This is the final version revised on November 1, 2010. Table 5 has been corrected for temperature data.

FINAL REPORT

Evaluating the Effectiveness of Dairy Bedded Pack Systems in Ohio

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INTRODUCTION

In 2007, Ohio had 3,650 dairy farms and a total of 458,465 dairy cows with cash receipts of approximately $862 million for milk and other dairy products (USDA, 2009). Of the Grade A dairy farms housing these cows, it is estimated that 94% have less than 200 cows and approximately 58% of them use liquid manure storage (Rausch, et al, 2007). Liquid manure systems require careful management to minimize the risks of manure runoff and can have high costs associated with transport of a material that is up to 90% water. For dairy farms to remain economically viable, production systems that improve the health of the cow, minimize manure handling costs, and reduce potential environmental impacts are needed.

An alternative system that has been evaluated by the University of Minnesota (UMN) over the last several years is the compost bedded pack dairy barn. The compost bedded pack dairy barn is a loose-housing system which incorporates periodic mechanical stirring of the bedded area. Table 1 provides a summary of the design and management recommendations for Minnesota's composting bedded pack barns.

Table 1. Design and management recommendations (Janni, et al, 2007)

Activity	Recommendations
Barn design	
Spacing	65 sq. ft./900 lb cow; 80 sq. ft./1200 lb cow
Concrete wall	4 ft. high around pack area; walkways for cow and equipment movement every 115-130 feet along wall between pack and feed alley
Feed alley	Concrete; 12 ft. wide
Ventilation	Typically natural ventilation with 16 ft. high building sidewalls
Waterers	In feed alley adjacent to concrete wall but not in pack area
Bedding management	
Type	Fine, dry sawdust
Initial depth	12-18 in.
Additions	1-2 in. when begins to stick to cow after lying on pack
Stirring	2 times/day to a depth of 10-12 in. using a cultivator pulled by a tractor or similar equipment
Maximum depth	4 ft. as limited by concrete side walls
Manure management	
Feed alley	Scrape 2 times/day; store separately
Pack	Clean out every 6-12 months; typically, full clean out in fall with partial clean out (1/2 – 2/3) in spring

In 2005, a 3-month study of 12 compost barns in Minnesota, with an average herd size of 73 cows, indicated that this system is beneficial for cow comfort and longevity and is easy to manage. The study concluded that animal welfare in the bedded pack system, as evidenced by cow hygiene, lameness and hock lesions, ranged from equivalent to significantly improved in comparison to cows in freestalls (Bargerg, et al, 2007). Comparison of the bedded pack system to 2 years of DHIA data indicated an improvement in milk production, reductions in mastitis infections and no impact on contagious pathogen in the bulk tanks compared to systems used previously. However, researchers noted that other changes had been made on some farms which may have affected the results and that excellent management of the system is essential (Bargerg, et al, 2007).

OBJECTIVES

The potential positive impacts for milk production as well as the ability to handle manure as a dry material have resulted in increased interest in bedded pack systems in Ohio. This study was undertaken to evaluate the effectiveness of compost bedded pack systems in Ohio and to develop design and management recommendations for Ohio dairies. The objectives of this study were to:

- Analyze the UMN recommendations to determine if they meet animal needs and can be applied in Ohio's climate.
- Evaluate compost bedded pack systems in Ohio to document current practices and assess their effectiveness.
- Develop recommended design and management guidelines for dairy bedded pack systems.

METHODOLOGY

To meet the project objectives, four dairy farms using a compost bedded pack system were selected. Each site was visited by the research team in October 2008 to assess the barn design and collect data from the farmer on pack and manure handling practices. Additional visits were made during each season to monitor air quality, collect bedded pack samples, and record information regarding current management practices and cow health.

Four Hobo monitors were installed at each facility, three in the barn and one outside, to record temperature and humidity readings every 30 minutes throughout the study period. During the site visits, concentrations of CO_2, NH_3, and H_2S measurements and the temperature and relative humidity were taken at cow nose height (approximately 30-36 inches) at the representative locations indicated in Figures 1-4. Samples of the pack were collected from depths of 6 in, 12 in, and 18 in at six locations which were determined using a random number sampling plan (Appendix A). Table 2 summarizes the parameters measured and the equipment and procedure used.

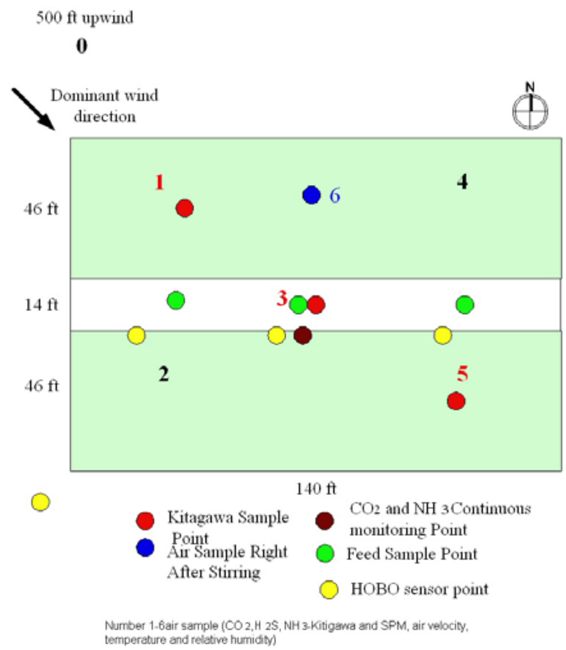

Figure 1. Diagram for D-1 farm, Zanesville, OH, including air quality sampling locations.

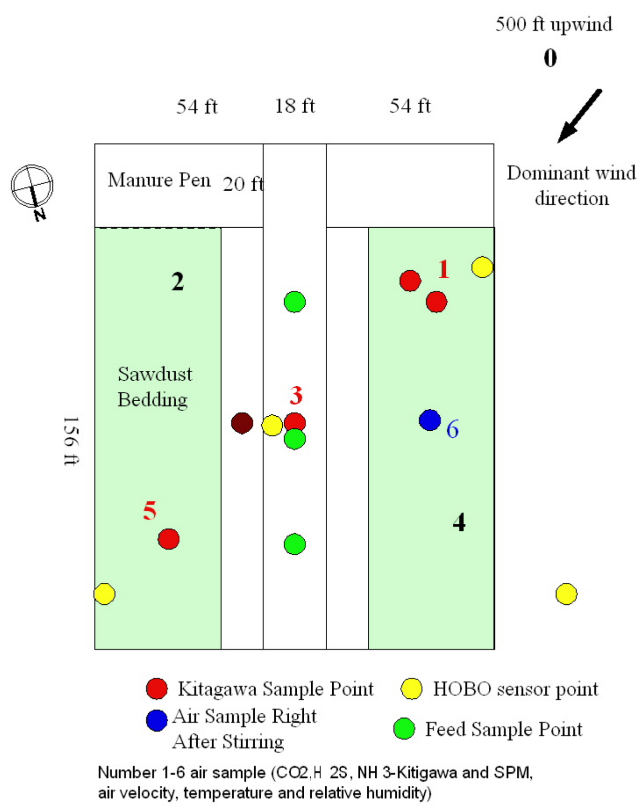

Figure 2. Diagram for D-2 farm, Millersburg, OH, including air quality sampling locations.

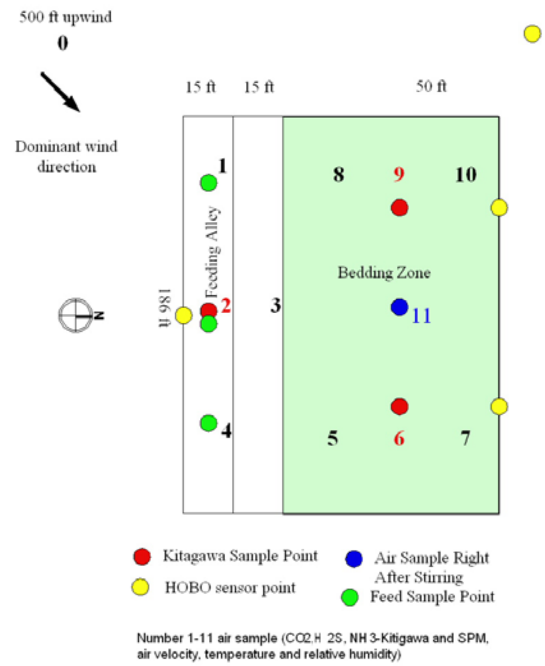

Figure 3. Diagram for D-3 farm, Lodi, OH, including air quality sampling points.

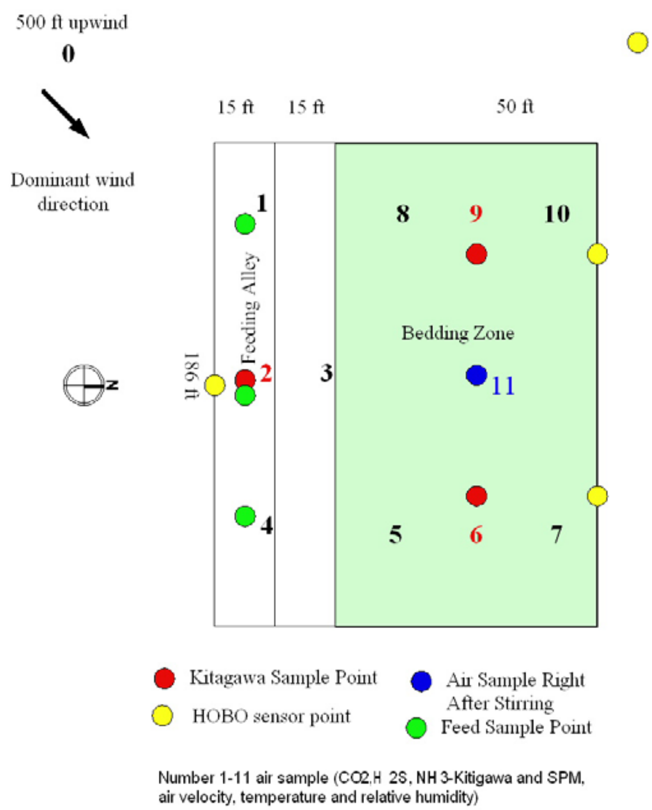

Figure 4. Diagram for D-4 farm, Mantua, OH, including air quality sampling locations.

Table 2. Equipment and procedures used for data collection.

Parameter	Equipment	Procedure
Air Quality		
Relative humidity and air temperature	Hobo monitor; Vaisala sensor	Data downloaded during site visits; 3 readings at each sampling location
Carbon dioxide (CO_2)	Vaisala sensor	3 readings at each sampling location
Hydrogen sulfide (H_2S)	Jerome meter	3 readings at each sampling location
Ammonia (NH_3)	Single point monitor (SPM)	3 readings at each sampling location
Ammonia (NH_3)	Kitagawa tubes	2-3 reading at specified locations
Bedded Pack		
Temperature	Temperature probe	Depth of 6-,12-,18-in @ 6 locations
Oxygen concentration	Oxygen probe	Depth of 6-,12-,18-in @ 6 locations
Total-N; Ammonia-N; moisture; ash; carbon; pH	Laboratory analysis	Grab samples at depths of 6-,12-,18-in @ 6 locations combined for each depth to create 3 composite sample

RESULTS AND DISCUSSION

The oldest of the four study farms began operations in May 2006 (D-1) and the newest began in November 2008 (D-4). The farms generally used the layout and management recommendations developed at the University of Minnesota for compost bedded pack dairy systems (Table 1). However, some variations in both design and management practices do exist, which may reflect the herd management practices. For example, farms D-2 and D-4 practice rotational grazing from spring through fall, thus the time the cows spend on the bedded pack is reduced to as little as 3 hours per day. As a result, the frequency of bedding additions, pack stirring and feed alley scraping is reduced. The reduced volume of manure may also affect the rate of composting. Additional factors that may impact the design or management practices are discussed where relevant.

Layout and management practices

All layouts followed the general recommendations of having a separate feed alley and resting area. Three of the four barns had walls between the resting area and feed alley. The D-4 barn did not have a wall. In this barn, the bedded area sloped down to the feed alley along the entire length of the barn. This condition did not seem to significantly affect the performance of the composted bedded pack. However, this arrangement does reduce the storage volume in the resting area. The reduced storage volume needs to be considered when developing a manure management plan. Three of the four barns had the waterers separate from the bedded pack area, which helped keep the bedded area drier. Manure in the feed alleys was scraped daily to a storage that could handle the liquid manure. The liquid manure storage ranged from a pit at the end of the bedded pack area to an in-ground concrete storage tank.

All barns had good design for natural ventilation. The sidewalls were high with plenty of openings for good air movement. Some had fans for summer cooling. The ventilation systems were managed to provide a healthy environment in each barn.

The layout recommendations for the compost bedded pack system were designed to provide adequate space for all cows to lie down with space available to get up as needed, to enable composting of the manure and pack, and to provide ventilation that compensates for the heat generated from the pack

(Janni, et al, 2007). Table 3 summarizes the design and practices recommended by Minnesota and documented for the study farms.

Table 3. Design and management practices for study farms.

Practice	Recommend	Farm D-1	Farm D-2	Farm D-3	Farm D-4
Cow spacing (sq ft)	65-80	75	88	90	80
Concrete wall (ft)	4	4	4	4	3
Sidewall height (ft)	16	16	16	16	14
Bedding type	sawdust	sawdust	sawdust + straw[1]	sawdust	sawdust + straw[2]
Bedding depth (in)[4]	12-48	12-48	12-48	12-48	12-36
Bedding additions	as needed	as needed	as needed	as needed	as needed
Stirring frequency	2 times/day	2 times/day	2 times/day[3]	2 times/day	2 times/day[3]
Feed alley	scrape 2x/day	scrape 2x/day	scrape 2x/day[3]	scrape 2x/day	scrape 2x/day[3]
Pack clean out	6-12 months	12+ months[5]	12 months	12 months	9 months

[1] Straw added during winter months when sawdust not available.
[2] Straw added during winter months, alternating with sawdust to extend limited sawdust supplies.
[3] Frequency reduced during spring through fall when cows on pasture for ~20 hours/day.
[4] Initial depth of bedding is ~12 in and increases with additions.
[5] North alley cleaned out 1 time since May 2006. South alley never cleaned out, as slope at base appears to reduce liquid accumulation.

The study farms provide spacing for each cow that is within the recommended range or larger. With the exception of D-4, the concrete and sidewall heights are as recommended. With the exception of D-1, the feed alleys and waterers are separated from the bedded pack area by the concrete wall, thus limiting additional water on the pack. It was noted that the pack tended to be wetter and more compacted at the walkways from the feed alley to the pack for all barns. The smaller height for D-4 is not expected to affect the overall performance of the composting bedded pack system but could affect the frequency of complete cleanout.

All farms stirred the pack twice daily, except D-2 and D-4 when cows were on pasture, and reported adding sawdust when the pack became moist enough to stick to the cow. Generally, sawdust was added every 10-14 days, with the exception of D-2 and D-4 as the time interval increased during the period cows were on pasture. All farms experienced difficulty obtaining sawdust during the winter months due to availability and cost. D-2 was without sawdust from February through April and used straw along with picking out manure patties daily, but not turning during that time. Based on researcher observations during this time, the pack appeared compacted and it was difficult to obtain samples through the straw layer. To extend sawdust supplies, D-4 alternated using straw from a round bale, which was sliced before application, with the sawdust. Stirring was continued and researchers observed that the pack was well mixed and not compacted.

Recommended practices for feed alley scraping and complete barn clean out were generally followed. As noted above, D-2 and D-4 reduced the frequency of feed alley scraping when the cows were on pasture. D-1 did not clean its barn during the study period but no concerns with the pack were reported by the farmer or observed by the research team. The cows in D-1 were heifers while those in the other barns were milk cows. This meant a smaller amount of manure per cow was produced which would permit the pack to be used for a longer period of time (Bulletin 604).

<u>Air quality</u>

Table 4 summarizes the air quality data collected at each facility during the four season's visits. With the exception of the ammonia (NH_3) measure using the Kitagawa tubes, the values are the mean of the readings taken at the sampling locations inside the barn (Figures 1-4) before and after turning of the pack.

Table 4. Gas concentrations as measured at each facility. Note: n/a indicates data were not collected.

Farm	Visit	CO_2	NH_3 - SPM	NH_3 - K.tube	H_2S	Temp	Rel. Humid	Air Vel.
	Date	ppm	ppm	ppm	ppb	°F	%	ft/min
D-1[1]	5-Mar-09	712.00	0.27	0.50	12.27	28.15	44.90	94.49
after turn[2]		766.67	0.53	0.50	15.67	29.19	43.40	86.61
D-1[1]	7-May-09	585.33	n/a	1.08	7.29	64.84	61.04	33.99
after turn[2]		510.00	n/a	0.00	1.67	67.60	60.01	127.95
D-1[1]	7-Jul-09	641.33	1.23	0.17	3.60	77.67	49.05	66.08
after turn[2]		610.00	1.30	0.75	2.67	79.03	50.17	49.26
D-1[1]	7-Oct-09	486.07	n/a	0.00	7.60	53.17	66.77	122.80
after turn[2]		636.67	n/a	0.75	15.00	58.82	54.99	119.67
D-2[1]	17-Feb-09	531.33	0.82	0.50	n/a	32.29	61.63	80.07
after turn[2]		n/a	n/a	n/a	n/a	n/a	n/a	n/a
D-2[1]	14-May-09	427.33	n/a	0.00	2.27	60.66	90.30	348.56
after turn[2]		n/a	n/a	n/a	n/a	n/a	n/a	n/a
D-2[1]	14-Jul-09	430.00	0.00	0.00	0.73	68.88	52.36	306.17
after turn[2]		423.33	0.00	0.00	2.67	72.15	41.40	286.09
D-2[1]	13-Oct-09	470.00	n/a	0.00	1.67	47.95	79.87	211.67
after turn[2]		516.67	n/a	0.00	4.33	48.85	81.40	436.33
D-3[1]	17-Feb-09	630.00	n/a	1.58	0.10	41.17	49.08	35.85
after turn[2]		696.67	n/a	1.50	n/a	42.41	46.65	50.67
D-3[1]	14-May-09	522.00	n/a	0.00	2.97	71.95	48.49	281.50
after turn[2]		540.00	n/a	0.00	26.00	71.92	46.70	225.72
D-3[1]	14-Jul-09	534.67	0.00	0.00	2.13	73.35	34.33	135.70
after turn[2]		713.33	0.00	0.00	4.33	75.85	39.35	160.70
D-3[1]	13-Oct-09	472.00	n/a	0.00	2.17	47.99	61.35	240.63
after turn[2]		533.33	n/a	0.05	14.00	48.75	63.26	101.33
D-4[1]	24-Feb-09	668.83	0.54	1.00	n/a	21.86	73.66	78.33
after turn[2]		753.33	n/a	1.33	n/a	26.92	60.10	4.33
D-4[1]	21-May-09	632.22	n/a	0.00	2.33	71.90	38.77	149.50
after turn[2]		940.00	6.67	3.00	7.33	74.44	43.71	70.21
D-4[1]	16-Jul-09	405.56	0.73	0.00	2.37	76.79	54.59	106.41
after turn[2]		513.33	3.40	0.25	7.00	78.49	54.69	173.88
D-4[1]	16-Oct-09	463.89	n/a	0.00	1.06	37.45	88.03	143.72
after turn[2]		456.67	n/a	0.00	4.00	37.44	87.67	52.00

[1] Samples collected before turning pack.
[2] Samples collected immediately after turning the pack.

In the four barns, average indoor temperature range from 28 to 78 °F over the whole year; average relative humidity ranged from 35 to 90%; and average air velocity from 0.2 to 1.8 m/s. Barn temperature variations followed outdoor weather changes. Except that D-4 and D-2 had high relative humidity in the spring and fall, the rest of barns had relative humidity within cow comfortable zone. Air velocity in barns varied significantly with the season and between barns. The higher air velocity in warmer seasons can enhance cow cooling and water evaporation of bedded pack. It is an indicator of good natural ventilation systems and management.

In terms of indoor air quality concerns, carbon dioxide (CO_2) concentrations in the barns ranged from 400 to 700 ppm throughout the whole year with higher CO_2 concentration in winter due to reduced natural ventilation rate achieved through reduced side-wall openings. Ammonia concentrations (NH_3) fluctuated significantly in seasons from 0 to 1.6 ppm in the barns. Hydrogen sulfide concentrations ranged from 1 to 12 ppb with lower levels in warm seasons because of the high ventilation rates. In reference of OSHA indoor air quality standards and NIOSH indoor air quality recommendations, all the gas concentrations are well below the suggested indoor air quality thresholds (25 ppm ammonia, 10 ppm hydrogen sulfide). This indicates that there is no air quality concern in the bedded pack composting dairy barns

Composting of bedded pack

Table 5 summarizes the data collected on the bedded pack. Temperature and oxygen values represent the mean of readings from the six bedded pack sample locations. The average temperatures of approximately 90-120°F indicate composting (microbial activity) is occurring. Higher temperatures of 140-160°F seen in many commercial composting systems were not achieved, probably because of the shallow bedded pack depths (typical compost piles are 6-8 feet or more). Oxygen levels were well below ambient levels (21%) at 7-9%, another indicator of composting. These levels have been found to be adequate to allow aerobic composting with little offensive odors. The remaining data are from lab analyses conducted on composite samples from the six locations.

The pH values of the bedded pack were basic, ranging from 7.9 to 9.6. This is an indicator the composting was aerobic in nature since anaerobic activity would produce an acidic compost. Two other indicators of composting activity, decreasing C/N ratio and increasing ash content, cannot be used in this study since manure (feces+urine) from the cattle was increasing in proportion to the bedding. The manure would decrease C/N and increase ash. At the 18 inch depth, the C/N for D1 and D2 dropped from 24 to 15 and 27 to 9 from March to October, respectively. As D2 had total clean out of the barn in June, the C/N decrease from March-October is not valid. For D3 and D4, C/N dropped from 36 to 20, and 33 to 26 from March-July, respectively. The increases in ash samples were 9.6 to 13.3, 11.7 to 52.0, 9.3 to 15.8 and 6.7 to 10.8, respectively. The high ash concentration in D2 may be the result of the inadvertent collection of clay from the base of the pack. The end C/N ratios (i.e. at time of bedded pack removal) would mean the material should be a good soil amendment with minimal effects on causing nitrogen deficiency on growing plants.

The NPK values of the bedded pack manure at clean out are reported in Table 6. The nutrient levels on a dry basis of 1.8-3.3 for N, ~1 for P_2O_5 and 2-3 for K_2O would be considered average to above average compared to most compost (Hansen, et al, 2002). Lower N values were observed at the 12" and 18" depth in almost all cases, probably due to N losses occurring over time plus possibly manure with high nitrogen continually being added in the top six inches. This result also suggests minimal downward movement of N from the upper layers. Assuming a 2.5:1:2 fertilizer analysis and approximately 65% moisture for the pack material at clean out, each ton of compost would supply 17.5, 7 and 14 lbs of N, P_2O_5, and K_2O per wet ton, respectively.

Table 5. Bedded pack data from each facility as indicated.

Bedded Pack Data										
Farm	Visit	Moisture[1] (%)			C:N Ratio[1]			Ash[1] (%) dry basis		
	Date	6"	12"	18"	6"	12"	18"	6"	12"	18"
D-1	5-Mar-09	68.34	68.89	66.95	23.96	22.18	24.23	6.67	8.22	9.60
D-1	7-May-09	65.40	67.82	67.23	18.92	19.33	15.60	9.52	9.63	10.89
D-1	7-Jul-09	63.30	76.62	80.06	20.34	23.74	17.57	10.21	11.29	12.91
D-1	7-Oct-09	65.52	69.12	68.64	13.51	13.70	15.10	14.02	15.50	13.26
D-2	17-Feb-09	77.21	68.56	68.82	17.70	27.80	26.70	15.19	11.20	11.73
D-2	14-May-09	70.85	72.34	71.53	18.77	19.52	18.46	13.61	15.09	9.76
D-2	14-Jul-09	52.83	55.17	56.51	21.49	13.99	7.91	19.22	27.94	32.20
D-2[3]	13-Oct-09	40.76	44.29	37.72	11.91	15.66	9.30	25.79	24.89	51.97
D-3	17-Feb-09	69.31	69.05	69.03	34.80	31.40	35.50	10.85	8.64	9.26
D-3	14-May-09	67.67	67.39	69.44	22.19	25.27	28.07	10.53	9.49	9.62
D-3	14-Jul-09	59.34	62.29	66.20	16.80	16.31	20.55	15.79	16.32	15.80
D-3[6]	13-Oct-09	39.18	n/a	n/a	72.30	n/a	n/a	3.00	n/a	n/a
D-4	24-Feb-09	71.51	70.94	71.23	31.90	30.40	32.70	6.77	8.68	6.86
D-4	21-May-09	68.25	70.46	71.19	21.10	26.01	25.18	9.79	8.78	8.45
D-4	16-Jul-09	50.43	64.38	68.67	18.10	16.44	25.70	14.01	12.58	10.82
D-4[6]	16-Oct-09	64.41	n/a	n/a	28.38	n/a	n/a	6.50	n/a	n/a

Bedded Pack Data (continued)										
Farm	Visit	Temperature (°F)[2]			O_2 (%)[2]			pH[1]		
	Date	6"	12"	18"	6"	12"	18"	6"	12"	18"
D-1	5-Mar-09	49.70	52.70	59.30	21.30	21.67	21.67	9.30	9.16	9.20
D-1[4]	7-May-09	94.10	98.90	98.30	9.00	9.67	17.00	9.33	9.28	9.39
D-1[4]	7-Jul-09	100.99	110.30	111.56	6.00	12.00	6.80	9.17	9.28	9.23
D-1	7-Oct-09	87.44	92.48	97.52	21.00	21.20	21.20	8.93	8.84	9.03
D-2	17-Feb-09	62.90	n/a	n/a	6.83	n/a[1]	n/a[1]	8.07	8.29	8.36
D-2[4]	14-May-09	78.80	81.80	82.10	14.83	11.50	2.83	9.22	9.10	9.09
D-2[4]	14-Jul-09	91.99	97.70	92.48	7.67	4.67	3.17	9.29	9.20	9.21
D-2	13-Oct-09	95.31	107.60	111.20	10.67	8.00	11.00	9.56	9.36	9.24
D-3	17-Feb-09	49.40	50.30	50.36	17.33	15.00	17.00	7.93	7.86	7.96
D-3[5]	14-May-09	80.60	80.00	77.36	15.50	13.50	8.50	8.88	8.68	8.63
D-3	14-Jul-09	86.31	88.70	86.90	9.50	5.17	3.83	9.31	9.17	9.15
D-3[6]	13-Oct-09	80.91	n/a	n/a	13.67	n/a	n/a	8.19	n/a	n/a
D-4	24-Feb-09	50.30	58.10	60.80	17.00	16.50	17.80	8.05	8.17	8.10
D-4	21-May-09	99.50	103.40	98.60	13.00	19.00	9.70	8.95	8.80	8.38
D-4	16-Jul-09	117.81	122.31	117.19	13.00	8.83	6.33	9.56	9.45	9.09
D-4[6]	16-Oct-09	61.70	n/a	n/a	18.17	n/a	n/a	8.75	n/a	n/a

[1] Composite sample collected from six locations.

[2] Average from six sample locations.

[3] High ash at 18" may reflect contamination from clay base.

[4] O_2 at some locations may not be accurate due to possible instrument error.

[5] Probe hit dirt at less than 18" at 2 sampling locations, no data collected.

[6] Due to recent clean out of barn, only 6" of pack present.

Table 6. N-P-K analysis for samples collected before total cleanout of barn.

Bedded Pack Data													
Farm	**Visit**	**Total N** (% dry basis)			**NH_4-N** (% dry basis)			**P_2O_5** (% dry basis)			**K_2O** (% dry basis)		
	Date	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
D-1	7-Oct-09	3.28	2.82	2.85	0.10	0.15	0.17	0.64	0.85	1.01	1.92	2.06	2.18
D-2	17-Feb-09	2.34	1.74	1.78	n/a	n/a	n/a	0.87	0.41	0.39	3.00	1.76	1.25
D-3	14-Jul-09	2.67	2.68	2.17	0.03	0.07	0.07	1.12	1.05	1.01	2.17	2.14	1.99
D-4	16-Jul-09	2.50	2.75	1.86	0.04	0.15	0.26	1.40	1.15	0.96	3.16	2.77	2.36

Cow performance, health and comfort

Farmers reported good cow health and performance. On one farm (D-3), the cows were just moved into the new barn from a good tie stall barn after a few months in a free stall barn shortly before the project started. The farmer reported improved feet health, better milk quality and improved milk production. The improved feet health and milk quality can be directly correlated to the bedded pack. The increased milk production may be partially related to the bedded pack and partially to a change in feeding program to a total mixed ration. The cows were consistently much cleaner in the composted bedded pack barns than cows were in the traditional bedded pack barns of the past.

The composting bedded pack dairy system replaced other systems, including tie-stall with daily hauling (D-4) and bedded pack with no stirring (D-1), at each study farm. All farmers reported satisfaction with the new system from a management perspective as well as cow health and comfort. Table 7 summarizes the production data for each farm as reported by the producer.

Table 7. Production data for study farms

Farm	Cow Type	Cow Size	Average Number of Cows	Average Milk Production	Avg. Somatic Cell Count
D-1	Holstein heifers	900-1100 lbs	160-170	Not applicable	Not applicable
D-2	Jerseys	900-100 lbs	150-160	50 lbs/cow/day	180,000
D-3	Holsteins[1]	1400-1500 lbs	60-65	75 lbs/cow/day	144,000
D-4	Holsteins[2]	800-1400 lbs	80-90	45 lbs/cow/day	188,000

[1] Herd included a few Jersey and Brown Swiss cows.

[2] Herd included crosses as follows: Holstein-Jersey and Holstein-Jersey-Normandy.

CONCLUSIONS

This study found that the composted bedded pack barns in Ohio followed the general recommendations from Minnesota. There were some small differences in area per cow, which will vary over time as cows are added or removed from the herd. One had a 3-foot wall instead of a 4-foot wall. This difference did not affect the performance of the building; but will affect the storage capacity in the bedded pack area.

This study confirmed that the design guidelines for composted bedded pack barns from Minnesota would work well in Ohio. The air quality in the barns was very good. The cow health and performance was very good. There was good composting action when the bedded pack was stirred as recommended.

When long straw was used instead of sawdust, the ability to stir the top layer was lost. The dairyman who alternated sawdust with chopped straw was able to stir the bed and maintain a better bedded pack surface. This result points out the need for having a reliable source of sawdust, as there have not been many good alternatives identified that work well in the compost bedded pack barns. Chopping of bedding such as straw may alleviate the problems as observed in this study for D-4

Design and management guidelines:

- The design and management recommendations from Minnesota as given in Table 1 are appropriate for Ohio.
- Design, construction, and management of the barns should ensure good natural ventilation. The design requirements for free stall barns are appropriate for composted bedded pack barns. A 14’ to 16’ curtain wall above the concrete wall provides for good ventilation. Manage the natural ventilation system the same as for free stall barns. Fans in the resting area and/or soakers above the feed alley reduce summer heat stress in these barns as in free stall barns.
- If straw is to be used to extend the sawdust, it needs to be finely chopped and alternated with the sawdust to keep a pack that can be properly maintained.

RECOMMENDATIONS

The recommendations for compost bedded pack barns in Ohio are described below. Except where noted, the recommendations are the same as for Minnesota (Table 1).

<u>Barn Design</u>

- **Spacing.** To ensure adequate space for cows to lie down and maintain a manure and bedding mixture that allows for composting, the cows should be provided a minimum of 65 square feet/cow for Jerseys (900 lbs) to 89 square feet/cow for larger cows (1200-1400 lbs).
- **Concrete wall.** The concrete wall surrounding the pack area holds the bedding in place and allows accumulation of manure and bedding for 6-12 months. The recommended height is 4 feet, although heights of 3 feet are adequate but may require more frequent clean out. At least two walkways should be included in the wall between the pack and feed alley or barn entrance to allow access for cows and equipment.
- **Feed alley.** The feed alley should be concrete and 12 feet wide. Ideally, it should be separated from the pack by the concrete wall. If it is not separated, the base of the pack should be sloped toward the alley to minimize the addition of liquid to the pack.
- **Waterers.** To minimize excess water in the pack, the waterers should be located on the concrete wall but in the separate feed alley, if present.
- **Ventilation.** A 14 - 16 foot side curtain should be located on the two long sides of the building. Door or other openings should be located on the short sides of the building. Fans should be installed overhead to provide additional cow cooling and barn ventilation on hot days.

<u>Bedding Management</u>

- **Type.** Fine, dry sawdust is preferred for the best handling and composting. As the cost of sawdust increases and its availability decreases during the winter months, adequate supplies should be stockpiled during the summer and fall. If straw is needed to supplement sawdust supplies, it should be chopped and alternated with additions of sawdust.
- **Depth.** The initial bedding depth should be 12-18 inches and should include bedding from the cleaned out pack to inoculate the pack with microbes to speed up the onset of the composting processing. When the pack accumulates to a depth of 3-4 feet, depending on the height of the concrete wall, the barn should be cleaned out completely.
- **Additions.** Sawdust (1-2 inches) should be added when the moisture content of the top layer increases such that is sticks to the cow after lying down, generally every 10-14 days.
- **Stirring.** The pack should be stirred twice a day to a depth of 10-12 inches using a cultivator or similar equipment. Stirring increases aeration, which increases the composting process and allows drying of the top layer of the pack.

<u>Manure Management</u>

- **Feed alley.** The feed alley should be scraped twice a day and the manure stored separately from the pack.
- **Pack.** The entire pack should be removed every 6-12 months depending on the depth of the pack and the condition of it, such as excess moisture.

Other Considerations

- **Pasture.** For systems that have cows on pasture during the year, adjustments can be made in the frequency of stirring, bedding additions, and alley scraping. The length of time the cows are on the pack should be considered and the experience and judgment of the farmer are key to good management.
- **Land application.** The pack can be land applied following removal from the barn. However, the farmer may want to have a sample analyzed for carbon (C) and nitrogen (N). If the ratio of C:N exceeds 30:1, the pack may cause nitrogen deficiency in the crop. In this case, the pack should be stored to allow additional composting or land applied well ahead of a growing crop.

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APPENDIX A
Random Sampling Plan for Collecting Pack Samples

Barn Length

		1	2	3	4	5	6	7	8	9	10
	1	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1
	2	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.2
	3	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.3
Barn	4	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.4
Width	5	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.5
	6	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.6
	7	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.7
	8	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.8
	9	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.9
	0	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1

	B-1	B-2	B-3	B-4
Dec	0.73	0.25	0.35	0.49
	0.66	0.29	0.94	0.22
	0.99	0.58	0.93	0.22
	0.42	0.23	0.83	0.42
	0.43	0.57	0.04	0.87
	0.98	0.07	0.09	0.09
Mar	0.34	0.21	0.77	0.09
	0.32	0.64	0.52	0.65
	0.77	0.39	0.33	0.99
	0.03	0.55	0.61	0.81
	0.33	0.73	0.20	0.90
	0.07	0.60	0.23	0.32
Jun	0.79	0.64	0.05	0.21
	0.83	0.43	0.99	0.55
	0.08	0.10	0.57	0.97
	0.41	0.78	0.69	0.14
	0.94	0.03	0.08	0.20
	0.74	0.40	0.82	0.30
Sep	0.67	0.57	0.18	0.80
	0.72	0.03	0.95	0.29
	0.78	0.77	0.63	0.22
	0.47	0.34	0.44	0.68
	0.67	1.00	0.72	0.11
	0.95	0.33	0.36	0.78