

William H. Miner Agricultural Research Institute

**THE USE OF BIOAUGMENTATION TO REDUCE ODOR AND
LIQUEFY SOLIDS IN STORED DAIRY MANURE**

FINAL REPORT

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Research Report



Introduction

Manure management has become an increasingly complex issue for livestock producers, causing many farmers to alter their manure handling techniques. Other changes are resulting from nuisance legislation and increasing environmental awareness about odor emissions from livestock facilities. Over 60 volatile compounds of biodegradation, many considered objectionable by the non-farm public, have been identified in gases emitted from animal wastes (Sweeten et al., 1995).

Pro-Act Microbial™, Inc. has developed a bioaugmentation process that builds a three-stage digester in manure lagoons and pits. The three-stage digester reportedly works faster and more efficiently than a one-stage anaerobic digestion present on most dairy farms. According to Pro-Act Microbial, during the first stage of digestion, the facultative microbes consume the gases produced by the anaerobes, alleviating manure odor gases. The aerobic microbes act as an odor cap, and finish off any gases that get through the facultative layer as the second stage of digestion. The droppings from this digestion process, detritus, fall to the bottom and fertilize the microbes below. The increased microbial activity requires carbon supplied by the manure solids. During the final digestion phase, the microbes pull the carbon out of the solids converting it to water and carbon dioxide. The microbes found in the Pro-Act Microbial product are similar to the ones that digest the raw manure when applied to the field. In this system, this digestion function is now performed in storage. When the manure is field applied, reportedly much of the nitrogen is fixed making it a fast-acting fertilizer.

The objective of this study was to determine:

- 1) The effect of the Pro-Act Microbial system on the nutrient composition of manure at the upper and lower depths of stored dairy manure slurry.
- 2) The efficacy of the Pro-Act Microbial system to reduce objectionable odor and volatile ammonia (NH_3) and H_2S in stored slurry manure.
- 3) The efficacy of the Pro-Act Microbial system to reduce solids content of stored slurry manure.

Materials and Methods

Eight 1000-gallon vertical poly tanks (64" diameter, 79" height) were stored above ground at a site close to an electrical supply. On August 5, 2004, approximately 850 gallons of untreated slurry manure from the Miner Institute dairy barn manure pit was added to each tank at a solids content averaging 4.16% (Fig. 1). Since slurry manure at Miner Institute contained approximately 8% solids, 2000 gallons of water was added to an empty liquid manure spreader followed by 2000 gallons of slurry manure. Filling the tank seemed to provide sufficient mixing of water and manure to obtain an approximate solids content of 4% when filling the 1000 gallon vertical poly tanks. Two manure spreader loads were used to fill the 8 poly tanks. Tanks were blocked by fill order from the spreader (1st, 2nd, 3rd and 4th



Figure 1. Filling of tank with slurry manure.

1000 gallons respectively) and randomly assigned to one of two treatments: Control and Pro-Act Microbial (Pro-Act). Each treatment was replicated four times. The Pro-Act Microbial system was added to the poly tanks within ½ hour of filling with the amount of Microbes [IS], Growth Accelerator [GA] and Cycle Additive [CA] recommended by the manufacturer.

After being inoculated, the treated tanks were equipped with one Hagen Maxima R aquarium pump each, working as a surface aerator running continuously (Figs.2-4). Initially, one aerator pump with two outlets (2500cc/minute; 2.5 psi(17.24 Kpa)) was used with five air stones suspended over both the left and right side of the storage tank. On August 27th, a second pump was added to the Pro-Act tanks because there was a concern that sufficient aeration of the tanks was limited by the single pump. Two stones were removed per side to increase the aeration activity of the remaining stones. On October 8th, an air pump on one tank was replaced because the original unit failed.

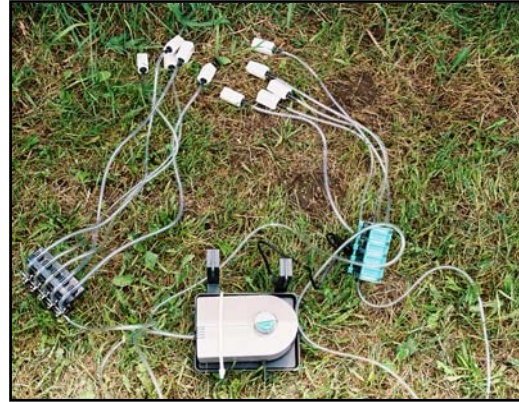


Figure 2. Aquarium pump and aeration stones prior to immersion in tank.



Figure 3. Aeration activity on surface of tank.

The manure from each tank was sampled at filling and analyzed for dry matter, pH, total nitrogen, ammonia N (as % of total N), phosphate equivalent (P_2O_5), potash (K_2O) and phosphorus. The manure remained in the tanks for sixty-seven days.

Temperatures were recorded weekly via a twelve-inch compost thermometer suspended into the center of each tank. No noticeable changes in tank levels due to evaporation or rainfall were noted over the course of this study. Top crust

depth was measured on Day 38 by visually identifying the discernable solid and liquid layers through the side of the translucent tanks.

On September 13th, at Day 38, and again on October 12th, at Day 67, the manure was carefully sampled at two depths: top 15-30 cm using a 2.5cmID x 114 cmL “tote” coliwasa; and bottom 15-30 cm using a 2.5cmID x 224 cmL “tanker” coliwasa (Ben Meadows Co., Janesville, WI). Approximately 2 liters of manure was collected into a 4-liter plastic cubitainer. A subsample of collected sample was analyzed for dry matter, pH, total nitrogen, ammonia N, organic N, P_2O_5 , and K_2O . To determine if treatment altered nutrient retention in the samples an analysis of covariance was



Figure 4. Manure tank set-up 4 days after filling.

performed using the initial nutrient analysis of the samples as the covariate. Samples from the two depths were also evaluated for hydrogen sulfide and ammonia gas emissions and for smell by odor panel evaluation.

After 39 days of storage, the tanks were re-inoculated with 342 g of microbes and 500 ml of growth accelerator through a hole punched into the center of the crust. A hole was also made in the center of the control tank crust, however nothing was added to the tank.

Odor gas emissions

A modification of the technique described in Miner et al. 1995 and Miner and Licht 1981 was used. This technique was a closed system using compressed house air to advect manure gas odors at 1 L/min. from the slurry to gas detection tubes. The various components of this detection apparatus were connected by 1/4" R1000 Nalgene tubing (Nalgene Nunc International, Nutting Lake, MA).

The compressed house air first passed through an activated carbon trap to remove any contaminants and was then bubbled through a 1 L flask of Milli-Q (Millipore Foundation, Bedford, MA) water to minimize drying. The air was humidified to facilitate the odorous constituents moving through the system. The humidified air then passed through a 4 liter cubitainer reservoir of dairy manure. The output from the manure sample was split into two lines for the determination of NH₃ and H₂S via detector tubes (Draeger Safety Inc., Pittsburgh, PA).

The sampling process began by opening the cubitainer with manure and inserting a # 7 two-hole rubber stopper (inlet and outlet flow) in place of the standard cap. The rubber stopper was secured and sealed with Parafilm strips (American National Can, Chicago, IL). Next, the detection tubes (NH₃, 5-700 ppm, P/N: CH20501; H₂S, 5-600 ppm, P/N: CH29801) were prepared by breaking open both ends of the tubes and inserted one end into the split tubing line coming from the manure sample. The output end of each of the detector tubes was connected by tubing to a beaker of water. Once this was completed the system was closed, allowing the cubitainer to pressurize and to deliver moistened air through the sample and to the detector tubes. Once the output from the detector tubes began to bubble into the final beaker, a 4-channel NIST traceable timer (Control Company, Friendswood, Texas) was started.

Over the course of the experiment the detector tubes would change color on an indicator scale in mg/L of NH₃ or H₂S. The time taken to achieve 20 mg/L was recorded and compared.

Odor Panel Evaluation

For the olfactory evaluation of manure slurry stored for 38d, clean cotton flannel was heated at 105°C for 2 hours to eliminate residual odors. The fabric was cut into 13 x 20 cm pieces and each swatch was suspended over 1 liter of manure obtained from the top or bottom 15-30 cm of one of the eight tanks in a sealed 4 liter cubitainer for 1 hour. After exposure to manure, the swatch was cut in half and each half placed into a plastic bag for panel evaluation (Miner and Licht, 1981). Individuals were selected for the odor panel by screening the individuals' ability to detect odors. Cotton flannel swatches exposed to heifer manure (slight smell) and lactating cow manure (strong smell) were assembled into a triangular test design: two swatches exposed to heifer and one swatch

exposed to lactating cow manure. Earlier work by Miner and Licht (1981) has indicated that if the odors are different, each of the panel members will be able to identify the swatch that is different. Persons correctly identifying the different swatch were determined to have an ability to detect odors and were included on the odor panel, resulting in a final panel of thirteen. Each panelist was given three groups of three individually bagged swatches. Each group contained two swatches of one treatment and one swatch of the other treatment from the respective sampling depth. The panelists were asked to identify which of the three swatches was different from the other two. Panelists were then asked if they find the different swatch more or less offensive. Each panelist was asked to evaluate no more than three groups of swatches to avoid olfactory fatigue. Test responses for correctly identifying the single swatch were evaluated using the Chi-Square test for specified proportions, assuming that a panelist would select the different swatch 33.33% of the time by random selection. Test responses for determining if the treated manure was more or less offensive than untreated manure slurry was evaluated using the Chi-Square test for equal proportions.

To improve the intensity of the samples for evaluation a slight modification of the above procedures was made for the olfactory evaluation of the manure stored at 67d of storage. One milliliter of manure slurry was placed in the bottom of a plastic milk-sampling bottle and covered with two cotton balls to minimize any visual bias. The intensity of the odor was improved by this method of sample preparation. Evaluation of the odors by panelists was performed as described for the 38d evaluation.

Results and Discussion

The manure tank temperatures are plotted in Figure 5. The manure temperatures did not appear to be influenced by treatment. They tended to follow ambient temperature trends. The depth of the top crust was not significantly different for the Pro-Act tanks compared to the control (34.29 vs. 32.23 ± 2.33 cm, $P > 0.10$).

The chemical composition of the slurry manure after 38 and 67d of storage are presented in Tables 1 and 2, respectively. Dry matter was determined at Miner Institute and sometimes differed from the total solids analyzed at the Dairy One laboratory. Differences in analytical technique may have contributed to these variations as well as sub-sampling error. For both treatments, there was a striation of solids in the tanks, with the highest level of solids being located toward the bottom of the tanks. Within the striation, the top contained higher levels and the bottom contained lower levels of dry matter for the treated tanks when compared to the untreated tanks at both 38 and 67d of storage. The density of the slurry was similar for treatments and tank levels at both 38 and 67d of storage. Total nitrogen content did not differ for treatment at either the upper or lower levels of tanks at 38 and 67d of storage. Ammonia N levels, although not statistically different, tended to be lower at both top and bottom of Pro-Act treated tanks at 38 and 67d of storage. No treatment differences in organic N levels were observed.

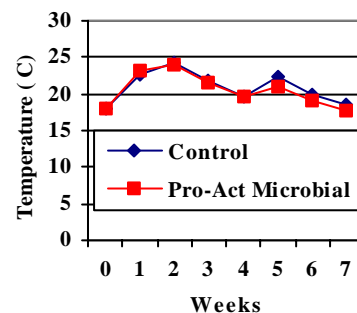


Figure 5. Tank temperature by week of storage.

Table 1. Chemical composition of slurry manure after 38d storage. (Ismean +/-se).

Item	Control	Pro-Act	SE	P-value
DM (%)				
Top	1.41	1.78	0.09	0.093
Bottom	4.39	3.94	1.01	0.787
Solids (%)				
Top	1.53	3.06	1.46	0.554
Bottom	6.66	6.28	1.31	0.863
Density (lbs./gal.)				
Top	8.01	8.02	0.15	0.933
Bottom	8.04	8.12	0.08	0.589
Nitrogen (lbs./1000 gal.)				
Top	9.99	10.08	0.36	0.880
Bottom	14.88	12.49	1.14	0.278
Ammonia N (lbs./1000 gal.)				
Top	6.23	5.87	0.12	0.186
Bottom	6.73	6.30	0.12	0.145
Organic N (lbs./1000 gal.)				
Top	3.84	4.21	0.25	0.406
Bottom	8.19	6.21	1.00	0.295
Organic N (%Total N)				
Top	38.42	41.61	1.65	0.307
Bottom	51.75	51.58	0.94	0.916
pH				
Top	7.60	7.78	0.004	0.001
Bottom	7.38	7.61	0.014	0.008

Table 2. Chemical composition of slurry manure after 67d storage. (lsmean +/-se).

Item	Control	Pro-Act	SE	P-value
DM (%)				
Top	1.95	2.43	0.17	0.189
Bottom	5.47	4.80	0.10	0.044
Solids (%)				
Top	1.44	1.81	0.19	0.337
Bottom	3.86	2.77	0.26	0.108
Density (lbs./gal.)				
Top	8.03	8.10	0.05	0.425
Bottom	8.12	8.11	0.03	0.817
Nitrogen (lbs./1000 gal.)				
Top	11.09	10.68	0.69	0.719
Bottom	15.77	12.73	1.92	0.380
Ammonia N (lbs./1000 gal.)				
Top	6.47	5.90	0.19	0.191
Bottom	7.01	6.48	0.26	0.308
Organic N (lbs./1000 gal.)				
Top	4.70	4.70	0.60	0.999
Bottom	8.75	6.28	1.65	0.400
Organic N (%Total N)				
Top	41.46	44.14	2.62	0.547
Bottom	50.88	51.47	1.77	0.846
pH				
Top	7.76	7.64	0.03	0.098
Bottom	7.38	7.46	0.04	0.275

Phosphorus levels understandably followed similar striation in the tanks as the dry total solids with highest levels being in the bottom of the tanks (Tables 3 and 4). There was no treatment difference at either the top or bottom of the tanks at 38d of storage. After 67d, there were no significant treatment differences in phosphorus levels at the top or bottom of the tanks, however the Pro-Act Microbial-treated tanks tended to have lower phosphorus levels toward the bottom of the tank when compared to the control. The P₂O₅ levels were similar for both treatments at 38 and 67d of storage. Potash (K₂O) was significantly lower for the Pro-Act Microbial-treated slurry toward the bottom of the tank after 38d of storage, however the numeric difference is of little biological significance. No treatment differences for potash were realized after 67d of storage.

Table 3. Chemical composition of slurry manure after 38d storage. (lsmean +/-se).

Item	Control	Pro-Act	SE	P-value
Phosphorus (lbs./1000 gal.)				
Top	1.91	1.82	1.09	0.958
Bottom	3.71	3.24	0.38	0.474
P ₂ O ₅ Equiv. (lbs./1000 gal.)				
Top	4.01	4.45	2.50	0.915
Bottom	8.49	7.44	0.95	0.527
K ₂ O (lbs./1000 gal.)				
Top	11.00	9.30	1.19	0.423
Bottom	10.79	10.56	0.02	0.043

Table 4. Chemical composition of slurry manure after 67d storage. (lsmean +/-se).

Item	Control	Pro-Act	SE	P-value
Phosphorus (lbs./1000 gal.)				
Top	1.04	1.18	0.20	0.572
Bottom	3.34	1.85	0.44	0.143
P ₂ O ₅ Equiv. (lbs./1000 gal.)				
Top	2.34	2.81	0.44	0.532
Bottom	7.36	4.56	1.18	0.244
K ₂ O (lbs./1000 gal.)				
Top	12.09	12.01	0.13	0.714
Bottom	12.16	12.06	0.13	0.697

The measurement of odor gas emissions is presented in Table 5. The length of time in seconds was measured for levels of ammonia and hydrogen sulfide to reach 20 mg/L. After 38d of storage, no treatment difference in emission of ammonia gas was found however at 67d of storage, it took longer for ammonia levels of manure collected from the bottom of the treated tanks to reach the 20 mg/L threshold, indicating lower levels were being emitted from the treated tanks. No difference in ammonia levels was found for samples taken at the top of the tanks. The length of time it took for hydrogen sulfide gases to reach 20 mg/L was significantly lower for untreated slurry manure at the top and bottom depths of the tanks at both 38 and 67d of storage. These findings indicate that hydrogen sulfide gas emissions were lower for Pro-Act Microbial-treated manure.

Table 5. Time required for odor gas levels of slurry manure to reach 20 mg/L after 38 and 67d storage (lsmean seconds +/-se).

Item	Control	Pro-Act	SE	P-value
38d Storage				
Ammonia	Time (seconds)			
Top	258.50	290.25	35.01	0.567
Bottom	452.50	537.25	32.78	0.165
Hydrogen Sulfide				
Top	177.50	629.75	12.11	<0.001
Bottom	209.50	403.75	7.61	<0.001
67d Storage				
Ammonia	Time (seconds)			
Top	388.50	480.25	51.16	0.294
Bottom	474.00	630.00	18.66	0.010
Hydrogen Sulfide				
Top	451.50	1848.50	61.69	<0.001
Bottom	430.00	1217.75	22.21	<0.001

The results of the odor panel evaluation are presented in Table 6. The odor panel could detect no treatment differences after 38d of storage using the exposed fabric swatch method. The intensity of the samples was re-evaluated and modifications to the testing procedures were used to enhance the odor for evaluation. Using these modified procedures, the 67d evaluation found that there were discernable differences in odor of untreated and treated manure collected from the top section of the tanks. Of the panelists correctly identifying the single sample, 83.33% found the treated slurry less offensive than the untreated manure. No treatment differences were found when evaluating the bottom section of the tanks. After modifying the intensity of the samples being evaluated, a concern arose in regards to olfactory fatigue of the panelists due to the intensity of the samples being evaluated. Most panelists, although they could correctly identify the single swatch in the first two groups of three samples being evaluated, failed to identify the single swatch in the third group of samples evaluated. Therefore, a second analysis of the 67d samples was conducted, using only two groups of evaluations per panelist. The single swatch for both top and bottom sections of the tanks could be identified indicating discernable odor differences between treatments. Of the panelists correctly identifying the single swatch, 88.89% found the treated manure less offensive in the top section, while only 44.44% found it less offensive in the bottom section.

Table 6. Odor panel evaluation of slurry manure after 38 and 67d storage.

Item	Single sample correctly identified				n	Pro-Act sample offensive		
	n	No	Yes	P-value		More	Less	P-value
38d Storage								
Top	21	57.14	42.86	0.355	9	44.44	55.56	0.739
Bottom	18	66.67	33.33	1.000	6	66.67	33.33	0.414
67d Storage								
Top	22	45.45	54.55	0.035	12	16.67	83.33	0.021
Bottom	20	50.00	50.00	0.114	10	50.00	50.00	1.000
67d Storage*								
Top	14	35.71	64.29	0.014	9	11.11	88.89	0.020
Bottom	14	35.71	64.29	0.014	9	55.56	44.44	0.739

*Modified 67d evaluation only using the first two evaluations for each odor panel member.

Conclusion

Based on this study's findings, Pro-Act Microbial did not appear to influence solids content, or density of manure slurry near the top or bottom of the storage unit after 38 and 67d of storage. Total nitrogen levels were similar for both treatments. However, ammonia N levels tended to be slightly lower for Pro-Act Microbial treated manure at the top and bottom of the tanks at both 38 and 67d of storage. Phosphorus, phosphate equivalent and potash content were similar for both treatments at each monthly interval. The emissions of hydrogen sulfide were significantly less for the Pro-Act Microbial-treated manure for both the top and bottom of the storage unit after 38 and 67d of storage when evaluated quantitatively in the lab. These findings were confirmed by the odor panel evaluation at 67d, which found the treated slurry manure was less offensive from the top section of the storage unit. No discernable difference in odor offensiveness was detected for the bottom section of the tank.

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