USE OF POST-DIGESTED SEPARATED MANURE SOLIDS AS FREESTALL BEDDING: A CASE STUDY[1]

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Introduction

In the recent past, animal agriculture has seen an upward swing in society's interest in the impact animal waste has on the environment. Governmental legislators have responded by passing ever increasing environmental laws that affect U.S. livestock farmers. This, coupled with farmers' goals of reducing production costs to maintain or increase overall farm profitability and also perhaps to minimize their visual and/or odor profile with neighbors, has resulted in much attention in on-farm waste treatment systems.

From an overall management perspective, a waste treatment system is a tool or series of tools to support the goals, objectives, and needs for a particular farm. Since goals and objectives do vary from farm-to-farm, so should the waste treatment systems. Several potential goals of a dairy manure waste treatment system are provided by Gooch and Ludington (2005); a specific goal that is of interest to those who study freestall bedding material from a perspective of its contribution to udder health and milk quality is goal No. 8 - "Processing of separated manure solids for use as stall bedding material".

Many producers who have, or who are considering, manure treatment systems desire, from a business/economic perspective, to use processed manure solids as freestall bedding material. Dairy producers are finding that integrated manure treatment systems incorporating anaerobic digestion can have an initial capital cost greater than $1,000 per cow. In the U.S. dairy industry, capital investment at this level generally requires a return on investment in order for the investment to make sense. However, most U.S. dairy producers are primarily attracted to anaerobic digestion because of its odor control benefit.

The goals of this paper are 1) to introduce, from an economic standpoint, why producers currently need to use post-digested separated manure solids in a cost-effective manner, and 2) to provide results from an on-farm pilot-scale study that looked at opportunistic pathogen concentrations present in various sampling points including freshly separated post-digested manure solids to those solids present in freestalls after a two to three day residence time.

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Economic Justification

U.S. dairy producers do not have the direct ability to increase the sale price for their milk. Rather, they must find ways to increase milk production at a low cost and/or improve on-farm efficiencies in order to compensate for higher costs of land, labor, and purchased goods and services. To date, this approach has worked well for many dairy producers. However, the recent need for farms to look seriously at treating manure to control odor and pathogens and to comply with comprehensive nutrient management plans (CNMPs) has resulted in the consideration by many, and employment by some, of manure treatment systems with high capital and operating costs.

Our work at Cornell has shown that the estimated total annual cost for five operating anaerobic digesters on production dairies in New York State was -$38, $22, $24, -$299, and $106 per cow on farms with 500, 850, 1,100, 725, and 100 cows, respectively in 2003 (Wright et al., 2004). (Negative values represent an annual income, and the fourth farm listed had a high income due to tipping fees received from food processors.) Otherwise, treatment system revenue was limited to electrical power generation, and in three of the cases it did not offset the estimated annual cost of the systems. Clearly, investing $1,000 per cow or more in an anaerobic digestion system does not make good business sense based on these estimated total annual cost numbers. (It should be noted here that each farm received grant funding to offset a portion or all of the capital costs.)

Consequently, producers are evaluating post-digested separated manure solids from a revenue generation or expenditure reduction standpoint. The former includes retail sale or wholesale of fresh or composted separated manure solids. This option also helps the farm export some nutrients and may be important from a CNMP standpoint. The latter option is to use the separated manure solids as freestall bedding material; this can save farms $60 to $100 per cow per year in purchased bedding costs.

To further illustrate the need to reduce cash outflow or increase cash inflow specifically on farms with anaerobic digesters, we can review the results of a feasibility study conducted for owners of a 900-cow New York State dairy farm that considered constructing an anaerobic digester (Gooch and Ludington, 2005). The following four options were thoroughly investigated as part of the feasibility study analysis.

Option No.	**Option Objectives**
Option I.	Odor reduction of liquid manure
Option II.	Odor reduction and electric generation
Option III.	Odor reduction, electric generation, and use of post-digested separated manure solids for stall bedding
Option IV.	Odor reduction, electric generation, nutrient exportation, and bedding material generation

A comparison of the economic analysis for each option investigated is shown in Table 1.

Table 1. Comparison summary costs ($) for the four options analyzed (Gooch and Ludington, 2005).

	Option I	*Option II*	*Option III*	*Option IV*
Total Capital Cost	215,100	482,000	615,850	782,700
Total Capital Cost Per Cow	269	603	770	978
Total Est. Annual Capital Cost	18,400	45,100	59,700	78,300
Total Est. Annual Capital Cost Per Cow	23	56	75	98
Total Est. Annual Operating Cost	12,000	23,700	35,100	51,100
Total Est. Annual Operating Cost Per Cow	15	30	44	64
Total Est. Annual Cost	30,400	68,800	94,800	129,400
Total Est. Annual Cost Per Cow	38	86	119	162
Total Est. Annual Revenues	----	66,000	130,000	143,600
Total Est. Annual Revenues Per Cow	----	82	162	180
Total Est. Annual Cost or Benefit[1,2]	-30,400	-2,800	35,200	14,200
Total Est. Annual Cost or Benefit Per Cow	-38	-3.50	44	17.80

[1]*Does not include treatment system electrical use (parasitic power).*
[2]Negative numbers mean that the farm incurs a net loss from the treatment system.

If the use of post-digested reclaimed manure solids (not composted) can be used as freestall bedding material without compromising the farm's udder health and milk quality goals, then Option III provides the greatest economic benefit of the four systems analyzed, $35,200 annually. However, if the reclaimed manure solids cannot be used as bedding under Option III, then the annual cost for this option becomes $4,400, an annual difference of $39,600. The analysis for Option IV shows that the economic benefit of aerobically composting post-digested separated solids does not exceed the cost. This option is only a viable option to consider if Option IV is not permissible due to inability to use raw separated solids for bedding.

The remainder of this paper presents the pilot scale analysis.

Literature Review

The use of separated manure solids as stall bedding material has received much interest in the past and in the present. Separated manure solids are organic materials exhibiting similar properties of other organic materials commonly used for freestall bedding. Unlike inorganic materials such as sand and limestone, all organic materials provide environmental pathogens with nutrients and moisture needed for growth and reproduction. Environmental pathogens of concern from an udder health and milk quality standpoint are streptococci and coliform bacteria.

There appears to be little advantage of using one organic material over another (Smith and Hogan, 2000). The numbers of environmental pathogens in organic bedding materials are generally low prior to bedding placement in stalls but several studies have shown that once they are placed in stall the numbers will increase 100 to 1,000 fold within 24 hours (Smith and Hogan, 2005). Prudent stall management is needed for organic bedded stalls to achieve low somatic cell counts. Stalls need to be generously bedded and bedding material must cycle through the stall readily; this is contrary to the goal of conserving bedding many dairy producers have, especially those who experience high purchase prices. Removal of soiled or wet separated manure solids from the freestall at each milking episode is needed.

Farm Information

Noblehurst Farms, Inc. is located in Livingston County in Western New York State. The farm milked 1,250 cows that were housed in multiple freestall barns. All freestalls had a mattress bedded with organic bedding. At the time of the study, the freestalls in two pens (about 400 total stalls) were bedded with recovered manure solids. The farm intended to bed more freestalls with recovered manure solids if the cows in the initial two pens responded well.

The recovery system consisted of a Vincent screw press solid-liquid manure separator (SLS), model No. KP-10 with $1/32^{nd}$ screen openings. The separator processed effluent from an anaerobic digester (AD) that was constructed in 2003. The AD was managed to operate in the mesophilic temperature range. For further information on the Noblehurst manure treatment system, go to www.manuremenagement.cornell.edu. Click on “documents” then “case studies” and finally “case study AD-5”.

The farm’s management protocol called for freestalls to be bedded three times per week (target days were Monday, Wednesday, and Friday) with about 30 lbs. of bedding per stall (wet basis). The pens not bedded with separated manure solids were bedded with a 50:50 mixture (by volume) of green sawdust and a byproduct from a paper recycling process, hereafter referred to simply as “sawdust”.

Procedure

Bedding material samples were taken on average once per week from mid August to early October 2005 on a day when stall bedding was performed but prior to it happening. Five sampling locations included: 1) freshly separated post-digested manure solids, 2) stockpiled separated post-digested manure solids, 3) separated post-digested manure solids used as stall bedding (stall residence time of two to three days), 4) stockpiled sawdust, and 5) used sawdust bedding (stall residence time of two to three days). For the stall sampling sites, composite samples were obtained by mixing three grab samples, one-third each taken from the rear one-third of the freestall bed. The same three stalls in the pen bedded with separated manure solids and the same three stalls in the pen bedded with sawdust were sampled each time. Samples from each of the seven sampling days were frozen and subsequently shipped on ice in an insulated container to the laboratory for analysis at The Ohio State University. Samples from six of the seven sampling days were analyzed; one shipment could not be analyzed due to packaging problems. Sample analysis included dry matter, streptococci, Klebsiella spp., coliform, and Gram-negative bacteria.

The laboratory analysis procedure used was as follows. Twenty-five grams of sample were placed in a convection oven at 100°C for 24 h to determine dry matter. A total of 10 g of bedding were suspended in 90 ml of sterile distilled water, and pH was measured. Bacterial populations in bedding were enumerated by adding 10 g of sample to 90 ml of sterile PBS and mixing the solution for 40 s in a stomacher (Stomacher Lab-Blender 400; Tekmar Co., Cincinnati, OH). Serial dilutions of the liquid phase in sterile PBS were plated on the surface of MacConkey agar (Beckman Dickinson Microbiology Systems, Cockeysville, MD), MacConkey-inositol-carbenicillin agar (MCIC), and modified Edwards agar containing 5 mg/L colistin sulfate and 2.5 mg/L oxolinic acid (Beckman Dickinson Microbiology Systems). Inositol (10 mg/L; Sigma Chemical Co., St. Louis, MO) and carbenicillin (75 mg/L; Pfizer Co., New York, NY) were added to MacConkey agar for MCIC. Bovine plasma (50 ml/L) was substituted for whole blood to prepare modified Edwards media. Serial dilutions plated on all media were $1:10^{2}$ to $1:10^{6}$. Inoculated plates were incubated 24 h at 37^{o}C. Colony forming units (CFUs) per gram were identified as Gram-negative bacteria (total growth on McConkey agar), coliforms (lactose-positive colonies on MacConkey agar), Klebsiella spp. (pink to red colonies on MCIC), and streptococci (total growth on modified Edwards agar). Counts were transformed to $\log_{10}$ per gram dry matter.

Results

The average values for each parameter analyzed were calculated from the raw laboratory data. Appendix Figures 1 through 5 show the results graphically for dry matter, streptococci, Klebsiella spp., coliform, and Gram-negative counts, respectively.

The following statements are based on the trends shown by the data.

- Fresh and stockpiled separated manure samples had a lower dry matter content that those collected from the freestalls. Moisture content decreased by about 30 percent over the two to three day period the bedding material was in the freestalls.
- Stockpiled sawdust and sawdust in the stalls after two to three days on average had the same moisture content.
- Stockpiling of separated manure solids destined for stall bedding resulted in a decrease in sample CFU's for streptococci, Klebsiella spp., coliform, and Gram-negative counts with the greatest reduction, about 100-fold, see by streptococci counts when compared to freshly separated manure solids.
- The CFU's of the two to three day old reclaimed manure bedding samples significantly increased for all bacterial parameters analyzed.
- Two to three day old sawdust sample CFU concentrations increased for streptococci, Klebsiella spp., coliform, and Gram-negative over the samples from stockpiled material while Klebsiella spp. counts remained the same.

Discussion

The data trends are consistent with other studies that compared bacterial concentrations of unused bedding with aged bedding samples taken from freestalls. Environmental streptococci and coliform bacteria present in the cows' environment quickly inoculate new bedding material

and their concentrations rapidly grow to large numbers within 24 to 48 hours. The extent of the growth is dependent on the season of the year, type of housing and ventilation system used, weather, bedding material particle size, and others.
The anaerobic digestion process, which has been shown to affectively reduce concentrations of Johne's disease and fecal coliform in manure (Wright et al., 2004 and Gooch et al., 2005), does not appear to have a lasting affect on pathogens tested during this pilot study; further work is needed to develop statistical data to support a firm conclusion.

Old-fashioned elbow grease is needed to make any organic bedding material, apparently including post-digested separated manure solids, work effectively in freestall housing situations. Freestall management protocols should be written for employees to follow. The successful protocols should include frequent bedding of freestalls and removal of soiled bedded and replacement with cleaner bedding from the front of the stall least as often as cows are milked. Therefore, the main challenge that a dairy producer faces is finding ways to ensure that freestall management protocols are followed by employees.

Summary

A seven week pilot scale study was performed at the Noblehurst commercial dairy farm. The farm had 1,250 freestalls with 850 bedded with sawdust and 400 with post-digested separated manure solids. The goal of the study was to compare sample environmental pathogen concentration differences and to determine if there were any trends that may differentiate post-digested separated manure solids from other organic bedding sources with respect to their ability to retard or preclude growth of key environmental pathogens.

Samples were taken once per week of fresh, stockpiled, and used post-digested separated manure solids and of stockpiled and used sawdust bedding materials. The "sawdust" was actually a 50:50 mixture (by volume) of green sawdust and a byproduct from a paper recycling process.

The data trends are consistent with other studies that compared bacterial concentrations of unused bedding with aged bedding samples taken from freestalls. The anaerobic digestion process does not appear to have a lasting affect on pathogens tested during this pilot study. Further work is needed to develop statistical data to support a firm conclusion. Old-fashioned elbow grease is needed to make any organic bedding material, apparently including post-digested separated manure solids, work effectively in freestall housing situations. Two challenges that face a dairy producer desiring to successfully use post-digested separated manure solids for bedding are: 1) to find ways to ensure the freestall management protocols are followed by employees, and 2) to be committed to keeping the AD system operating so a steady supply of bedding material is produced.

Conclusions

The dairy industry needs effective waste treatment systems that meet or exceed the expectations of regulatory requirements and of society in general. The current systems available to producers for their consideration generally have high capital and operating costs with comparatively low or nonexistent revenue returns. Anaerobic digestion is the treatment process of focus today due to its ability to control odor emissions from stored treated manure. Successful use of reclaimed manure solids from an anaerobic digestion system is the key to shifting the system economics from the red to the black in many states in the U.S.

The pilot scale study data showed trends that are comparable to those established from prior studies that looked at the environmental pathogen concentrations in unused and used organic bedding materials. A more controlled study that is designed to be statistically sound is needed to confirm the data trends developed by this study. If subsequent research confirms the trends, then the success in using reclaimed manure solids for bedding lies in diligent bedding management. Even with this level of management in place, a concern still will exist with a chronic outbreak of environmental mastitis. Warm and moist environmental conditions present in the microenvironment surrounding freestall bedding will hasten and increase such outbreaks.

References

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Appendix

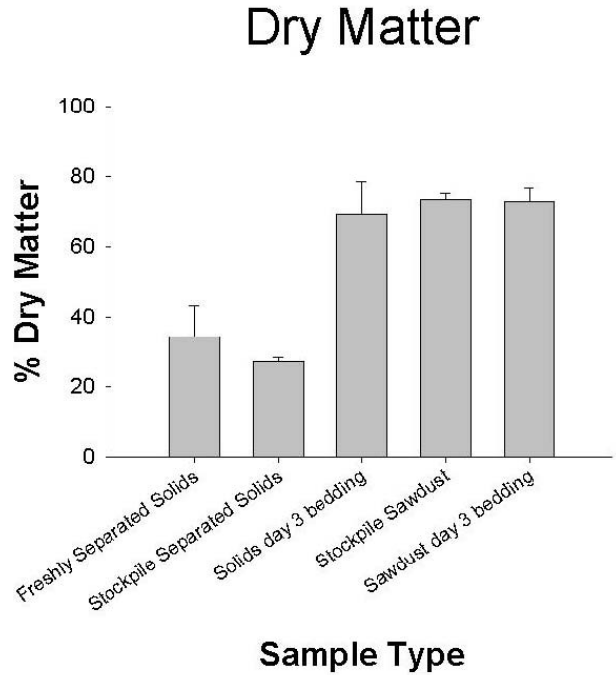
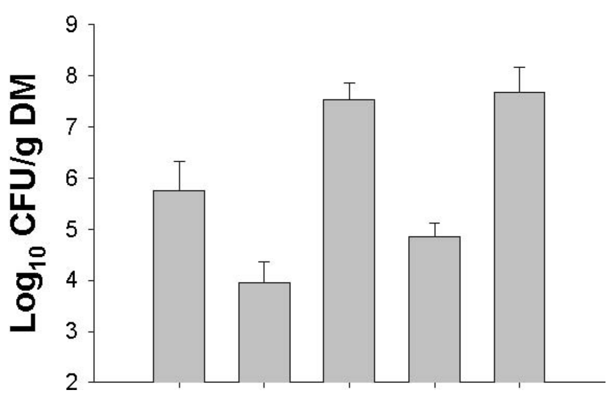


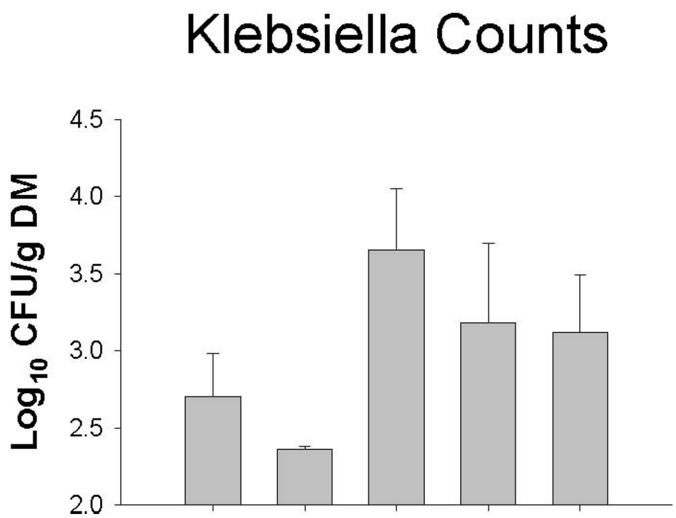
Figure 1. Average percent dry matter of the five sampling locations.

Streptococcal Counts



Sample Type

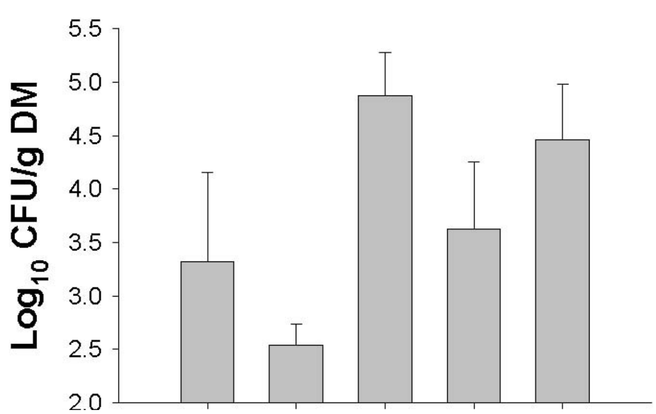
Figure 2. Average concentration of streptococcal, Log_{10} CFU per gram of dry matter for the five sampling locations.



Sample Type

Figure 3. Average concentration of *Klebsiella spp.*, Log_{10} CFU per gram of dry matter for the five sampling locations.

Coliform Counts



Sample Type

Figure 4. Average concentration of coliform, Log_{10} CFU per gram of dry matter for the five sampling locations.

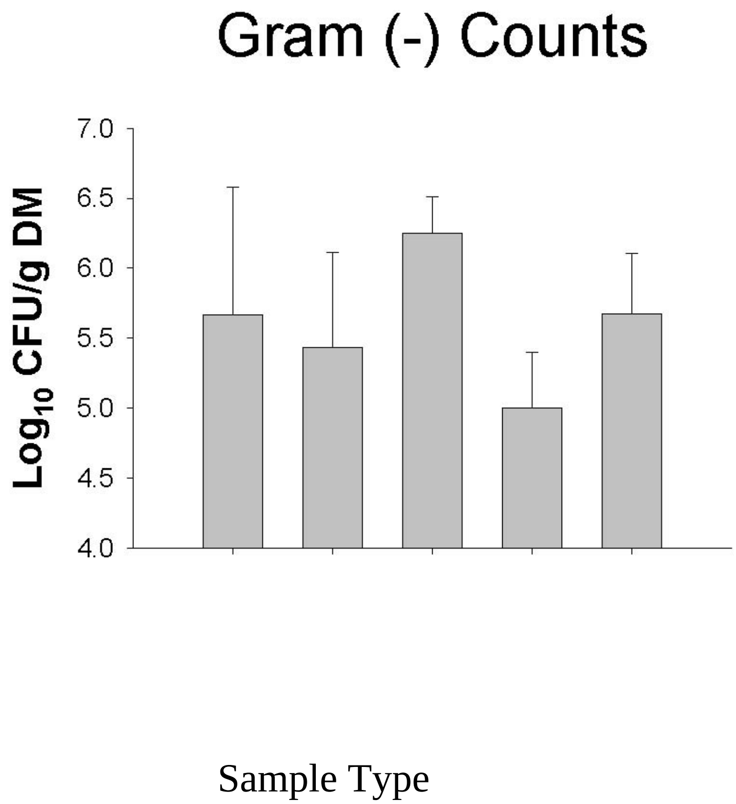


Figure 5. Average gram negative counts, Log_{10} CFU per gram of dry matter for the five sampling locations.