedding used in the stalls of cows can have a significant impact on the health of the cow and the quality of the milk that she produces. The number and types of bacteria present in the bedding has a direct correlation to the risk of new infections in the cows' udder (mastitis). Mastitis continues to be the most expensive cow health issue today. Over 140 species of bacteria can cause mastitis, but a large percentage of all recorded cases today are due to environmental sources. These are microbes that the cow, and in particular, the udder comes in contact with in the environment.

The ideal cow environment is often described as "clean, dry and comfortable". The "clean and dry" was assessed by measuring the numbers of bacteria in the test bedding versus conventional bedding. Additionally, bacteria numbers on the teat ends as well as overall cow cleanliness was evaluated. Cow lying times and hock condition scoring was also evaluated.

Pathogenic Bacteria Concentrations in the Bedding Material

Bacterial populations of mastitis causing organisms (total coliform, Klebsiella spp and Streptococucus spp.) were tested in the in the wood-wallboard bedding and compared to sawdust and kiln dried shaving bedding. Tests were done on the product on day 0 (from the pile) and on day 2 and day 14 (from the stall) after fresh bedding was added.

For each farm the protocol for sample collection was similar. Both barns had six numbered locations where the bedding samples were taken at each sampling event.

At Day 0, two samples were taken directly from the delivered truckload of the bedding material. At Day 2 and 14, nine grab samples of bedding were taken from each location in the barn (back of stall for the Freestall or in a central location in the compost dairy barn) where the cows hind end (including the udder) would be located when they lay down. The subsamples were mixed to make one sample for each location. Samples (minimum of 500 cc or 2 cups volume) were taken in areas that did not have obvious fecal material. The samples were taken on the surface and not more than 1 inch deep.

Gloves were changed between each bag sample. All samples were placed in a bag, labeled and frozen until it could be shipped to the Atlantic Veterinary College (AVC) for analysis.

In the Freestall barn, bedding was removed from the back 1/3 of the stalls and replacement bedding was added as necessary.

In the Compost dairy barn, fresh bedding was added daily and the pack was aerated 1-2 times per day.

Bedding Bacteria Counts – Compost Dairy Barn – August, 2012

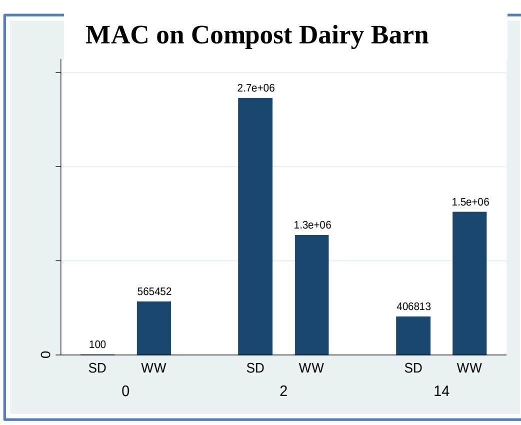
August typically has the highest bacteria tests due to hot humid conditions. Bacteria counts reading of more than 1,000,000 colony-forming units per ml (cfu/ml) is seen as a tipping point of increased risk of new infections.

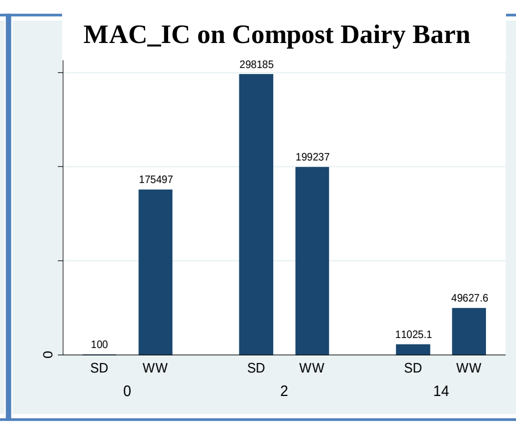
The MAC graphs identify total coliforms; the IC graphs identify Klebsiella numbers, the EMCO graphs identify Streptococcus numbers using a modified MacConkey Agar

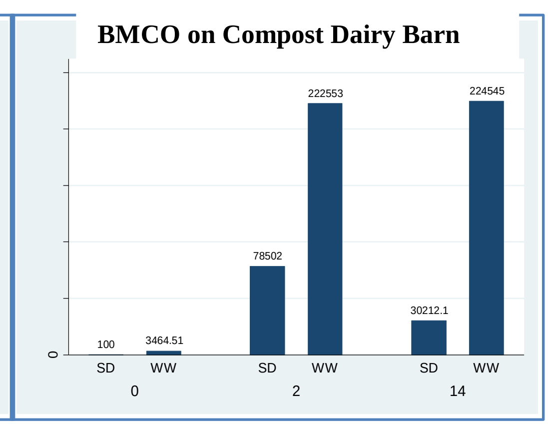
The analysis was quite different for the compost dairy barn as compared to the Freestall barn. The numbers of pathogenic bacteria are in general much lower in the compost dairy barn than at the Freestall barn.

There was no difference between wood-wallboard and kiln dried shavings, even though there may seem to be more bacteria in the wood-wallboard. The test for Klebsiella numbers shows 298,185 for the dried kiln shavings and 199,237 for the wood-wallboard at Day 2. At Day 14, the bacteria counts were 11,025 for dried kiln shavings and 49,627 for wood-wallboard. Both below the threshold levels.

Tables 5-7 Bacteria Testing in Compost Dairy Barn in August





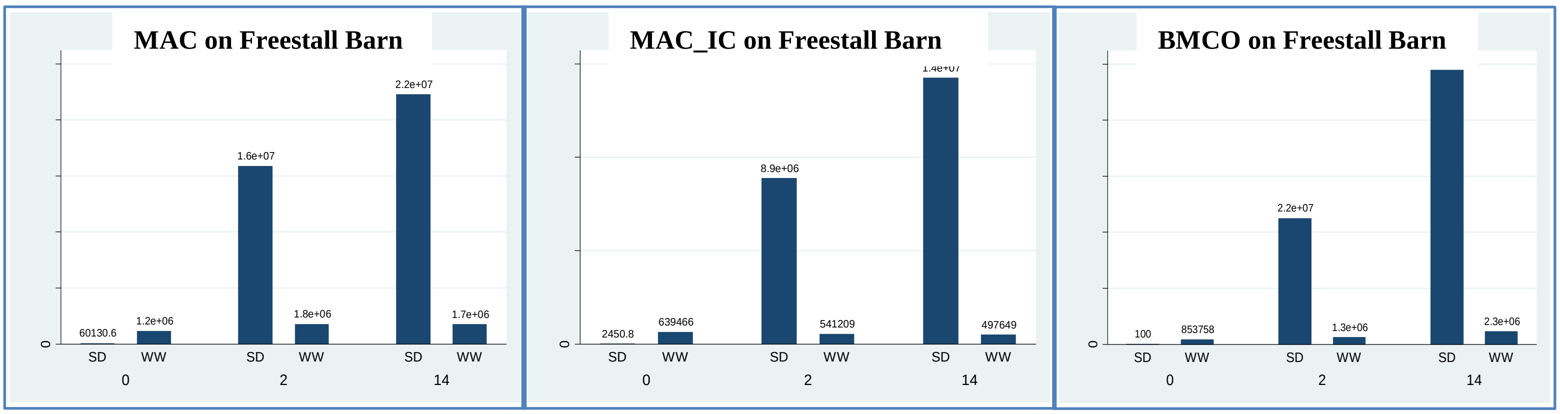


Bedding Bacteria Counts – Freestall Barn – August, 2012

In the free-stall barn, the counts for all 3 bacteria types were equal on day 0 but were statistically lower for the wood-wallboard fiber at day 2 and 14. The test for Klebsiella numbers shows 8.9 million for the sawdust and 541,209 for the waste wood-wallboard fiber at Day 2. At Day 14, the bacteria counts were 14 million for sawdust and 497,649 for waste wood-wallboard fiber.

Not only is there a significantly large difference in bacterial counts between the bedding but the waste wood-wallboard fiber bacteria count is low for the month of August (which August typically has the highest bacteria tests due to hot moist conditions)

Tables 8-10 Bacteria Testing in Freestall Barn in August



Bedding Bacteria Counts – Average of all Testing

Three media, examining different important pathogen groups, were used to assess bacterial burdens in bedding materials from the farms. The laboratory work was done with a spiral plater (able to do log dilutions on the plate) and a) a modified Edwards media (to ID Streps); b) a regular MacConkey (for gram negatives); and c) a modified MacConkeys media (to better determine the Klebsiella from other gram negatives).

Samples from each bedding were examined prior to use day 0 and at day 2 and 14 after delivery.

Most statistical procedures require data to be normally distributed (i.e. have a bell-like curve when graphed). Typically employed linear regression models could not be used for the bedding data because numbers of bacteria varied widely between bedding types and time periods (fresh versus used) and could not be transformed mathematically to create this normal curve.

As a result, a statistical procedure called a Mann-Whitney Rank Sum was used. This procedure looks at the order or rank of each bedding count number rather than its true value. This is what is termed a "non-parametric" test and does not require that the data be normally distributed. The test compares each bedding type with the next bedding type in rank and determines if they are statistically different. It is a very conservative method - i.e. if differences are found with this method, then there is confidence they are real. Alternatively, it is not very powerful - i.e. when differences are not found, they may in fact exist but the method is not robust enough to detect them. For this reason, data trends were discussed that were not statistically significant.

Tables 11 through 16 show the individual rank comparisons for each bedding type. Each barn system is considered separately because the bedding management (Compost dairy barn versus Freestall barn) is dramatically different. The letter value (A or B) and P-value indicates if the rank sum was significantly different between the bedding materials. A P-value of <0.05 is traditionally used to indicate a statistical difference beyond chance, but a P-value of 0.1 can be used to identify trends within the data. The ratio provided is the relation of observed to expected rank sum values. The distance and direction of this value away from 1 indicates the strength of the effect. **Values greater than 1 indicate more bacteria in the bedding than expected.**

Table 11. Bedding count ranks for growth on Modified Edward's media (Primarily Streptococci) for the 2 bedding materials on days 0, 2, and 14 for the Compost dairy barn.

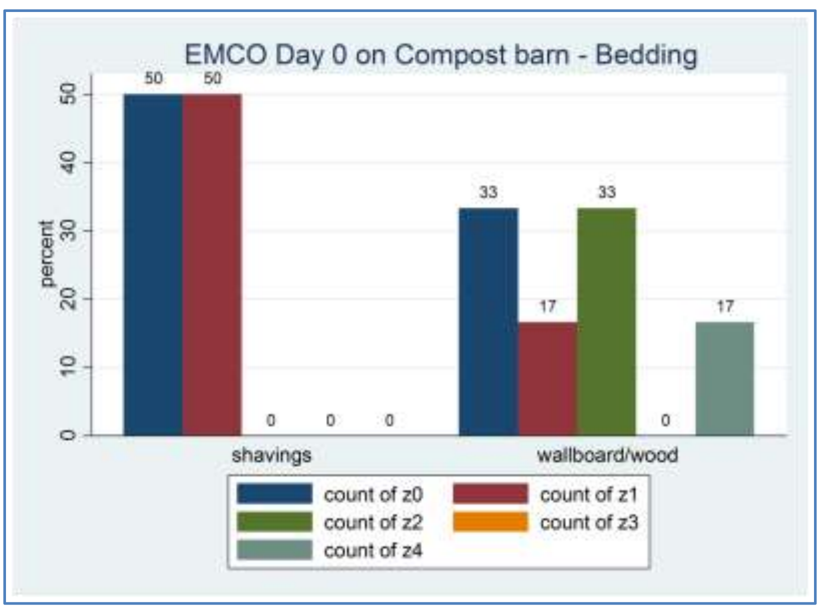
	KDS (ratio*)	WW (ratio*)	P-value
Day 0	A (0.82)	A (1.18)	0.24
Day 2	A (1.14)	A (0.86)	0.15
Day 14	A (1.15)	A (0.85)	0.11

Ratio=observed rank sum/expected rank sum

There were no statistical differences in the bedding counts between the kiln dried shavings (KDS) and the wood-wallboard (WW). The wood-wallboard started out numerically higher but, after use, the shavings quickly caught up.

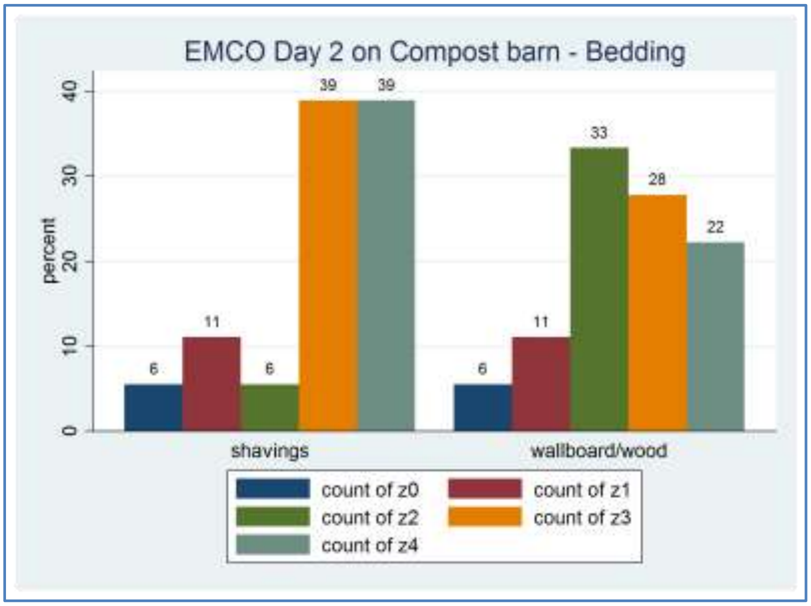
Figure 3 shows the proportion of bacterial counts above various thresholds for the Modified Edwards media. Any bedding above 1,000,000 (z3) is contaminated and, according to the literature, is at risk for intra-mammary infection. Samples with bedding counts above 10,000,000 (z4) are highly contaminated.

Figure 3. **Proportion of samples in 5 bacteria count categories for Edwards media (Streps) in the Compost dairy barn.**



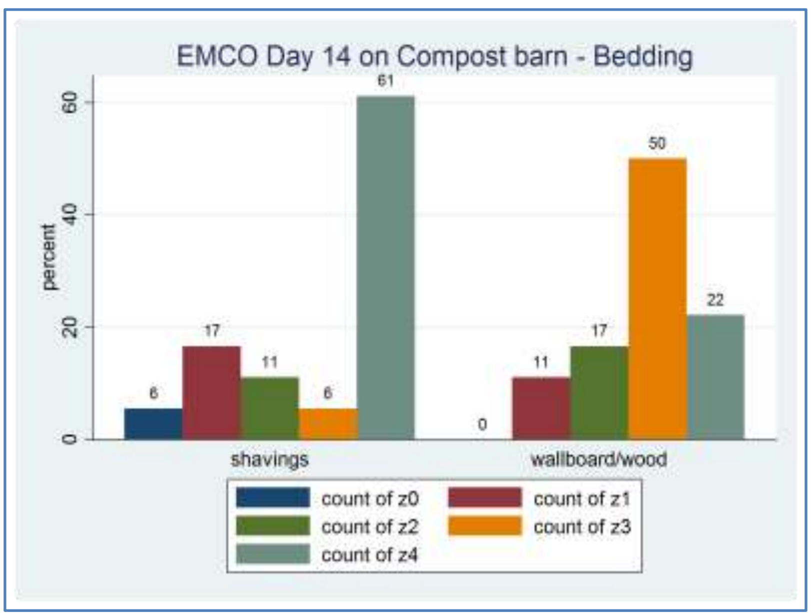
z0 = <10,000 bacteria/gram
z1 = 10,000-100,000 bacteria/gram
z2 = 100,000-1,000,000 bacteria/gram
z3 = 1,000,000-10,000,000 bacteria/gram
z4 = >10,000,000 bacteria/gram

On day 0, 17% of the wood-wallboard samples had very high bacteria counts whereas none of the kiln dried shavings were above significant thresholds.



By day 2, 78% of the kiln dried shavings samples are >1,000,000 bacteria per gram (z3 or more), whereas just 50% of the wood-wallboard samples are above this critical level.

This difference is, however not statistically different.



By day 14, numbers have stabilized, and the proportion >1,000.000 per gram is similar (67 versus 72%), however the number >10,000,000 is much higher for the kiln dried shavings.

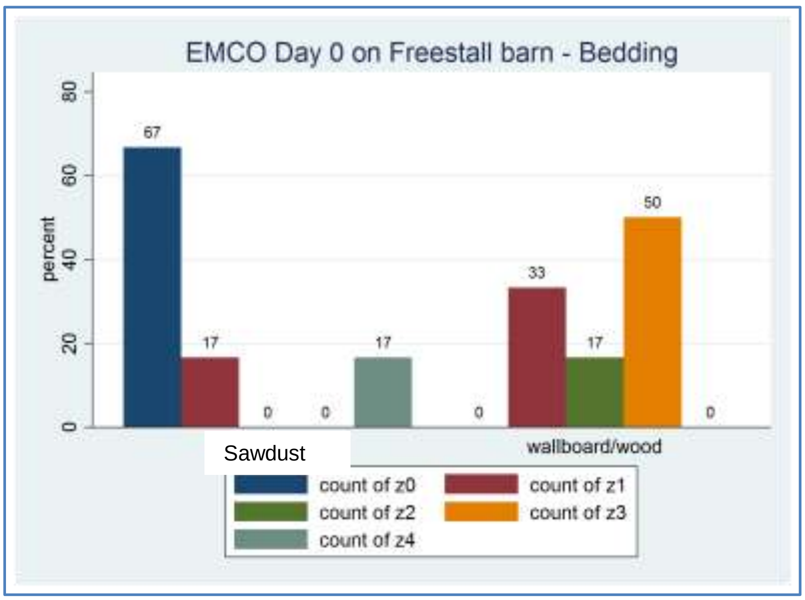
Table 12. Bedding count ranks for growth on Modified Edward's media (Primarily Streptococci) for the 2 bedding materials on days 0, 2, and 14 for the Freestall barn.

	SD (ratio*)	WW (ratio*)	P-value
Day 0	A (0.74)	A (1.26)	0.10
Day 2	A (1.18)	A (0.82)	0.06
Day 14	B (1.24)	A (0.77)	0.01

Again, Streptococci bacteria counts were marginally higher at day 0 in the wood-wallboard, but by Day 2 there was a strong trend for the counts to be higher in the sawdust and the trend was highly statistically significant by day 14.

Figure 4 shows the proportion of bacterial counts above various thresholds for the Edward media in the Free-stall barn.

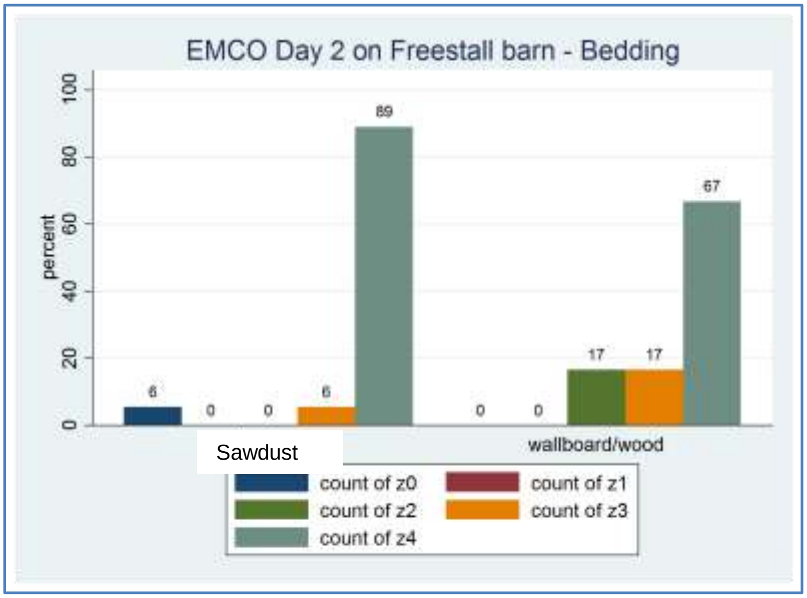
Figure 4. Proportion of samples in 5 bacteria count categories for Edwards media (Streps) on the Freestall barn.



z0 = <10,000 bacteria/gram
z1 = 10,000-100,000 bacteria/gram
z2 = 100,000-1,000,000 bacteria/gram
z3 = 1,000,000-10,000,000 bacteria/gram
z4 = >10,000,000 bacteria/gram

On day 0, 50% of the wood-wallboard was >1,000,000 streptococci bacteria per gram, whereas 17% of the sawdust were >10,000,000.

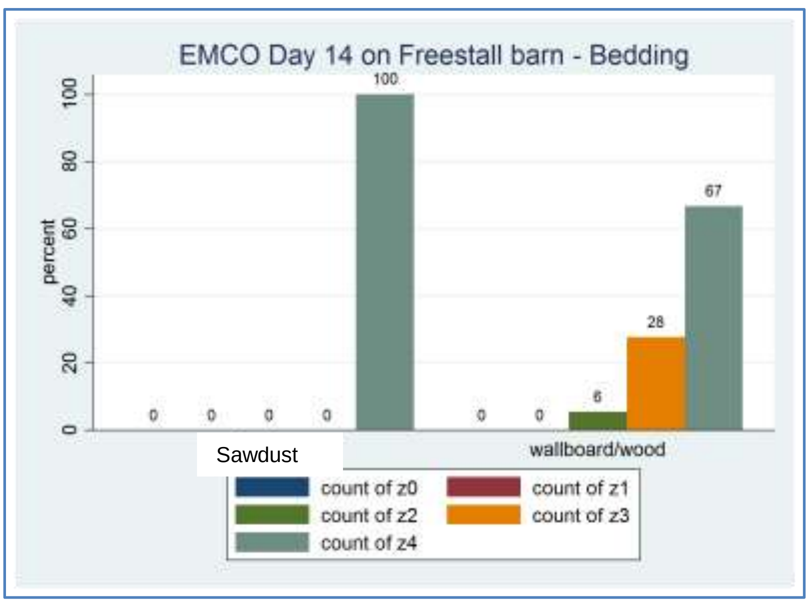
This trend is close to statistical significance indicating that the wood-wallboard starts out with more streptococci bacteria.



However, by day 2, the sawdust streptococci numbers have greatly increased.

Ninety-five percent of the sawdust was above the 1 million threshold with 89% of these above 10 million.

For the wood-wallboard 84% were >1,000,000. This trend is very close to statistical significance.



At day 14, the sawdust counts are all greater than 10,000,000, whereas the wood-wallboard numbers are consistent with the day 2 results.

This difference is now statistically significant - there are more bacteria in the sawdust samples.

Table 13 shows the individual rank comparisons for MacConkey media growth (Primarily gram-negatives) in the Compost barn.

Table 13. Bedding count ranks for growth on MacConkey media (Primarily gram-negative) for the two bedding materials on days 0, 2, and 14 for the Compost dairy barn.

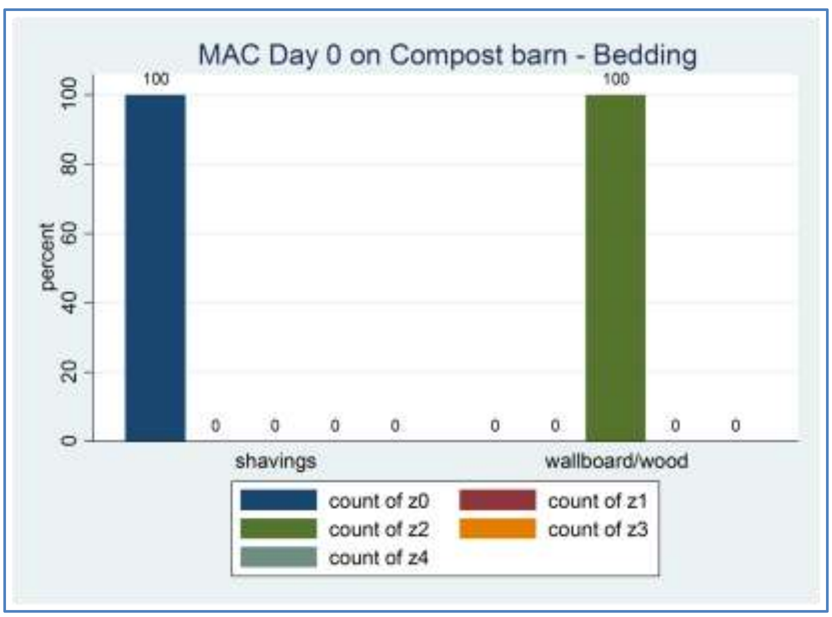
	KDS (ratio*)	WW (ratio*)	P-value
Day 0	A (0.54)	B (1.46)	0.002
Day 2	A (1.04)	A (0.96)	0.70
Day 14	A (0.81)	B (1.19)	0.04

Ratio=observed rank sum/expected rank sum

Again the wood-wallboard enters the bedding pack with higher gram negative bacteria burden than does the kiln dried shavings. However, the values are all relatively low (see figure 5 for day 0). Of greater concern is that the wood-wallboard material continues to support high bacteria burdens particularly at day 14.

Figure 5 shows the proportion of bacterial counts above various thresholds for the MacConkey media. Thresholds are similar as for the Edwards media. Any bedding above 1,000,000 is contaminated and, according to the literature, a risk for intra-mammary infection. Samples with bedding counts above 10,000,000 (10^7) are highly contaminated.

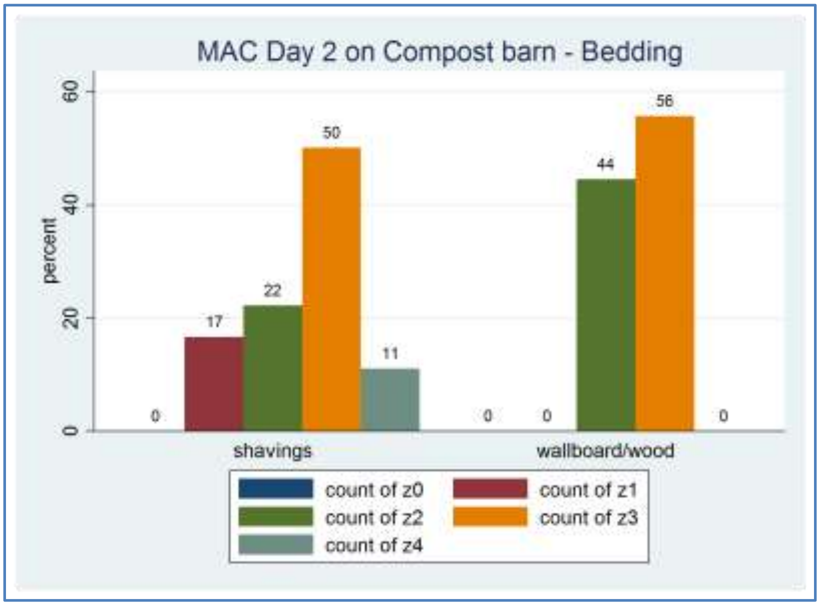
Figure 5. Proportion of samples in 5 bacteria count categories for MacConkey media (gram negatives) on the compost dairy barn.



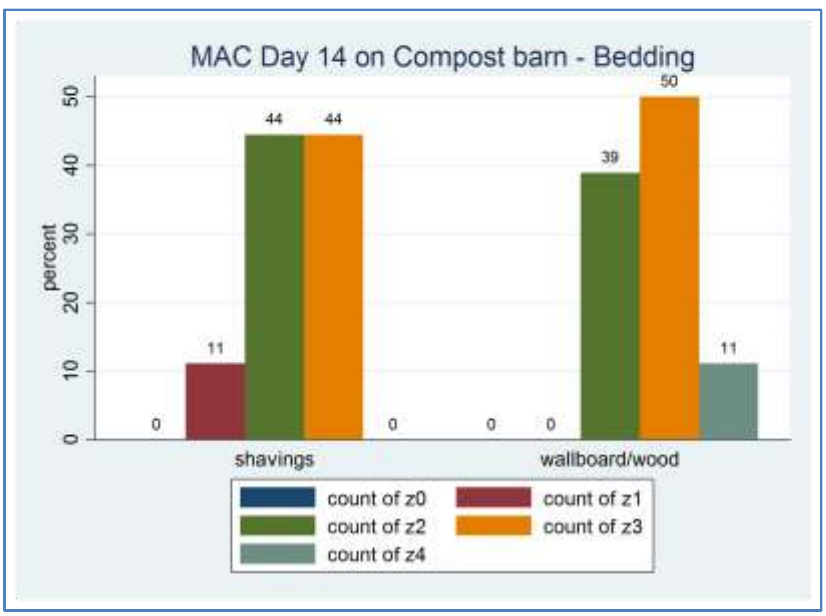
z0 = <10,000 bacteria/gram
z1 = 10,000-100,000 bacteria/gram
z2 = 100,000-1,000,000 bacteria/gram
z3 = 1,000,000-10,000,000 bacteria/gram
z4 = >10,000,000 bacteria/gram

On day 0 at the start of the trial, 100% of the kiln dried shavings were <10,000 bacteria per gram whereas 100% of the wood-wallboard was between 100,000-1,000,000.

This is a significant difference but none of the wood-wallboard samples exceeded the 1,000,000 threshold.



By day 2, 61% of kiln dried shavings and 56% of the wood-wallboard are >1,000,000.



By day 14, there are significantly more gram negative bacteria in the wood-wallboard samples.

Table 14. Bedding count ranks for growth on MacConkey media (gram negative bacteria) for the two bedding materials on days 0, 2, and 14 for the Freestall barn.

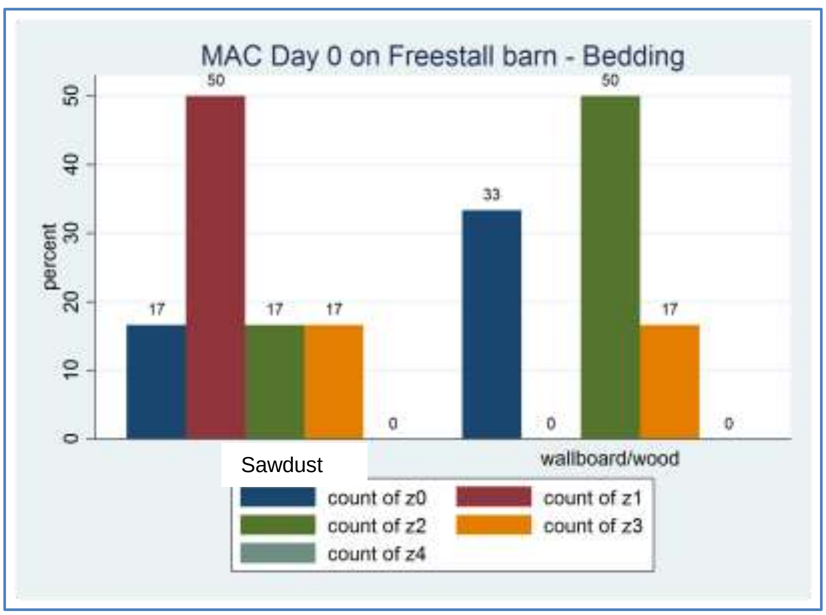
	SD (ratio*)	WW (ratio*)	P-value
Day 0	A (0.92)	A (1.08)	0.63
Day 2	A (1.04)	A (0.96)	0.68
Day 14	B (1.25)	A (0.74)	0.0100

Ratio=observed rank sum/expected rank sum

Again the wood-wallboard enters the Freestall barn with slightly higher gram negative bacteria burden than does the sawdust (not significant). However, by the end of the observation period there are more gram-negative bacteria in the sawdust bedding.

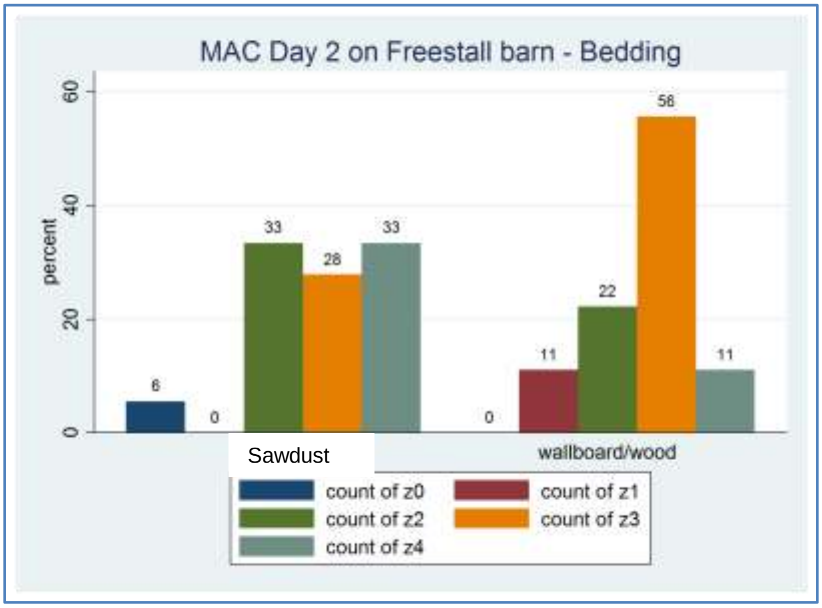
Figure 6 shows the proportion of bacterial counts above various thresholds for the MacConkey media. Thresholds are similar as for the Edwards media. Any bedding above 1,000,000 is contaminated and, according to the literature, a risk for intra-mammary infection. Samples with bedding counts above 10,000,000 (10^7) are highly contaminated.

Figure 6. Proportion of samples in 5 bacteria count categories for MacConkey media (gram negatives) on the Freestall barn.



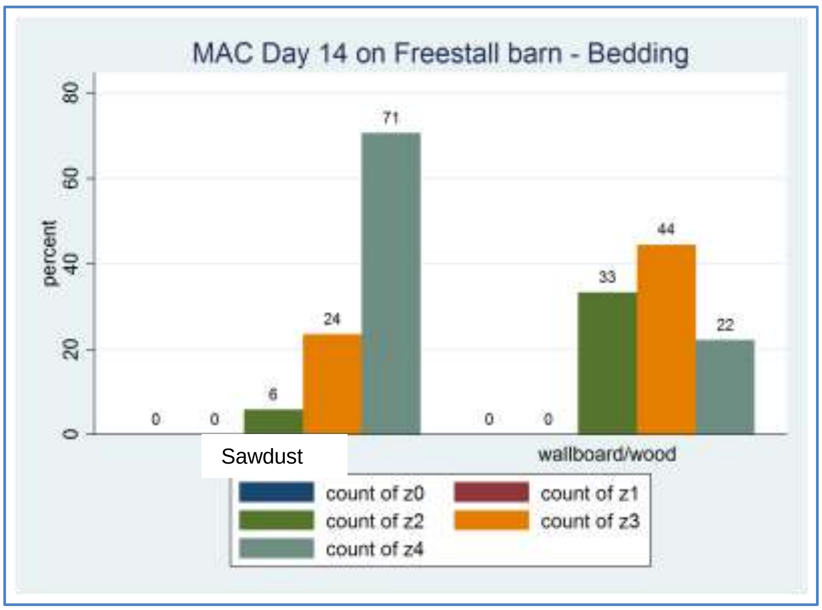
z0 = <10,000 bacteria/gram
z1 = 10,000-100,000 bacteria/gram
z2 = 100,000-1,000,000 bacteria/gram
z3 = 1,000,000-10,000,000 bacteria/gram
z4 = >10,000,000 bacteria/gram

On day 0, wood-wallboard has numerically higher gram negative bacteria counts but the difference is not significant.



By day 2, 28 and 33% of sawdust values are above 1,000,000 and 10,000,000 respectively.

For wood-wallboard, 56 and 11% of values are above 1,000,000 and 10,000,000 respectively.



By day 14, more than 70% of sawdust values > 10,000,000, whereas just 22% of wood-wallboard values reach this threshold.

This value is significantly higher.

Table 15. Bedding count ranks for growth on Modified MacConkey media (Primarily Klebsiella type) for the two bedding materials on days 0, 2, and 14 for the Compost dairy barn.

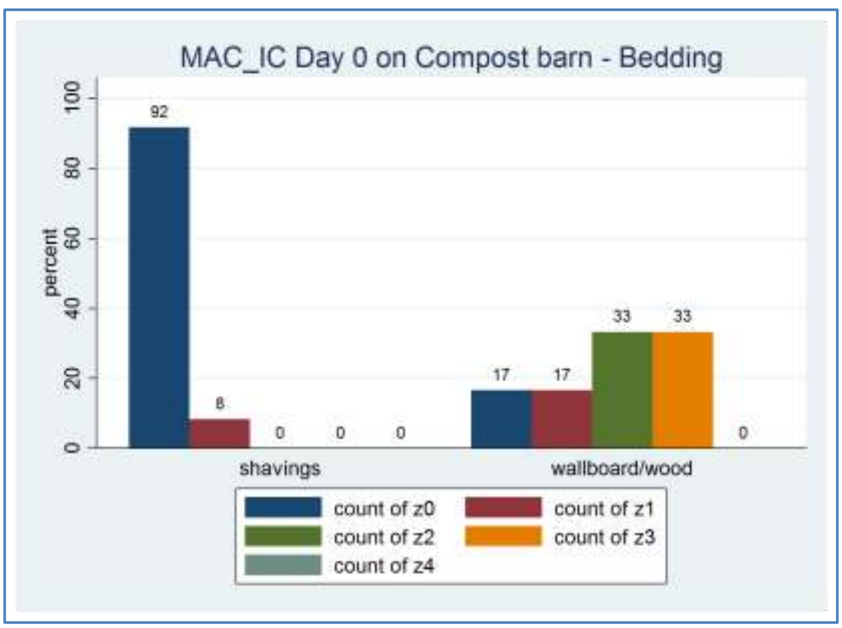
	KDS (ratio*)	WW (ratio*)	P-value
Day 0	A (0.54)	B (1.46)	0.002
Day 2	A (0.98)	A (1.02)	0.86
Day 14	A (0.86)	A (1.14)	0.14

Ratio=observed rank sum/expected rank sum

Again the wood-wallboard enters the bedding pack with higher Klebsiella-type bacteria burden than does the kiln dried shavings. The kiln dried shavings reached similar numbers within a short period of time.

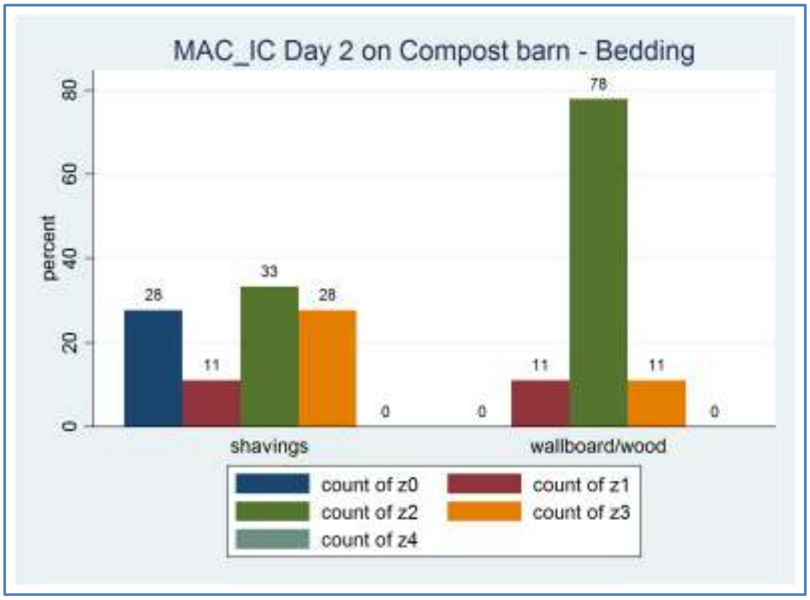
Figure 7 shows the proportion of bacterial counts above various thresholds for the Modified-MacConkey media. Thresholds for the modified MacConkey media should be somewhat lower, because these are primarily Klebsiella, but there are not well established criteria in the literature. In general, one expects them to be 1 log unit less - i.e. should be aiming to be less than 100,000.

Figure 7. Proportion of samples in 5 bacteria count categories for Modified MacConkey media (Klebsiella-type) on the Compost dairy barn.

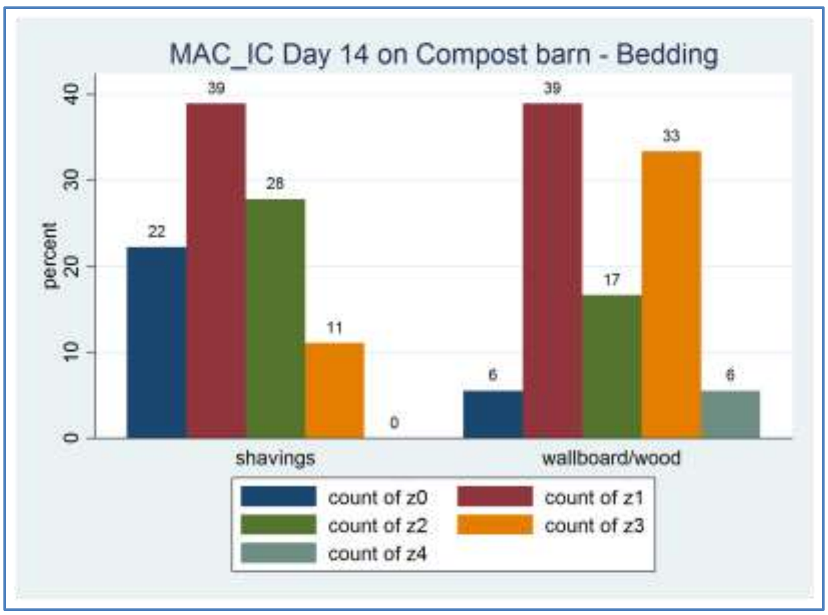


z0 = <10,000 bacteria/gram
z1 = 10,000-100,000 bacteria/gram
z2 = 100,000-1,000,000 bacteria/gram
z3 = 1,000,000-10,000,000 bacteria/gram
z4 = >10,000,000 bacteria/gram

At day 0, 66% of the wood-wallboard samples are above the 100,000 threshold with 33% being above the 1,000,000 level.



By day 2, counts are becoming more similar between the 2 materials with 28% of kiln dried shavings samples >1,000,000, whereas 11% of wood-wallboard samples are in this category. However, there are many more wood-wallboard samples in the next category (100,000-1,000,000).



By day 14, 39% of wood-wallboard samples are >1,000,000, whereas 11% of shavings samples are in this category.

Table 16. Bedding count ranks for growth on Modified MacConkey media (Primarily Klebsiella type) for the 2 bedding materials on days 0, 2, and 14 for the Freestall barn.

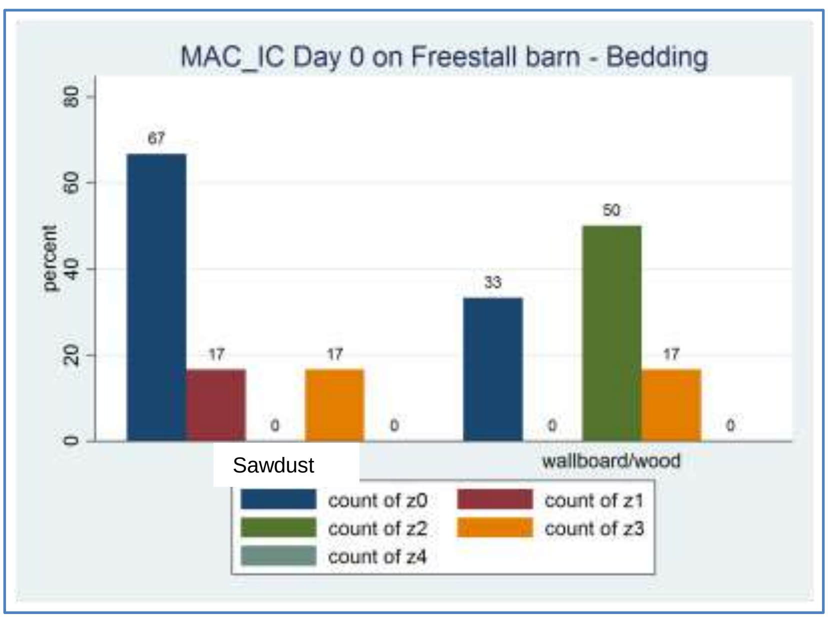
	SD (ratio*)	WW (ratio*)	P-value
Day 0	A (0.85)	A (1.15)	0.31
Day 2	A (1.12)	A (0.88)	0.22
Day 14	A (1.09)	A (0.92)	0.39

Ratio=observed rank sum/expected rank sum

Numerically there are again more bacteria in the wood-wallboard at day 0, but it doesn't take long for the sawdust to catch up once the bedding is applied on the stalls. Overall, there are no time points where the difference in bacteria burden on the modified MacConkey media approaches significance.

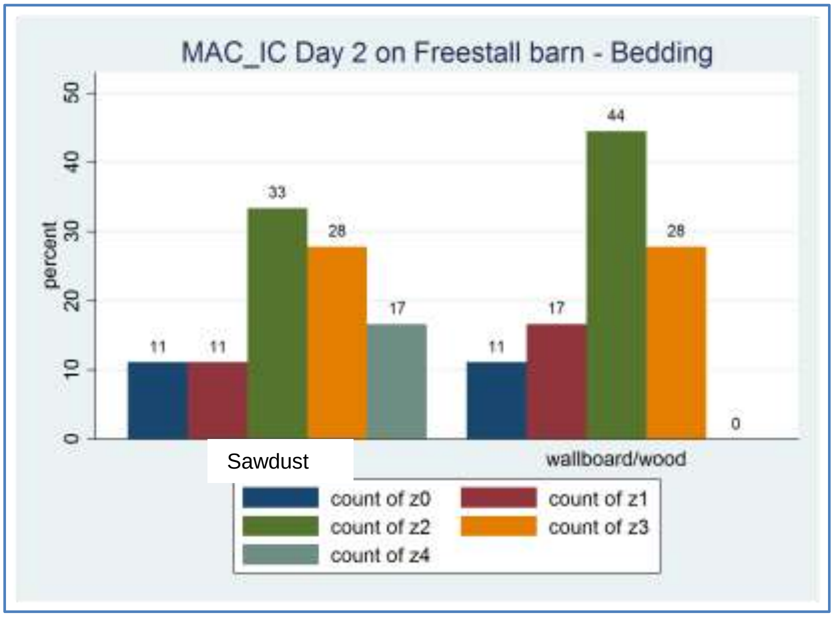
Figure 8 shows the proportion of bacterial counts above various thresholds for the Modified-MacConkey media. Thresholds for the modified MacConkey media should be somewhat lower, because these are primarily Klebsiella, but there are not well established criteria in the literature. In general, one expects them to be 1 log unit less - i.e. should be aiming to be less than 100,000.

Figure 8. Proportion of samples in 5 bacteria count categories for Modified MacConkey media (Klebsiella type) on the Freestall farm.

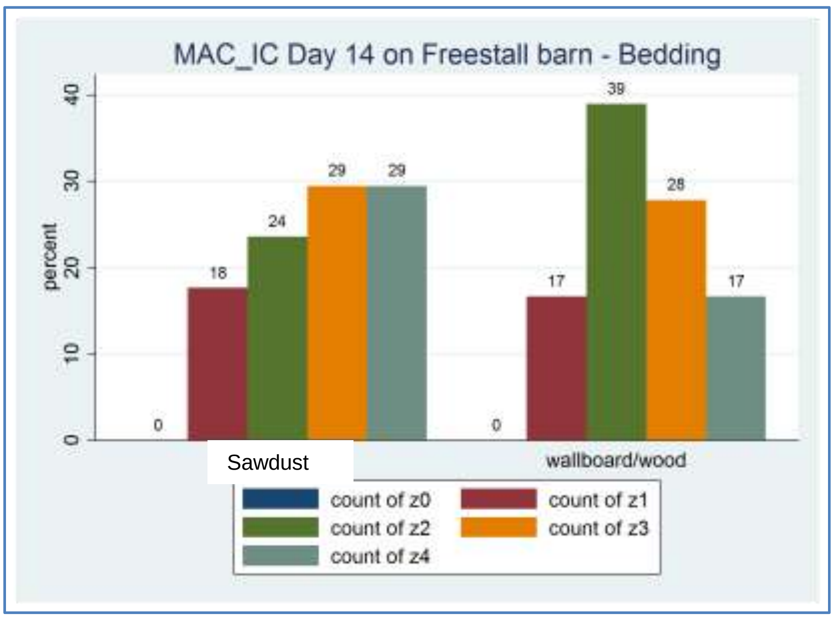


z0 = <10,000 bacteria/gram
z1 = 10,000-100,000 bacteria/gram
z2 = 100,000-1,000,000 bacteria/gram
z3 = 1,000,000-10,000,000 bacteria/gram
z4 = >10,000,000 bacteria/gram

On day 0, there is an overall trend for slightly higher bacteria counts in the wood-wallboard but there are a similar number of samples that are above the 1,000,000 bacteria per gram threshold for the two materials.



By day 2, a similar number of samples are above the 1,000,000 bacteria per gram threshold for both beddings but the sawdust bedding has 17% of samples above the 10,000,000 threshold while the wood-wallboard has 0%.



By day 14, a similar number of samples are above the 1,000,000 bacteria per gram threshold for the two materials, but there are numerically more samples above 10,000,000 in the sawdust category (29%) than the wood-wallboard treatment (17%).

Pathogenic Bedding Conclusion

With respect to bedding bacteria counts there are some clear trends in the data. The bedding counts for the wood-wallboard bedding was generally higher as it entered the barn. This was true of all bacteria types for both barn types. On some occasions this difference met the criteria for statistical significance and on others it did not.

For Gram-positive bacteria (most likely Streptococci-type), the kiln dried shavings and sawdust bedding quickly became contaminated and met or exceeded the levels in the wood-wallboard. By day 14, the higher levels of Gram-positive bacteria in the kiln dried shavings and sawdust bedding were at or very close to statistical significance.

For Gram-negative bacteria the results are less clear. For the Compost barn, there were more bacteria in the wood-wallboard and for the Freestall barn there were more bacteria in the sawdust. It should be noted that both materials had high bacteria burdens.

For the selective media, which promoted the growth of the Klebsiella-type bacteria, again there were some differences between barn types. As for the Gram-negative media, the highest numbers in the Compost dairy barn were for wood-wallboard, whereas for the Freestall barn the highest numbers were for the sawdust. Neither of these trends was statistically significant.

It should be noted, that during the project at the Compost barn, the rate of composting of the wood-wallboard bedding declined. This may have had a positive effect on the growth of the bacteria as the heat of composting action is usually seen as one factor in controlling bacteria growth.

Overall, the wood-wallboard bedding has shown to be in most cases, equivalent or superior to the traditional kiln dried wood shavings with regard to bacteria growth from common mastitis causing organisms.

Pathogenic concentration on Teats of Lactating Cows

Bacterial populations of mastitis causing organisms (coliform, Klebsiella spp and Streptococucus spp.) were tested on teats of lactating cows that bedded on the waste wood-wallboard fiber and sawdust or kiln dried shavings. Tests were done from teat swabs taken on the 14th day after the addition of fresh bedding material.

Teats were swabbed at the two farms to measure the bacteria that were deposited from the bedding onto teat skin. These bacteria, by their type and number, were an indication of the risk of mastitis created by the bedding.

For each farm the protocol for sample collection is similar. Prior to a normal teat preparation routine used by the farm, the teats are rubbed with sterile gauze (no alcohol) to reduce the organic load on the teats. Four swabs are moistened in an agar solution, one for each teat of the cow. A moistened swab is used to rub the teat end in a radius of 2-4 mm around the teat end orifice.

These four swabs were then placed in the vials with the remaining agar solution, stored at refrigerated temperatures and shipped to the Atlantic Veterinary College (AVC) for analysis.

The transport media was cultured (1 sample per cow containing the 4 individual teat swabs) on the same media as the bedding material to determine teat burdens with mastitis pathogens. The media included: a) a modified Edwards media (to ID Streps); b) a regular MacConkey (gram negatives); and c) a modified MacConkeys media (to better determine the Klebsiella from other gram negatives).

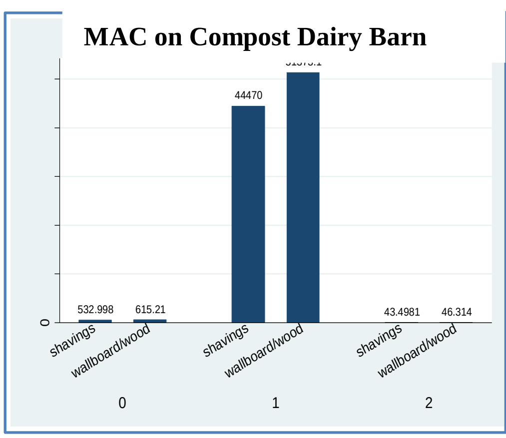
Statistical analysis of the teat swabs data was similar to the bedding bacteria data, using a statistical procedure called a Mann-Whitney Rank Sum. This procedure that looks at the order or rank of each teat bacteria count number rather than its true value. These tests compare teat bacteria numbers for cows on one bedding type with the next bedding type in rank and tell if they are statistically different. It is a very conservative method - i.e. if differences are found with this method, then you can be very confident they are real. Alternatively it is not very powerful - i.e. when differences are not found they may in fact exist but the method is not strong enough to detect them.

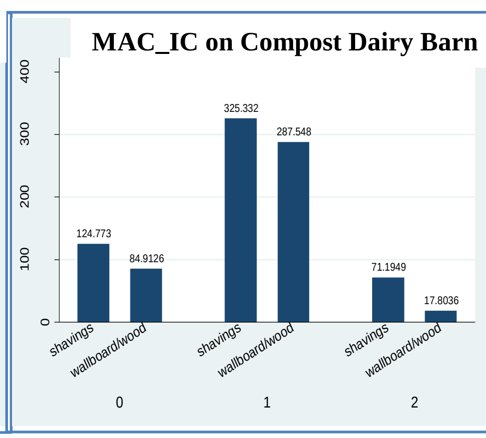
Teat Bacteria Counts – Compost Dairy Barn - August

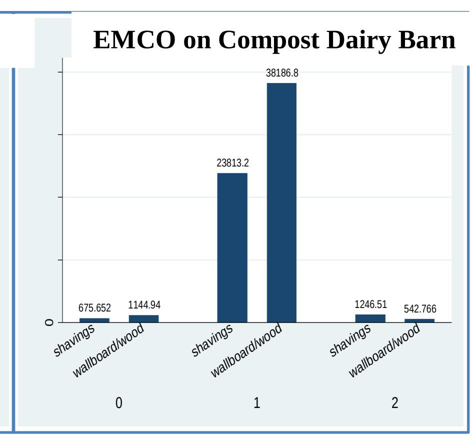
The results of the three sets of data have shown little difference between the two bedding groups with the only significant difference being on the November 19, 2012 tested for Klebsiella bacteria. It is interesting to note that the readings in August were much higher than those in May or November for both beddings. This is an expected result due to the elevated temperature and humidity levels commonly seen in August.

In summary, the data to date would indicate that the wood-wallboard bedding is equivalent to the kiln dried shavings used normally on this farm.

Tables 17-19 Bacteria Testing in Compost Dairy Barn in August







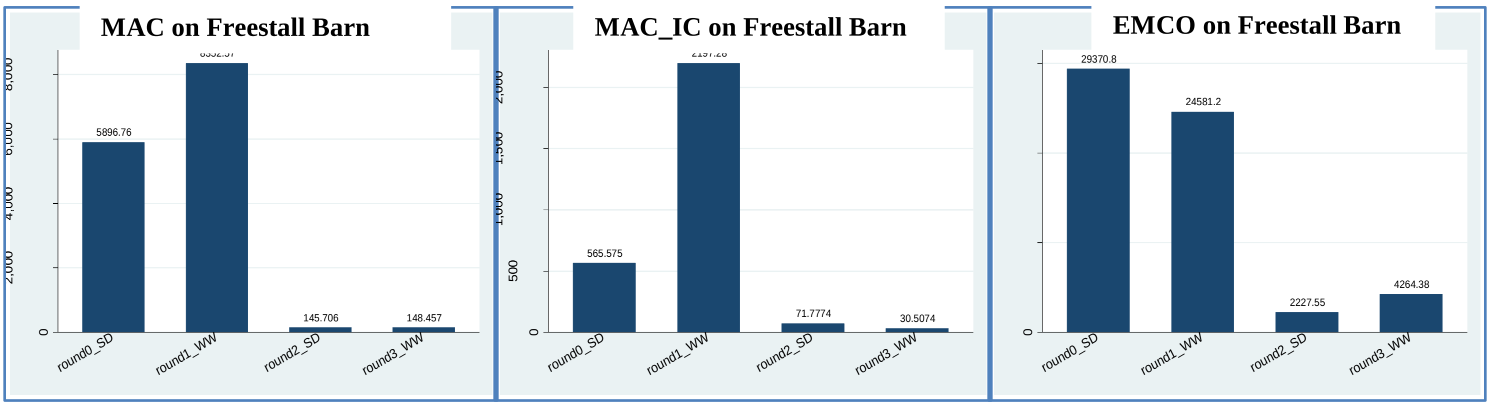
Teat bacteria counts – Freestall Barn - August

At the Freestall barn, four sets of tests were completed, each consisting of 20 tested cows.

There were no significant differences between the wood-wallboard and sawdust bedding types for any of the four tests.

This included all three groups of bacteria tested that were separately analyzed. The readings taken in October and November were much lower than those from late May and August.

Tables 20-22 Bacteria Testing in Freestall Barn in August



Teat bacteria counts – Average over the Project

Table 23. Teat end bacteria count ranks for growth on Modified Edward's media, MacConkey media and modified MacConkey media on day 14 of the trial for the Compost dairy barn.

	KDS (ratio*)	WW (ratio*)	P-value
MAC(cfu/ml)	A (1.01)	A (0.99)	0.82
MAC_IC(cfu/ml)	A (1.07)	A (0.94)	0.12
EMCO(cfu/ml)	A (1.04)	A (0.96)	0.39

Ratio=observed rank sum/expected rank sum

The bacterial burden at the teat end was not different for either the wood-wallboard or the kiln dried shavings on any of the three media used.

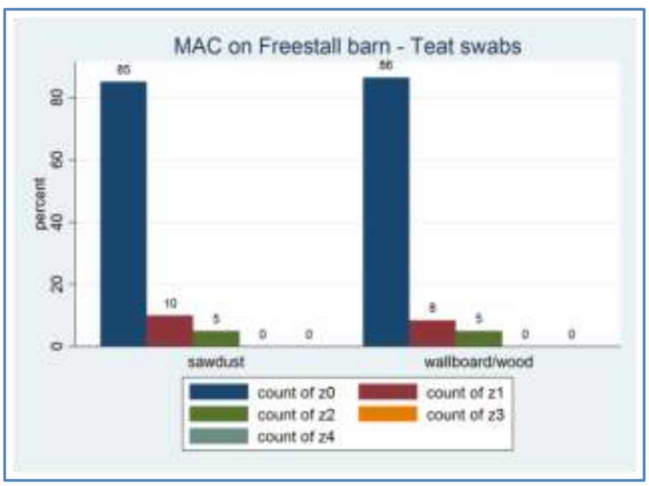
Table 24. Teat end bacteria count ranks for growth on Modified Edward's media, MacConkey media and modified MacConkey media on day 14 of the trial for the Freestall barn.

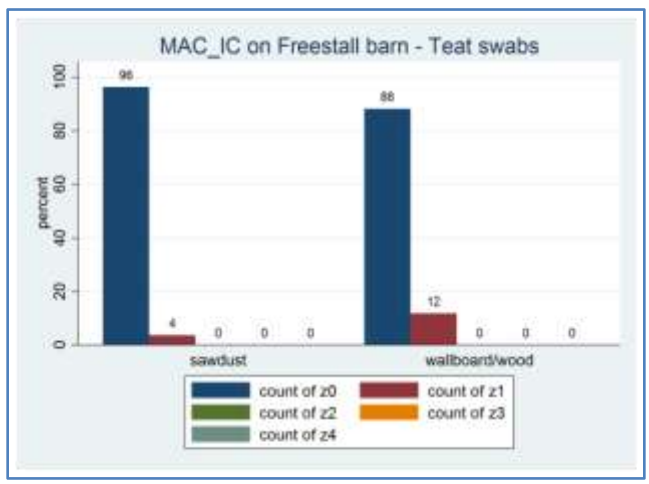
	SD (ratio*)	WW(ratio*)	P-value
MAC(cfu/ml)	A (0.92)	A (1.10)	0.07
MAC_IC(cfu/ml)	A (0.96)	A (1.04)	0.41
EMCO(cfu/ml)	A (0.89)	B (1.18)	0.001

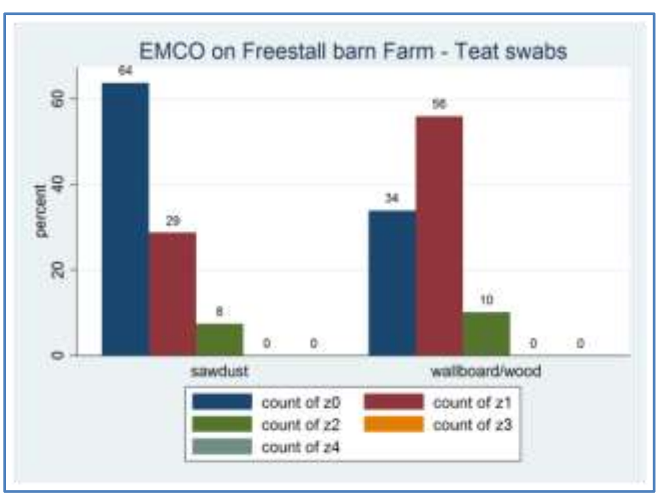
Ratio=observed rank sum/expected rank sum

As illustrated in the Figure 9 below, the bacterial burden at the teat ends was very low for all categories, but was significantly greater for the streptococci in the wood-wallboard bedding group. This is in contrast to the bedding count numbers which are significant in the opposite direction.

Figure 9. Teat end bacteria counts Teat end bacteria count ranks for growth on Modified Edward's media, MacConkey media and modified MacConkey media on day 14 of the trial for the Freestall barn.







Regarding teat end bacteria counts, generally there were no differences and levels were fairly low.

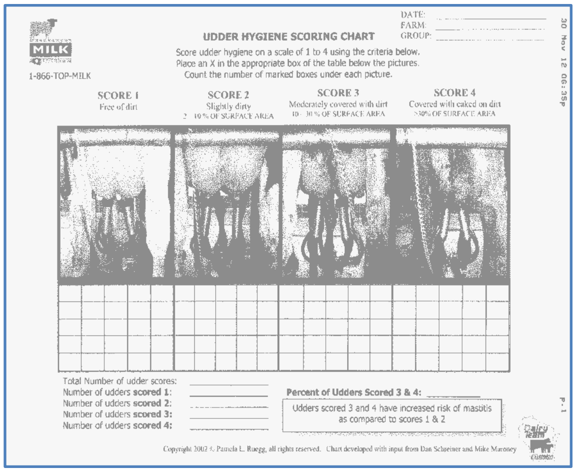
The only significant difference was the Gram-positive numbers at the Freestall barn, which were higher for the wood-wallboard. This is in contrast to the actual bedding counts. Investigation should take place to determine if the wood-wallboard causes more caking of material on teat ends leading to this finding.

Additionally, rates of new mastitis infection should be monitored closely. Again numbers were quite low so this finding should not cause alarm.

Cow Health

Udder Hygiene Scoring

Figure 10 Udder Hygiene Scoring Chart



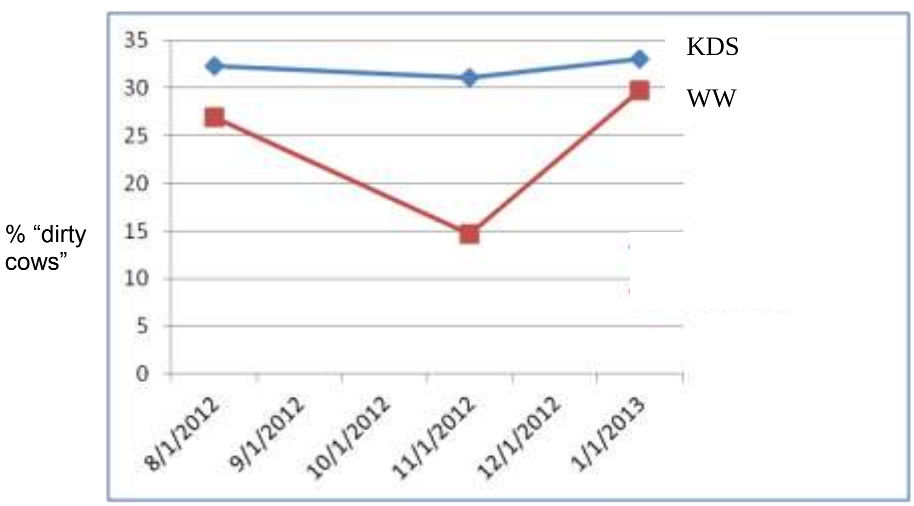
Cow cleanliness is a key management tool for dairy farms. The correlation between cow cleanliness and mastitis control has been proven by several research trials. Scoring systems have been established but the most accepted and utilized scoring system used by the industry, was developed by the University of Wisconsin. The Udder Hygiene Scoring Chart, developed by Dr. Pamela Ruegg, uses a four level scoring system.

When viewing the herd, each cow is assessed and categorized into one of the four levels as indicated by picture and description on the chart itself. The goal is to score at least 80% of the cows in the herd. Well managed herds should have at least 80% of the cows that are scored in the first and second category. This would indicate an acceptable level of cleanliness.

Conversely, the goal is to have less than 20% of the cows that are scored in the third and fourth categories. The sum of the third and fourth categories were recorded i.e. the % of "dirty" cows.

Udder Hygiene Scores Compost Dairy Barn

Figure 11 Hygiene Scores for CDB



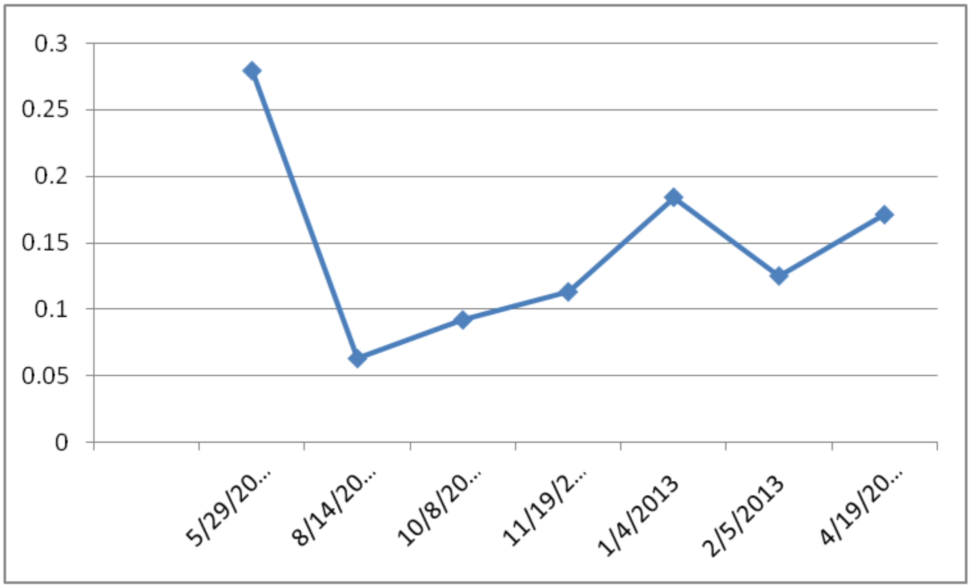
The Udder Hygiene Scores at the Compost dairy barn had interesting results. The high producing group, bedded on kiln dried shavings scored consistently between 32 and 37% of cows in the third and fourth category (dirty cows). This is higher than the preferred less than 20%.

The low producing group, bedded on wood-wallboard initially had similar counts as the kiln dried shavings group but decreased during the middle part of the trial, only to increase at the end of the trial to similar levels as the kiln dried shavings group.

It can be speculated that the reduction in composting action decreased the rate of moisture lost from the pack. This caused more cows to move into the "dirty" category. It should be noted that all readings from wood-wallboard bedding scored better than the kiln dried shavings bedding when measured at the same time.

Udder Hygiene Scores Freestall barn

Figure 12 Hygiene Scores for Freestall Barn



The graph of the Udder Hygiene Score for the Freestall barn, shows a definite trend.

After the initial reading, which was above the preferred reading of less than 20%, the scores dropped into the recommended range and remained there for the remainder of the project.

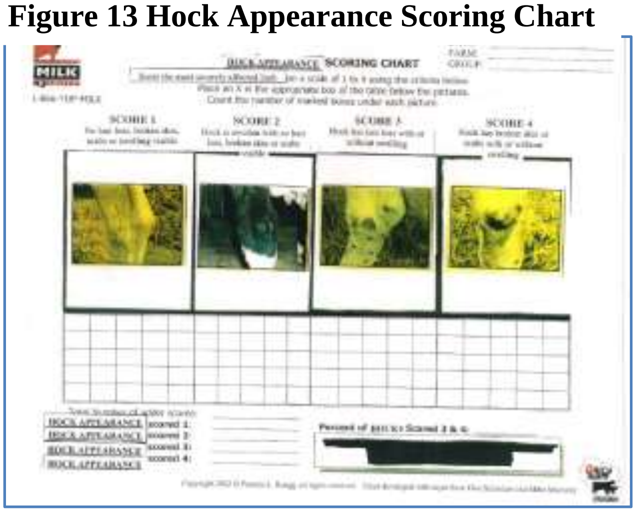
It was noted immediately by the farmer that the stalls were drier and the cows were cleaner. The gypsum content of the wood-wallboard bedding is the probable cause, as similar comments are common from dairy producers who add gypsum to their current bedding.

Based on these results, wood-wallboard bedding that can be seen as an advantage over the sawdust bedding.

Hock Health

Hock appearance scoring is a method to measure the cow comfort of the bedding and bedding surface. A lack of bedding, a hard stall surface or a bedding with a particular texture can affect the condition of the cow's hocks. In the worst case scenario, extremely poor condition of the cow's hocks may result in lameness and early culling which has a negative impact on the farms cash flow.

Figure 13 Hock Appearance Scoring Chart

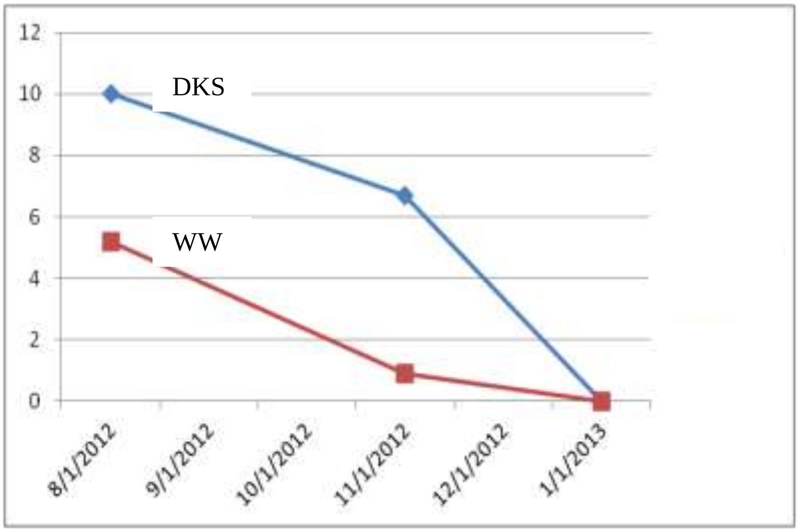


A four level chart was used. It is an adaption of a scoring system established by Dr. Neil Anderson of the Ontario Ministry of Agriculture of Rural Affairs (OMAFRA) and in the same format as the Udder Hygiene Scoring Chart from the University of Wisconsin.

As with the Udder Hygiene Scoring Chart, the goal is to have 80% of the herd scored in the first two categories. Also, as with the Udder Hygiene Scoring Chart, the sum of the third and fourth categories will be the number reported. The goal is less than 20%.

Hock Appearance Scores – Compost Dairy Barn

Figure 14 Hock Scores for Compost Dairy Barn



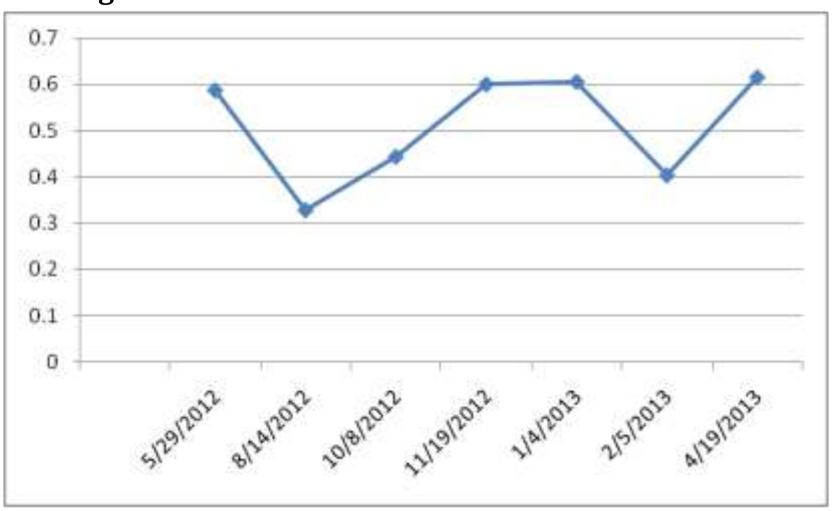
The Hock Appearance Scores of the Compost dairy barn were all in the preferred range of less than 20%.

Initially, the wood-wallboard group had a better rating then the group bedded on kiln dried shavings, but by the end of the trial all hock scores were in the excellent range.

This improvement for both groups is a strong indication of how comfortable cows can be in a compost dairy barn. Moving from Freestall to the new compost dairy barn less than two years ago, has allowed the hock appearance scores of this herd to improve dramatically

Hock Appearance Scores Freestall Barn

Figure 15 Hock Scores for Freestall Barn



The Hock Appearance Scores of the Freestall barn varied during the trial. The scores ended where they started the trial and over half of the values were similar – in the 60s range.

A dip to just above 30% was seen at the beginning of the project which slowly increased over the next few months to its original levels.

This can be explained, as these are the months when the herd is out on pasture for part of each day. During the winter months, when the cows are in the barn all of the time, they lie on a mattress that is known to have a negative effect on hock health.

The trend would indicate that the wood-wallboard bedding is similar to the traditional sawdust bedding used by most dairy farmers in Nova Scotia.

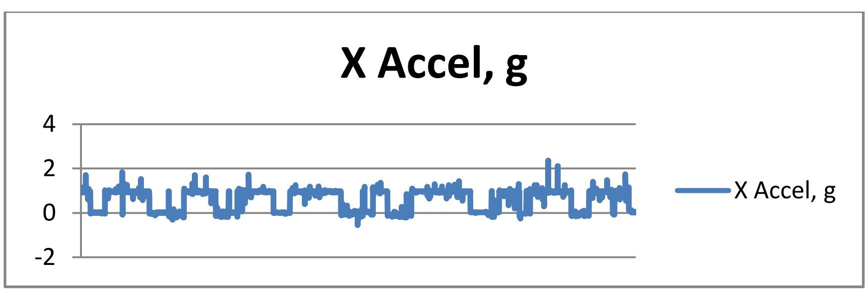
Cow Comfort

Recent research has quantified the normal lying time of a dairy cow at 12 to 14 hours per day. This number, combined with the number of times per day the cow lies and rises (called bouts) gives an indication of the cow comfort. Additionally, research has shown that blood flow to the udder increases substantially when lying as opposed to standing. This translates into a higher rate of milk production with the increased blood flow. Proper lying time and the number of bouts of lying will also reduce stress on feet and legs, contributing to a longer herd life.

Cow standing and lying behavior was assessed using HOBO data loggers, which record timed data for leg position (vertical versus horizontal). The dataloggers measured position every 30 seconds on 25 cows per bedding treatment in each barn type. Data was available for a minimum of 7 days for each period. Hobo Dataloggers are being used to measure lying time. Dataloggers have been used in many research experiments, including research at the University of British Colombia and the University of Guelph. They function by measuring the tilt of the datalogger in three dimensions.

Over 6 million positional data points were available for analysis. Data extraction was initially done using SAS code provided by Dr. Nuria Chapinal from UBC/U of Guelph. Data were recorded in 3 planes (X, Y and Z). The SAS code (designed for 2 plane recording) was modified to reflect the 3 dimensional model. This new model is not fully validated. As a result, it is more appropriate to compare the results within the current study (relative values) to those from previous research.

Figure 16 HOBO Pendant G data logger and output graph (Excel).



In the Excel graph, each switch from approximately +1 to 0 (X-axis) indicates a move from a lying position to standing position. Data shown is for a single cow (FS 7350 round 5) for 2 days. Analysis is on 300 cow records of 7 days each

Dataloggers are attached to the cow's leg just under the hock using surgical Vet Wrap in a standard procedure that was developed by the University of Guelph. Previous research at the University of Guelph, indicates only 3 ½ days of data are required to provide an accurate indication of lying time.

For the Freestall barn, 25 dataloggers were attached to cows' legs and for the Compost dairy barn 25 units were used for each of the high and low production groups, for a total of 50. There are many variables that can adversely affect the recordings. For example, the position of the data logger on the leg may shift or the unit may be removed prematurely.

For the Compost dairy barn, the average number of standing bouts per day was 8.3 for the kiln dried shavings material and 8.9 for the wood-wallboard. The mean, median minimum and maximum lying times (minutes) for the Compost dairy and Freestall barns are displayed in Table 25.

Overall apparent lying times were quite good. For the Compost barn, the lying time was approximately 13.8 hours on the dry kiln shavings and 12.1 hours on the wood-wallboard. These are significantly different ($P<0.001$). Interpretation of this result is somewhat confounded by the fact that the low producing cows were put on the wood-wallboard bedding and the high producing cows were put on the kiln dried shavings group which may have impacted the readings.

For the Freestall barn the lying time was approximately 13.7 hours regardless of bedding type.

Table 25. Lying times in the Compost and Free-stall barns by bedding type.

```
-> farmtype = Compost

Summary for variables: lyingtime
     by categories of: bedtyp
```

bedtyp	mean	sd	p50	min	max
SH	828.9949	112.8729	826	471.5	1098.5
WW	729.7596	126.6187	718.75	478	1096.5
Total	780.2076	129.6435	780	471.5	1098.5

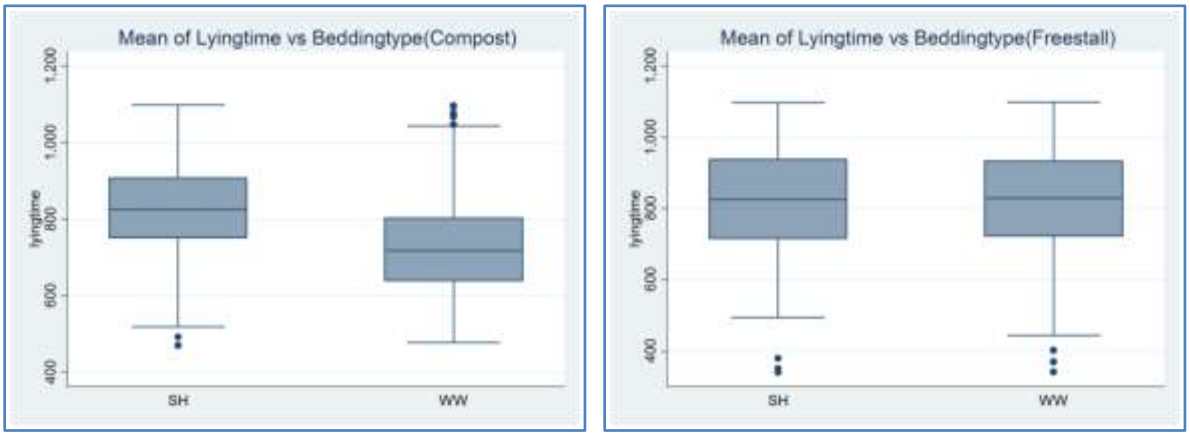
```
-> farmtype = Freestall

Summary for variables: lyingtime
     by categories of: bedtyp
```

bedtyp	mean	sd	p50	min	max
SH	819.3693	144.3304	825	339.5	1097
WW	822.6	151.4672	829.5	342	1098.5
Total	820.949	147.7939	826	339.5	1098.5

Figure 17 shows these data in a box and whisker plot. The central "box" represents the middle 50% of the observations. That is, anything above the top edge of the box in the highest 25% and anything below the bottom edge of the box is the lowest 25 % of observations. The dots represent outliers (data points that are unexpectedly different from the rest or the data set) and the whiskers represent the maximum and minimum values (excluding those outliers). The line through the box is the 50th percentile or median - 50th of the values were greater than this number and 50% were less.

Figure 17. Box and whisker plots of lying times for the two bedding types in each barn system.



For the Freestall barn, standing and lying times were virtually identical across the two bedding types. The lying times were more than 1.5 hours less on the wood-wallboard versus the kiln dried shavings in the Compost barn. The data collection design creates some challenges in this result because the wood-wallboard was only used by the low producing cows. They may have had a different lying pattern.

That being said all lying time averages fell within the 12 to 14 hours per day which is considered the target for dairy cows.

Farmer Experience

In addition to cow comfort, ease of use for the farmer is another important criteria. The bedding should be easy to apply, remove and dispose. It should be easily integrated into current manure handling systems. If the bedding can be stored outdoors, it should be able to shed water and not lose its absorbency factor.

Reports from both locations indicate that the wood-wallboard bedding stores well both indoors and outdoors. After a rain, the wood-wallboard bedding remained dry two inches below the surface.

Comments from the farmers were:

- Absorbed moisture well in the stalls and alley ways. Reduced slippage in alleyways which can reduce injuries.
- The product was dusty during application but settled quickly.
- Once the product was applied to the stall, it remained on the stall much better than sawdust.
- The cows liked to lie on the wood-wallboard bedding.

- Easy to remove from the stalls, did not harden like natural gypsum.
- No difference in mixing in the manure pit.

Project Education Program

An agricultural education program is essential for the industry to participate in the utilization of the waste wood-wallboard bedding. It is also important to educate government extension staff. The following activities were conducted:

1). Samples of the bedding were shown to the agricultural community at booth displays at the following events:

- Nova Scotia Dairy Farmers Annual Meeting – approximately 200 attendees
- Nova Scotia Federation of Agricultural Annual Meeting – approximately 350 attendees
- Atlantic Farm Mechanization Show – approximately 15,000 attendees

2). Presentations at the following meetings:

- Newfoundland and Labrador Dairy Farmers Annual Meeting
- New Brunswick Dairy Farmers Annual Meeting
- Moncton Nutrient Management Consultation
- Inverness County Federation Meeting

3). Bus tour of farmers and government to both the Compost and Freestall barns. Forty farmers and government staff participated.

4). Articles in an Atlantic Canada agricultural newspaper, “Farm Focus” and a Canadian publication, “The Milk Producer”.

Cost-efficient alternative

5) Mail outs were sent on the results of the project to over 100 farmers, NS Dairy Association, NS Federation of Agriculture and the NS Department of Agriculture.

6) After the project was complete at both barns, the product was sent to 12 Freestall barn farms to obtain further feedback on the use of wood-wallboard bedding. Several of the farms are now on their second load of wood-wallboard bedding. Comments were similar to the project participants’ comments.

The product is dusty to put into the barn but settles quickly and is very absorbent. It is difficult to ensure the product is fine enough for cow comfort and absorbency yet reduce the dust at application. Further testing will be conducted.

Economic Analysis

Most traditional bedding used by the Dairy industry, such as sawdust and kiln dried shavings are getting harder to access and can be expensive to ship from sawmills to farms across the province. There has been increased competition for wood products due to the expansion of biomass energy programs which has been increasing prices and decreasing availability.

Based on surveys from dairy farms across the province, the current cost per tonne of sawdust is $30 and $40-$50 per tonne for kiln dried shavings. The cost for a 30 tonne load of sawdust depends upon the distance from the plant and ranges from $2.50 - $11 per kilometer.

Current pricing on wood-wallboard bedding is $30/tonne. A truck that holds 30 tonnes of sawdust holds approximately 21 tonnes of wood-wallboard (53 foot walking floor trailer). The difference is that the sawdust has much higher moisture content. Dry kiln shavings have the least amount of moisture and a similar size truck weighs approximately 15 tonnes.

To compare sawdust, kiln dried shavings and wood-wallboard costs, using the same size truck, trucked 150 km from the plant:

- Sawdust = $1650
- Wood-wallboard = $1155
- Dry kiln shavings = $1425

Wood-wallboard has a 30% savings over sawdust for a drier more absorbent product and a 20% savings over kiln dried shavings. The cost for sawdust and kiln dried shavings will continue to increase as pressure for biomass energy increases. The increased value of the wood-wallboard as a soil amendment was not included in these calculations.

Conclusions

The project objective was to evaluate waste wood-wallboard fiber as an alternative dairy bedding. Competition for wood products in Nova Scotia has increased the cost and availability of traditional wood residue for animal bedding. Using waste wood-wallboard fiber as an alternative bedding material may not only provide an economic alternative for the dairy industry, it can also provide recycled gypsum for improved soil health when applied to agricultural fields. The production of waste wood-wallboard fiber into a valuable bedding resource can have a considerable impact on the Nova Scotia Strategy to reduce waste per person.

A bedding alternative must be at least as good as traditional bedding materials, be free of contaminants, be economical and cannot compromise udder health and milk quality. The product (75% wood fiber: 25% wallboard) was tested to ensure it is safe to livestock and the environment in two dairy barn systems, Compost dairy barn and Freestall barn. Testing included bacterial populations on bedding and cow teats, heavy metals, organic contaminants, cow comfort (length of lying time), hock health, cow cleanliness, odor, absorbency, ease of handling, nutrient value when applied to agricultural fields, and economic comparison to traditional bedding. An agriculture awareness program of the alternative bedding was also implemented.

Cyanide, asbestos and organochlorine pesticides were not detected in either pre or post-commercial wood-wallboard fiber bedding. The post commercial waste wallboard and wood fiber tested at 0 TEQ for TCDD. It also tested 0 for PCB’s. All other levels detected were far below levels of concern.

The Canadian Food Inspection Agency (CFIA) regulates maximum metal levels for products that are sold to be applied to agricultural land. The metals include arsenic, copper, molybdenum, cadmium, cobalt, mercury, nickel, lead, selenium, zinc and chromium. The wood-wallboard bedding had the highest level of metals but was far below CFIA maximum allowable levels. Other metals were tested but there are no maximum allowable levels. The kiln dried shavings had the highest metal levels but were at low levels.

The disposal of waste wallboard at landfills can lead to anaerobic conditions which allow bacteria to release noxious hydrogen sulfide gases. It is important to test for the potential release of hydrogen sulfide in bedding due to direct animal exposure. Formaldehyde gas (released from resins used to manufacture wood products) could also potentially have an adverse affect on livestock health in an enclosed area.

Neither gas was detected in either the Compost dairy barn or the Freestall barn. Hydrogen Sulfide gas was also tested when the Freestall barn manure pit was agitated but it still wasn't detected.

The wood-wallboard bedding provides approximately 6 % sulfur, 10% calcium and 30% organic matter. Maritime soils are low in sulfur and calcium. Current practices include adding sulfur to fertilizer recommendations and applying calcitic lime. The wood-wallboard bedding provided a higher soil amendment value than the other two beddings.

The wood-wallboard bedding has significantly less moisture than sawdust, which is important for restricting bacteria growth and improve absorbency of animal waste. Sawdust can have moisture content levels between 40-60% which is much higher than the wood-wallboard bedding at 17%.

Restricting bacteria growth is one of the most important aspects of bedding material. Bacteria count readings of more than 1,000,000 colony-forming units per ml (cfu/ml) is seen as a tipping point of increased risk of new infections. The project tested for total coliforms, Klebsiella and Streptococcus.

August typically has the highest bacteria tests due to hot humid conditions. At this time, in the Compost dairy barn, there was no difference between wood-wallboard bedding and kiln dried shavings for bacteria counts. At day 14, the bacteria counts were 11,025 for dried kiln shavings and 49,627 for wood-wallboard. Both were below the threshold levels.

In the Freestall barn, at day 14, the bacteria counts were 14 million for sawdust and 497,649 for wood-wallboard bedding. Not only was there a significantly large difference in bacterial counts between the bedding but the wood-wallboard bedding was low for the month of August.

Average of tests for the year in the compost dairy barn showed there were no statistical differences in the bacterial counts between the kiln dried shavings and the wood-wallboard. The wood-wallboard started out higher but, after use, the dry kiln shavings quickly caught up. It should be noted, that during the project at the compost dairy barn, the rate of composting of the wood-wallboard bedding declined. This may have had a positive effect on the growth of the bacteria as the heat of composting action is usually seen as one factor in controlling bacteria growth.

In the Freestall barn, bacteria counts were marginally higher at day 0 in the wood-wallboard, but by day 14, the bacteria counts were much higher in sawdust.

Overall, the wood-wallboard bedding has shown to be in most cases, equivalent or superior to the traditional kiln dried wood shavings and sawdust with regard to bacteria growth from common mastitis causing organisms in the bedding material.

Bacterial populations of mastitis causing organisms (total coliform, Klebsiella spp and Streptococucus spp.) were tested on teats of lactating cows that were bedded on the waste wood-wallboard fiber and sawdust or kiln dried shavings. Tests were done from teat swabs taken on the 14^{th} day after the addition of fresh bedding material.

In August, which typically has the highest bacteria tests due to hot humid conditions, there were little differences in teat bacterial counts between the different beddings.

The average tests for the year in the Compost dairy barn showed the bacterial burden at the teat end was not different for either the wood-wallboard or the kiln dried shavings. In the Freestall barn, the bacterial burden at the teat ends was very low for all categories, but was greater for the streptococci in the wood-wallboard bedding group. This is in contrast to the bedding count numbers which are significant in the opposite direction. Regarding teat end bacteria counts, generally there were no differences and levels were fairly low.

Cow cleanliness is a key management tool for dairy farms. The correlation between cow cleanliness and mastitis control has been proven by several research trials. The udder hygiene scoring chart assesses each cow and the goal is to have at least 80% of the cows in the first two scoring categories.

In the Compost dairy barn, the high producing dairy cows were bedded on kiln dried shavings and scored 31 % for the first two categories. The low producing dairy cows, bedded on wood-wallboard initially had similar counts as the kiln dried shavings group but decreased during the middle part of the trial, only to increase at the end of the trial to similar levels as the kiln dried shavings group. It can be speculated that the reduction in composting action decreased the rate of moisture lost from the pack which caused more cows to move into the “dirty” category. All readings from wood-wallboard bedding scored better than the kiln dried shavings bedding.

In the Freestall barn, after the initial reading, which was above the preferred reading of less than 20%, the scores dropped into the recommended range and remained there for the remainder of the project.

It was noted immediately by the farmer that the stalls were drier and the cows were cleaner. The gypsum content of the wood-wallboard bedding is the probable cause, as similar comments are common from dairy producers who add gypsum to their current bedding.

Based on these results, wood-wallboard bedding that can be seen as an advantage over the sawdust bedding.

Hock appearance scoring is a method to measure the cow comfort of the bedding and bedding surface. A lack of bedding, a hard stall surface or a bedding with a particular texture can affect the condition of the cow’s hocks. In the worst case scenario, extremely poor condition of the cow’s hocks may result in lameness and early culling which has a negative impact on the farms cash flow.

The hock appearance scores of the Compost dairy barn were all in the preferred range of less than 20%. Initially, the wood-wallboard group had a better rating then the group bedded on kiln dried shavings, but by the end of the trial all hock scores were in the excellent range.

The hock appearance scores in the Freestall barn varied during the trial. The scores ended where they started in the trial. A dip to just above 30% was seen at the beginning of the project which slowly increased over the next few months to its original levels.

This can be explained, as these are the months when the herd is out on pasture for part of each day. During the winter months, when the cows are in the barn all of the time, they lie on a mattress that is known to have a negative effect on hock health. Also, exposure on both beddings was only for 6 weeks therefore hocks may not have had time to heal between bedding types.

The trend would indicate that the wood-wallboard bedding is similar to the traditional sawdust bedding used by most dairy farmers in Nova Scotia.

Cow comfort is essential for optimum milk production. The normal lying time of a dairy cow at 12 to 14 hours per day. This number, combined with the number of times per day the cow lies and rises gives an indication of the cow comfort. Blood flow to the udder increases substantially when lying as opposed to standing. This translates into a higher rate of milk production with the increased blood flow. Proper lying time and the number of bouts of lying will also reduce stress on feet and legs, contributing to a longer herd life.

Cow standing and lying behavior was assessed using HOBO dataloggers, which record timed data for leg position. The lying times were quite good in both barns. In the Compost dairy barn, there was a small difference in lying time between the kiln dried shavings and the wood-wallboard bedding. The lying time was 13.8 hours on the dry kiln shavings and 12.1 hours on the wood-wallboard. For the Freestall barn the lying time was 13.7 hours regardless of bedding type. The cows were comfortable on all three bedding types.

The wood-wallboard bedding is a more economical product than the kiln dried shavings and sawdust. Based on current pricing, it costs 30% less than sawdust and 20% less than kiln dried shavings based on the same cubic meters of product. As competition for traditional wood residues increase, the savings will be even higher.

The farmer experience in the Freestall barn was that it met the bedding criteria of restricting bacteria, absorbing moisture from manure and urine production, provided good footing in the alley ways, stored well indoors and outdoors and was easy to apply and remove from the stalls. The gypsum component did not cake or harden. The bedding provided a dry comfortable resting area for the cows with little to no odors. The product is dusty when first spread in the stalls but it quickly settles down onto the stalls. In the Compost dairy barn, there were problems with compost temperatures in the wood-wallboard area. This may have been due to reduced air space as there are many fine particles in the bedding material.

Since the project ended, twelve Freestall farms are using the wood-wallboard bedding and agreed with the Freestall barn participant experience with the bedding.

The project indicates that udder health and milk quality are not compromised and that waste wood-wallboard fiber can be diverted from the landfill to provide a safe economically viable alternative bedding material. Overall, the wood-wallboard bedding has shown to be in most cases, equivalent or superior to the traditional kiln dried wood shavings and sawdust.

Appendix

Organic analysis Pre and Post Consumer Waste Wood-wallboard Fiber Analysis

Organic Analysis	RDL	Sample #1 Post	Sample #2 Pre	
Asbestos		ND	ND	
Pentachlorophenol (SVOC)	0.1	<0.1	<0.1	
2,4,6-Tribromophenol		63	71	
Chrysene-d12		82	74	
Organochlorine Pesticides				
alpha-BHC (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
a-Chlordane (Hfx 2012-03)	2.0	<2.0	<2.0	µg/kg
Aldrin (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
beta-BHC (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Dieldrin (Hfx 2012-03)	0.7	<0.7	<0.7	µg/kg
Endosulfan I (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Endosulfan II (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Endosulfan Sulfate (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Endrin (Hfx 2012-03)	2.0	<2.0	<2.0	µg/kg
Endrin Aldehyde (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Endrin Ketone (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
g-Chlordane (Hfx 2012-03)	2.0	<2.0	<2.0	µg/kg
Heptachlor (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Heptachlor Epoxide (Hfx 2012-03)	0.06	<0.06	<0.06	µg/kg
gamma-BHC (Hfx 2012-03)	0.03	<0.03	<0.03	µg/kg
Mirex (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
o,p'-DDD (Hfx 2012-03)	1.0	<1.0	<1.0	µg/kg
o,p'-DDE (Hfx 2012-03)	1.0	<1.0	<1.0	µg/kg
o,p'-DDT (Hfx 2012-03)	1.0	<1.0	<1.0	µg/kg
p,p'-DDD (Hfx 2012-03)	1.0	<1.0	<1.0	µg/kg
p,p'-DDE (Hfx 2012-03)	1.0	<1.0	<1.0	µg/kg
p,p'-DDT (Hfx 2012-03)	1.0	<1.0	<1.0	µg/kg
Oxychlordane (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Methoxychlor (Hfx 2012-03)	5.0	<5.0	<5.0	µg/kg
Decachlorobiphenyl		84	95	%
Polybrominated Dephenylethers (PBDE's) - Flame Retardants				
2,6-Dibromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
2,4-Dibromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
4,4'-Dibromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
2,4,6-Tribromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
2,2',4-Tribromodiphenylether (Hfx 04-2012)	2	16	<2	pg/g
2,4,4'-Tribromodiphenylether (Hfx 04-2012)	2	190	5.9	pg/g
2,2',4,5'-Tetrabromodiphenylether (Hfx 04-2012)	2	110	<2	pg/g
2,3',4',6-Tetrabromodiphenylether (Hfx 04-2012)	2	5.0	<2	pg/g
2,2',4,4'-Tetrabromodiphenylether (Hfx 04-2012)	5	3900	180	pg/g

2,3',4,4'-Tetrabromodiphenylether (Hfx 04-2012)	2	81	<2	pg/g
3,3',4,4'-Tetrabromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
2,2',4,4',6-Pentabromodiphenylether (Hfx 04-2012)	5	540	33	pg/g
2,3',4,4',6-Pentabromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
2,2',4,4',5-Pentabromodiphenylether (Hfx 04-2012)	5	2800	190	pg/g
2,2',3,4,4'-Pentabromodiphenylether (Hfx 04-2012)	2	25	3.7	pg/g
3,3',4,4',5-Pentabromodiphenylether (Hfx 04-2012)	2	<2	<2	pg/g
2,2',4,4',5,6'-Hexabromodiphenylether (Hx 04-2012)	4	190	15	pg/g
2,2',4,4',5,5'-Hexabromodiphenylether (Hx 04-2012)	4	330	18	pg/g
2,2',3,4,4',6-Hexabromodiphenylether (Hx 04-2012)	4	19	4.7	pg/g
2,2',3,4,4',6'-Hexabromodiphenylether (Hx 04-2012)	4	<4	<4	pg/g
2,2',3,4,4',5'-Hexabromodiphenylether (Hx 04-2012)	4	806	<4	pg/g
2,3,3',4,4',5-Hexabromodiphenylether (Hfx 04-2012)	4	<4	<4	pg/g
2,2',3',4,4',6,6'-Heptabromodiphenylether	4	12	<4	pg/g
2,2',3,4,4',5',6-Heptabromodiphenylether	4	1200	35	pg/g
2,3,3',4,4',5',6-Heptabromodiphenylether	4	<4	<4	pg/g
2,2',3,4,4',5,5'-Heptabromodiphenylether	4	25	<4	pg/g
2,2',3,3',4,4',6-Heptabromodiphenylether (04/2012)	4	10	<4	pg/g
2,2',3,3',4,5',6,6'-Octabromodiphenylether	4	<4	4.7	pg/g
2,2',3,3',4,4',6,6'-Octabromodiphenylether	4	480	13	pg/g
2,2',3,4,4',5,5',6-Octabromodiphenylether	4	170	12	pg/g
2,2',3,3',4,4',5,6'-Octabromodiphenylether	4	100	5.1	pg/g
2,3,3',4,4',5,5',6-Octabromodiphenylether	4	<4	<4	pg/g
2,2',3,3',4,5,5',6,6'-Nonabromodiphenylether	10	1600	68	pg/g
2,2',3,3',4,4',5,6,6'-Nonabromodiphenylether	10	2400	130	pg/g
2,2',3,3',4,4',5,5',6-Nonabromodiphenylether	10	610	110	pg/g
Decabromodiphenylether (Hfx 04-2012)	25	85000	3000	pg/g
Polychlorinated Biphenols (Total PCB's)				
Total PCBs	0.5	<0.5	<0.5	mg/kg
Decachlorobiphenyl		71	65	%
Dioxins & Furans (Soil, WHO 2005)				
2,3,7,8-Tetra CDD	0.1	<0.1	0.4	ng/kg
1,2,3,7,8-Penta CDD	0.1	0.1	1.6	ng/kg
1,2,3,4,7,8-Hexa CDD	0.1	<0.1	3.3	ng/kg
1,2,3,6,7,8-Hexa CDD	0.1	0.3	169	ng/kg
1,2,3,7,8,9-Hexa CDD	0.1	0.2	29.0	ng/kg
1,2,3,4,6,7,8-Hepta CDD	0.1	10.2	4390	ng/kg
Octa CDD	0.2	137	81700	ng/kg
2,3,7,8-Tetra CDF	0.1	0.2	2.5	ng/kg
1,2,3,7,8-Penta CDF	0.1	<0.1	1.0	ng/kg
2,3,4,7,8-Penta CDF	0.1	<0.1	1.2	ng/kg
1,2,3,4,7,8-Hexa CDF	0.1	<0.1	8.3	ng/kg
2,3,4,6,7,8-Hexa CDF	0.1	<0.1	3.3	ng/kg
1,2,3,6,7,8-Hexa CDF	0.1	<0.1	8.3	ng/kg
1,2,3,7,8,9-Hexa CDF	0.1	0.1	0.5	ng/kg
1,2,3,4,6,7,8-Hepta CDF	0.1	1.1	467	ng/kg
1,2,3,4,7,8,9-Hepta CDF	0.1	0.2	18.3	ng/kg
Octa CDF	0.1	14.7	2480	ng/kg
Total Tetrachlorodibenzodioxins	0.1	0.8	3.2	ng/kg

Total Pentachlorodibenzodioxins	0.1	0.7	7.4	ng/kg
Total Hexachlorodibenzodioxins	0.1	2.2	1120	ng/kg
Total Heptachlorodibenzodioxins	0.1	18.5	9130	ng/kg
Total PCDDs	0.2	159	92000	ng/kg
Total Tetrachlorodibenzofurans	0.1	0.9	30.7	ng/kg
Total Pentachlorodibenzofurans	0.1	0.5	9.6	ng/kg
Total Hexachlorodibenzofurans	0.1	1.6	500	ng/kg
Total Heptachlorodibenzofurans	0.1	7.2	2040	ng/kg
Total PCDFs	0.2	24.8	5060	ng/kg
2,3,7,8-Tetra CDD (TEF 1.0)		0	0.435	TEQ
1,2,3,7,8-Penta CDD (TEF 1.0)		0.122	1.56	TEQ
1,2,3,4,7,8-Hexa CDD (TEF 0.1)		0	0.331	TEQ
1,2,3,6,7,8-Hexa CDD (TEF 0.1)		0.0304	16.9	TEQ
1,2,3,7,8,9-Hexa CDD (TEF 0.1)		0.0236	2.90	TEQ
1,2,3,4,6,7,8-Hepta CDD (TEF 0.01)		0.102	43.9	TEQ
Octa CDD (TEF 0.0003)		0.0411	24.5	TEQ
2,3,7,8-Tetra CDF (TEF 0.1)		0.0177	0.252	TEQ
1,2,3,7,8-Penta CDF (TEF 0.03)		0	0.0310	TEQ
2,3,4,7,8-Penta CDF (TEF 0.3)		0	0.360	TEQ
1,2,3,4,7,8-Hexa CDF (TEF 0.1)		0	0.828	TEQ
1,2,3,6,7,8-Hexa CDF (TEF 0.1)		0	0.327	TEQ
1,2,3,7,8,9-Hexa CDF (TEF 0.1)		0	0.828	TEQ
2,3,4,6,7,8-Hexa CDF (TEF 0.1)		0.0127	0.0450	TEQ
1,2,3,4,6,7,8-Hepta CDF (TEF 0.01)		0.0108	4.67	TEQ
1,2,3,4,7,8,9-Hepta CDF (TEF 0.01)		0.00224	0.183	TEQ
Octa CDF (TEF 0.0003)		0.00442	0.743	TEQ
Total PCDDs & PCDFs (TEQ)		0.368	98.8	TEQ
13C-2378-TCDF		66	68	%
13C-12378-PeCDF		83	79	%
13C-23478-PeCDF		84	80	%
13C-123478-HxCDF		78	76	%
13C-123678-HxCDF		70	66	%
13C-234678-HxCDF		71	65	%
13C-123789-HxCDF		82	78	%
13C-1234678-HpCDF		69	62	%
13C-1234789-HpCDF		89	81	%
13C-2378-TCDD		70	72	%
13C-12378-PeCDD		92	85	%
13C-123478-HxCDD		81	78	%
13C-123678-HxCDD		77	70	%
13C-1234678-HpCDD		83	78	%
13C-OCDD		63	63	%

*Analysis conducted by AGAT Laboratories