TESTING OF AN IN-HOUSE LAYER MANURE COMPOSTING SYSTEM UNDER FIELD CONDITIONS

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Abstract: Many of the problems that have currently beset the commercial egg layer industry have arisen because of methods of handling the manure output from large flocks. Alternative techniques for handling of animal manure within animal production facilities will need to be developed to satisfy current and future zoning and environmental criteria placed on these types of operations. This paper discusses tests conducted in a commercial high-rise layer house involving an in-house deep litter manure management system. This involves layers at commercial densities, depositing their manure onto stacked litter materials located directly beneath the cages. Regular turning of the litter facilitates composting within the layer house resulting in a reduction of manure volume and weight.

Keywords: In-House Composting, Commercial Layers, Manure

INTRODUCTION

Animal agriculture is facing more problems today than just those associated with the proper care and feeding of animals to maximize production. Producers are having to deal with both state and federal regulations involving the manner and rate at which they dispose of their waste materials, potential litigation involving "good neighbor" practices associated with insect control and odor problems, zoning problems as subdivisions and cities encroach on farm lands and even the question in some states of farmers "right to farm."

Senator Tom Harkin (D-Iowa), ranking member of the Senate Agricultural Committee, proposed a bill in the current congress. The requirements of this bill included that: 1) integrated animal production companies will be responsible for all animal manures in an environmentally sound manner, 2) nutrient management plans for animal manures will have both nitrogen and phosphorus application requirements, and 3) strong Civil penalties will be levied against producers and persons violating the requirements of this act. While this bill was introduced late in the congressional session and did not make it out of committee, animal agriculture can expect that in future sessions similar legislation will be proposed and perhaps even passed.

Odor and insect control are becoming critical parameters in the design of animal production facilities. A large Alabama egg producer using a manure scrape system is involved in litigation because of complaints from neighbors caused by fly and odor problems. The neighbors are demanding that this poultry operation, containing 600,000 layers be closed. Much of the portion of the 1993 North Carolina state legislative session that was devoted to environmental issues was taken up with matters of odor abatement (Williams and Schiffman, 1996). Effective January 1, 1997, all waste management plans in North Carolina for animal facilities must include provisions for odor and insect control (Crouse, 1997). Animal agriculture is going to have to adopt more of a "good neighbor" policy in the future by controlling on-site odor and insect problems (Arends, 1996).

Alternative waste management systems are being investigated to alleviate producers of problems associated with manure production. Kauffmann (1997) reported on a deep-litter fermentation system for fattening pigs, in which sawdust was used as a ground cover in place of straw. An optimum depth of sawdust of 45 to 50 cm was found to be better than conventional ground covers such as wood chips or straw. The bedding material was turned every two weeks with no detrimental effects on biological activity. The dry bedding product had a final nitrogen content less than that normally observed with slurries. This was believed caused by a release of ammonia from the deep-bed material while in the house.

Many of the problems that have currently beset the commercial layer industry have arisen because of methods of handling the manure output from large flocks. While the egg industry is not necessarily at fault for all of the problems associated with disposal of animal manures, it is becoming increasingly important that better ways to manage layer manure be developed

and adopted. This paper will discuss an in-house layer manure management system which has been tested both under controlled conditions at the UGA Poultry Farm and currently in a production layer house. This paper will discuss how the system works and some of the effects observed in using such a system.

MATERIALS AND METHODS

Tests were conducted in a 100,000 hen capacity, curtain-sided, high-rise commercial layer house located in south Georgia, to determine if an in-house compost system would work under commercial conditions. The test house was chosen because of its concrete floor within the manure area which helped in using the mobile compost turner. Tests were started on October 28, 1997 and concluded on July 1, 1998.

The commercial layer house was approximately 150 m long by 12 m wide. Forty meter long sections of 0.12, 0.25 and 0.38 m deep piles of pine shavings, approximately 1.5 m wide, were initially placed beneath the cage rows so that the birds could directly deposit their manure onto the shavings. On a regular basis the piles were turned to incorporate any newly deposited manure material into the shaving manure mixture. Tests were conducted in only a portion of the house so that comparisons could be made between the test area and comparable areas under normal management. The birds were White Leghorns. The manure was deposited on the shavings at the rate of 0.017 m^2/bird. The commercial layer house was equipped with adjustable curtains which could be raised and lowered, and depended almost entirely on natural ventilation within the area containing the manure. During the Winter months (approximately November to April) the curtains were almost completely raised providing only minimal ventilation within the manure area.

The composting material was turned at two-week intervals using a mobile compost turner built by Farmer Automatic of Register, GA. The turner is a prototype model built specifically for these experiments and is not commercially available. The mobile compost turner is approximately 2 meters wide, 1.3 m tall and 2 m long and uses a gasoline powered engine. The compost turner was equipped such that the depth at which the tines on the turner operated could be adjusted. During the turning process the curtains were lowered to provide ventilation within the manure area. It is believed that growers would be less likely to use such a manure management system if the turning procedure needs to be done more often than once every two weeks.

Data Collection:

Gases:

Ammonia (NH_3), carbon dioxide (CO_2) and hydrogen sulfide (H_2S) was monitored every six weeks before, during and after turning of the litter material. Gases were sampled using a Matheson Toxic Gas Detector Model 8014K. Gases were sampled, prior to turning of the litter, at the four corners of the test area and in the center of the test area to determine the background gases within this region. Gases were also sampled in the middle of the house and within the cage area above the center of the test area and in the middle of the house. During the turning process, ammonia was sampled next to the turner where the operator would stand, at the rear end of the turner where the material exits the machine and then 5 m behind the machine to determine its zone of influence.

Nutrients:

Analytical sampling of the litter was performed every two months to determine the concentration of N, P, K and trace minerals. Grab samples were taken from different points within the piles to determine the nutrient concentration of the material.

Compost Temperature and Moisture:

Temperature measurements were taken every two weeks prior to turning of the litter. Temperature measurements were taken using thermocouple probes placed at different locations within the 0.12 m, 0.25 m, 0.37 m and raw manure piles. At two other times (during cold weather conditions and warm weather conditions) continuous temperature measurements (one hour sampling rate) were taken using an OM-5000 Omega data logger to determine the temperatures of the piles during the two-week turning cycle.

Pile Volumes and Manure Accumulation:

The volumes of the compost piles were monitored by measuring the cross profile of the compost on a monthly basis. Cross profiles were taken after turning of the compost at two different locations within each row. Manure accumulation by weight

was monitored every two months by cross-sectioning and weighing a 0.41 m length cut of each compost pile. Cuts were made at two different locations within the compost row. The material volumes and weights were compared to the buildup of manure within a layer line of raw manure.

Flies:
The compost was examined for the presence and density of fly larvae, pupae and pupae castings. Sheet metal pans were placed at the base of each pile to determine if the migration of fly pupae from the compost piles and the raw manure could be monitored. The fly population within the house was not monitored since the test area only covered a portion of the house and there would not be a way of knowing where in the house the flies came from and what generated them.

RESULTS AND DISCUSSION:

Figure 1, shows the cross-section profile of the raw manure over the first 181 days of testing. On day one of these tests the house was cleaned of all manure within the test area. As would be expected the pile grew according to the manner in which the manure was deposited by the birds and stacked. Drop boards exist on the cage battery system above and some manure piled on the drop boards prior to being deposited in the area below. This might explain some of the variation in the shape of the pile. This raw manure pile occupies almost the entire width of the bay within which the material is contained and the width of the pile is wider than that of the cage battery system above. In this pile the raw manure forms a thin fragile crust on the top and remains fairly wet within the central regions of the pile. The odor of the raw manure is the typical putrid, septic smell normally associated with layer manure.

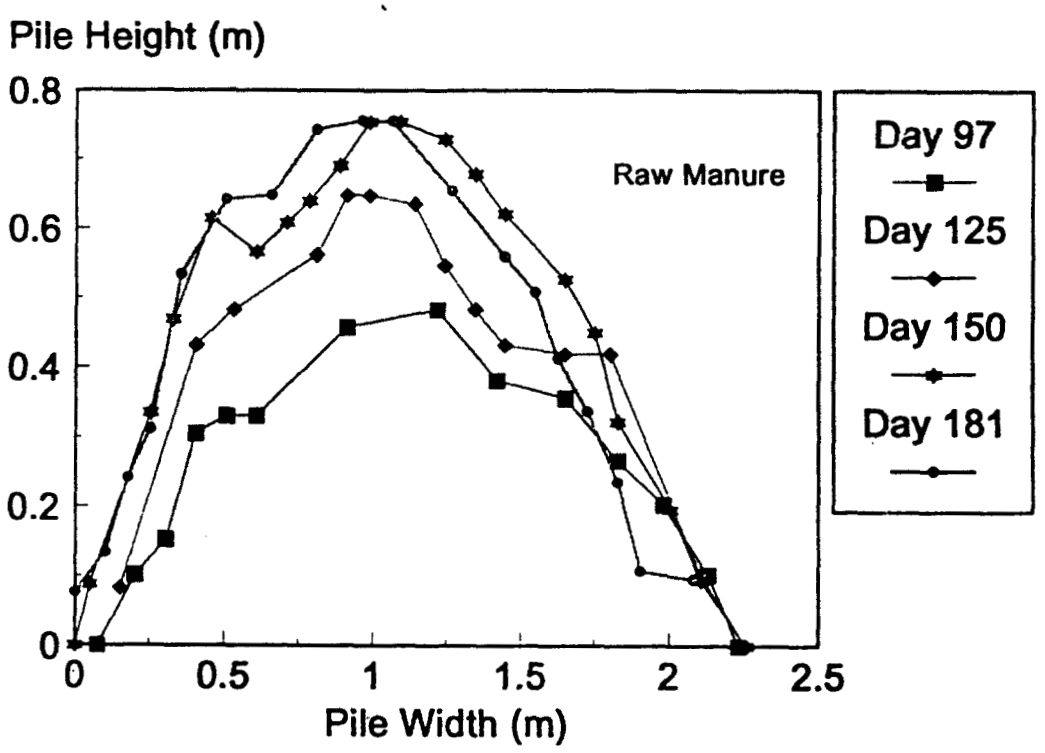


Figure 1. Cross section profiles of the raw manure pile over 181 days of testing within the commercial layer house.

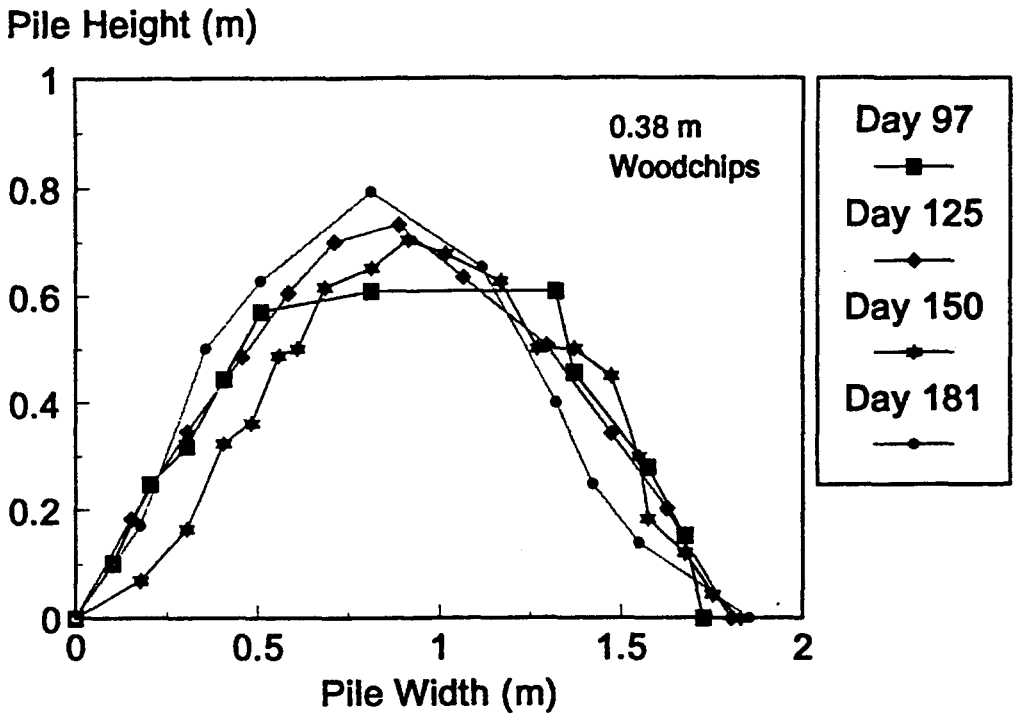


Figure 2. Cross-section profiles of the 0.38 m woodchips and manure over the first 181 days of testing within the commercial layer house.

In Figure 2, is shown the cross-section profile of the 0.38 m woodchip treatment over the first 181 days of testing. On day one of these tests a bed of woodchips 0.38 m tall and approximately 1.5 m wide was placed on the floor of the house. Since that time the manure from the birds located above was deposited onto the woodchips and then incorporated together using a mechanical turner which turned the material every two weeks. The cross-section profile above was measured after turning of the pile. The shape of the pile was formed by the mechanical turner as the compost material exits the machine. Very little variation in pile shape can be observed over the entire 40 m length of the test area. Only in those areas which were affected by excess water was the pile shape any different. In those regions the pile sides were much more steep and sometimes formed a vertical face caused by compression of the wet material against the interior sidewalls of the turner. The pile is slightly wider than the exit dimensions of the turner mechanism in that material sluffs off the slopes of the pile after it leaves the machine. Between turnings, this pile retains its approximate shape throughout the entire two-week cycle, with only a slight increase in width from material sliding down the pile slopes. This pile is approximately the same width as the cage battery system above. The turned material does not have the septic odor typical of the raw manure.

In Figure 3 is shown a comparison of the cross-section profile of the 0.38 m woodchip treatment and the raw manure pile after 208 days of testing. The woodchip manure mixture is obviously narrower and shorter than the raw manure. The 0.38 m woodchip pile has retained the same approximate dimensions as those observed after 181 days of testing while the raw manure continued to increase both in height and width. The woodchip pile originally started with 0.18 m^3 of woodchips per meter length of pile and after 208 days has increased in volume by only 41%. This figure shows the volumetric reduction which can be achieved using the in-house manure composting system. For this treatment a 34.5% reduction in volume was observed over that of the raw manure. If the whole house was littered, and a similar volumetric reduction was obtained, this would represent over 328 m^3 (11,600 ft^3) less material which would need to be removed by the grower during clean out operations.

In Figure 4 is shown the pile volume for each treatment over the first 208 days of testing. On day 208 the raw manure had the largest pile volume, followed by the 0.12 m, the 0.38 m and the 0.25 m woodchip treatments. The volume of the 0.25 m treatment and the 0.38 m treatment piles were approximately the same between days 100 and days 208. Many of the properties (volume, moisture contents, pile temperatures, and nutrient density) were similar for these two treatments

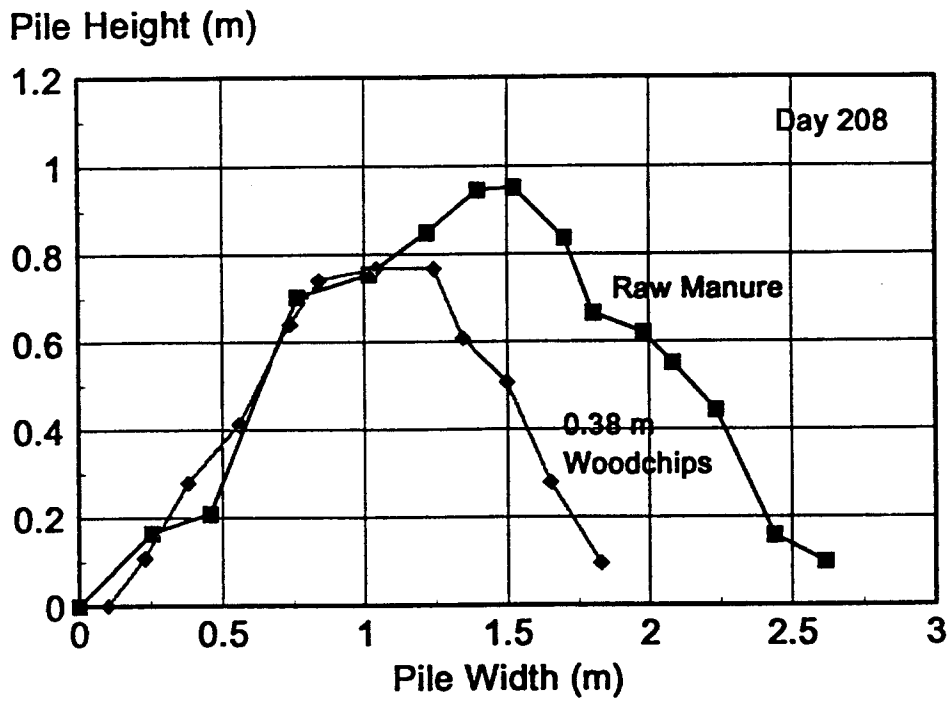
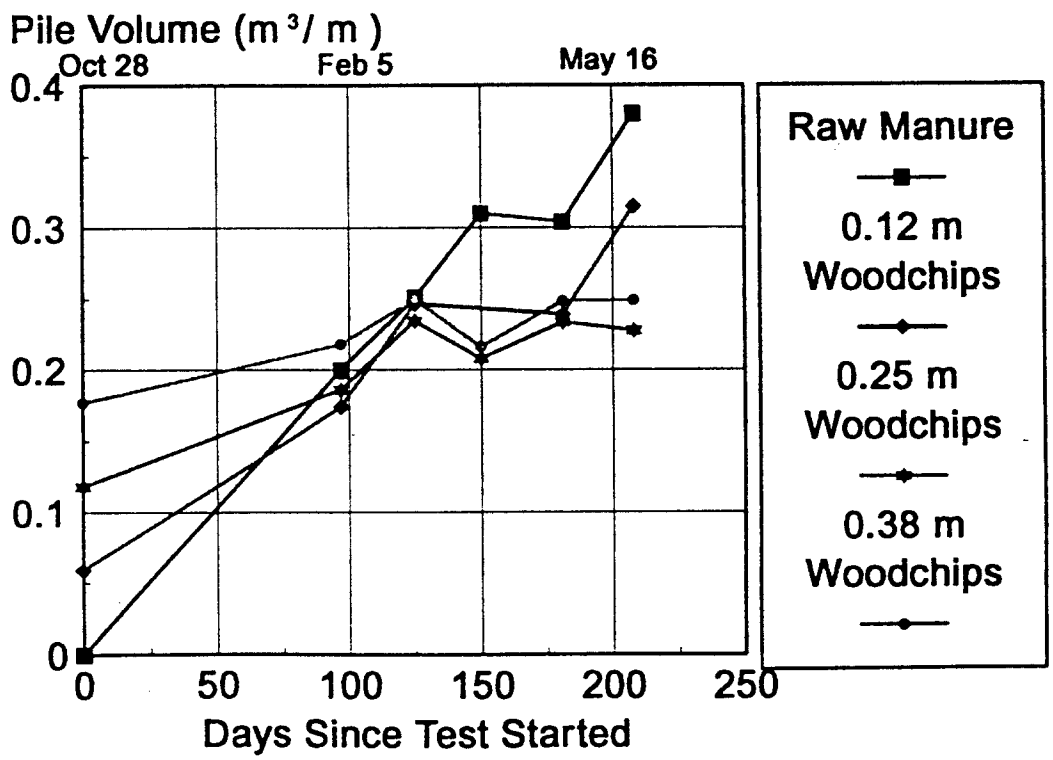


Figure 3. Comparison of the cross-sectional profile of the 0.38 m woodchip manure compost and the raw manure after 208 days of testing.

Figure 4. Volume per meter length of pile of the raw manure and the three woodchips treatments after 208 days of testing.



throughout this experiment. It appears that both the 0.25 m and 0.38 m depths were sufficient to allow composting to occur at this bird density and manure deposition rate over the duration of these experiments.

It is believed that more composting would have occurred and an even greater reduction in volume could have occurred in both the 0.25 m and 0.38 m treatments if the mechanical turner had been equipped with a larger engine. Because of power limitations, the tines of the turner could not be set at a depth nearest the floor. Therefore, not all of the woodchips were incorporated into the woodchip manure mixture for composting. However, the machine was a prototype model and at the beginning of these experiments the power requirements for such a system were not known.

Over parts of the 0.12 m woodchip pile leaking drinkers cause sections to become overly wet, which made this treatment difficult to turn with the mechanical turner. However, even in portions of the pile where moisture was not a problem it appeared that moisture from the deposited manure was building up within the pile and hindering the composting action. This pile was no longer turned after approximately the 125th day of these experiments. It appears that at this bird density and manure deposition rate this depth of woodchips is too shallow to allow the composting process to occur over a long period of time. For the 0.12 m woodchip manure mixture no volume measurements were taken on day 150, however, volume measurements for this pile was taken on both day 181 and day 208. Between day 181 and day 208 the volume of the 0.12 m woodchip pile and the raw manure pile increased the same amount. At this point in the experiment the 0.12 m woodchip pile treatment was not being turned and it performed in much the same way as the raw manure.

Between day 125 and day 181 the volume measurements decreased or stayed approximately the same for all treatments. During this time the weather changed and the curtains were lowered, providing much more ventilation within this region of the house. This would have allowed additional drying to occur. The birds were also molted during this time period. Induced molting of the birds involves an extended period of feed withdrawal (up to two weeks) followed by a period of another two weeks in which feed consumption is less than that of hens in production. This would have caused a decrease in manure volume output during this time period.

It is believed that one of the advantages of the in-house manure composting system is that it could be used over long periods of time because of the reduction in manure volume, thus extending the time between clean out. Based on these experiments no volumetric savings would occur using the in-house composting system if composting occurred for less than 70 days using the 0.12 m treatment, 90 days using the 0.25 m treatment and 125 days using the 0.38 m treatment. However, this manure management system could also be used over short periods of time, such as during Winter months, if desired. While short composting periods would only provide small reduction in volume, the woodchip manure compost would be much drier, easier to handle and have fewer objective odors than that of the raw manure, even over the short term.

In Figure 5 is shown the pile mass of the raw manure and the woodchip treatments over 208 days of testing. The pile mass is an estimate of the total mass of each pile over the 40 m test length. These estimates are based on data collected by cutting the pile (0.41 m cuts) at two different locations and weighing all the material contained within the pile across the cross-section. These tests were conducted on days 55, 125, 181 and 208. On day 208 the 0.12 m woodchip treatment was not weighed, since this pile was no longer being turned using the mechanical turner. The weight of the 0.25 m and 0.38 m woodchip treatments have been very similar throughout the experiment and were approximately the same on day 208. The weight of the raw manure has been higher than either of these two treatments since day 125. On day 208, a 24% reduction in weight on average was observed for these two treatments over the raw manure. If the whole house was littered and a similar reduction in weight was observed throughout the house, this reduction in manure weight would represent 188 metric tons less material which would need to be removed by the grower during clean out operations.

In Figure 6 is shown the manure mass and the percent reduction in the raw manure and the three woodchip treatments after 208 days of testing. The total amount of manure is the total weight of manure which was added to each pile over the 208 days of testing. This amount was determined by multiplying the average amount of manure produced by a layer per day by the number of birds by the number of days of testing. For the three woodchip treatments the total amount of manure also included the weight of the woodchips used in each treatment. For the raw manure, a 47.4% reduction in manure mass was observed during this test period while for the 0.25 m and the 0.38 m treatments, reductions of 63.9% and 68.5% were observed, respectively. This reduction in mass is believed caused by drying of the material as well as decomposition of the organics within the manure woodchip mixture. Patterson (1994) reported, after long-term manure storage in fan ventilated high-rise commercial layer houses, losses in manure mass consistent with a presumed loss of 50% or more in volume. While

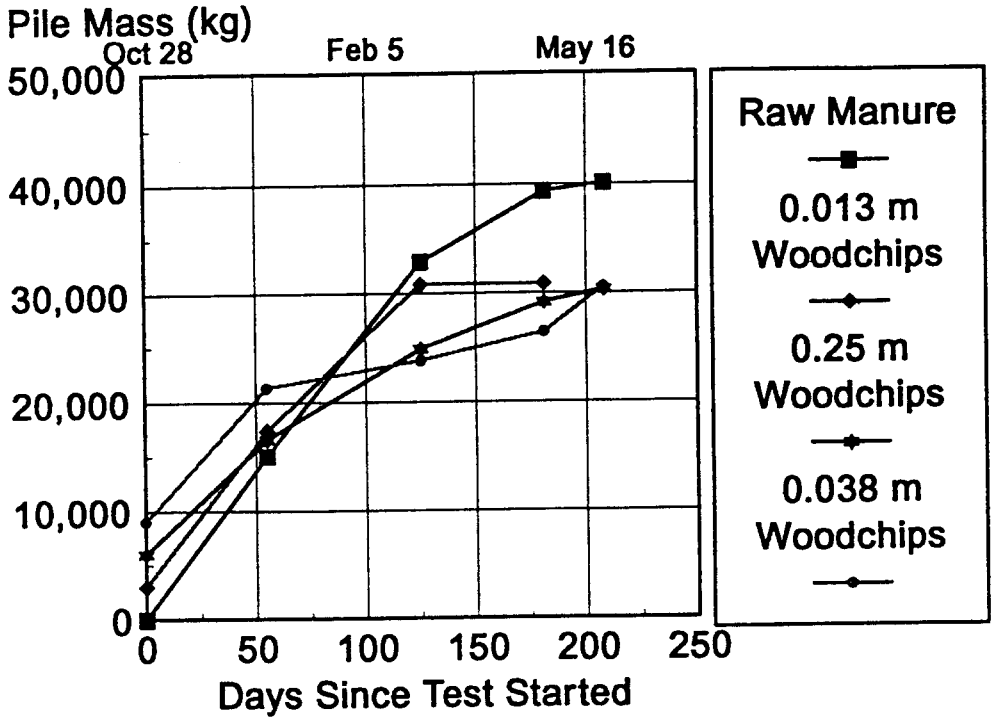
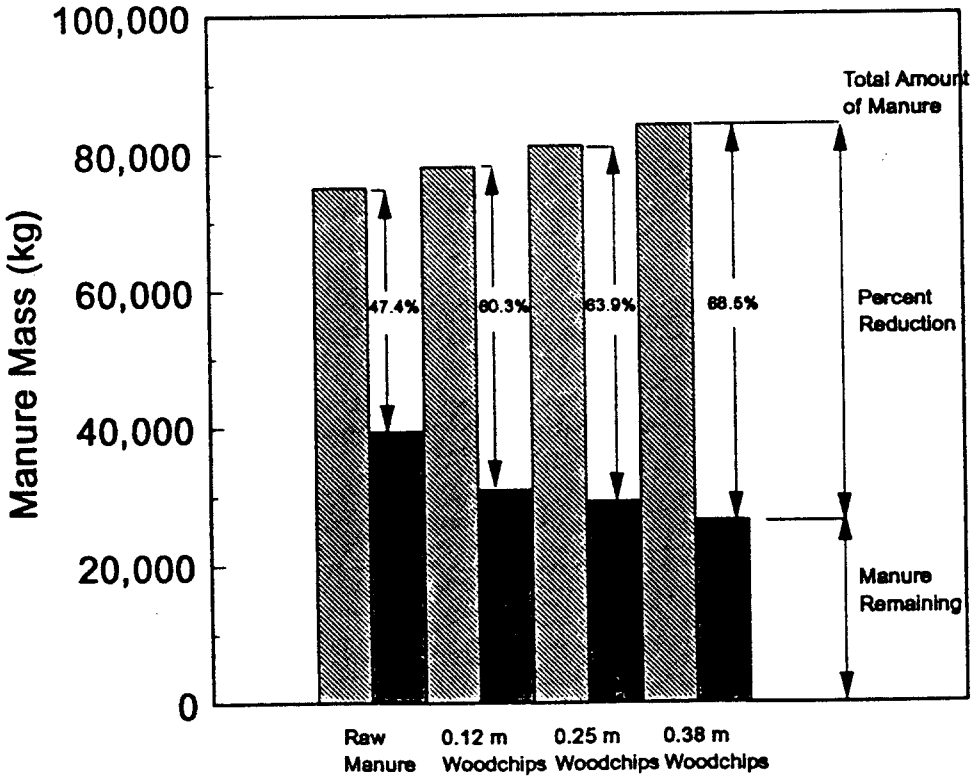


Figure 5. Pile mass of the raw manure and the three woodchip treatments after 208 days of testing.

Figure 6. Percent reduction in manure mass of the raw manure and the three woodchip treatments after 208 days of testing.



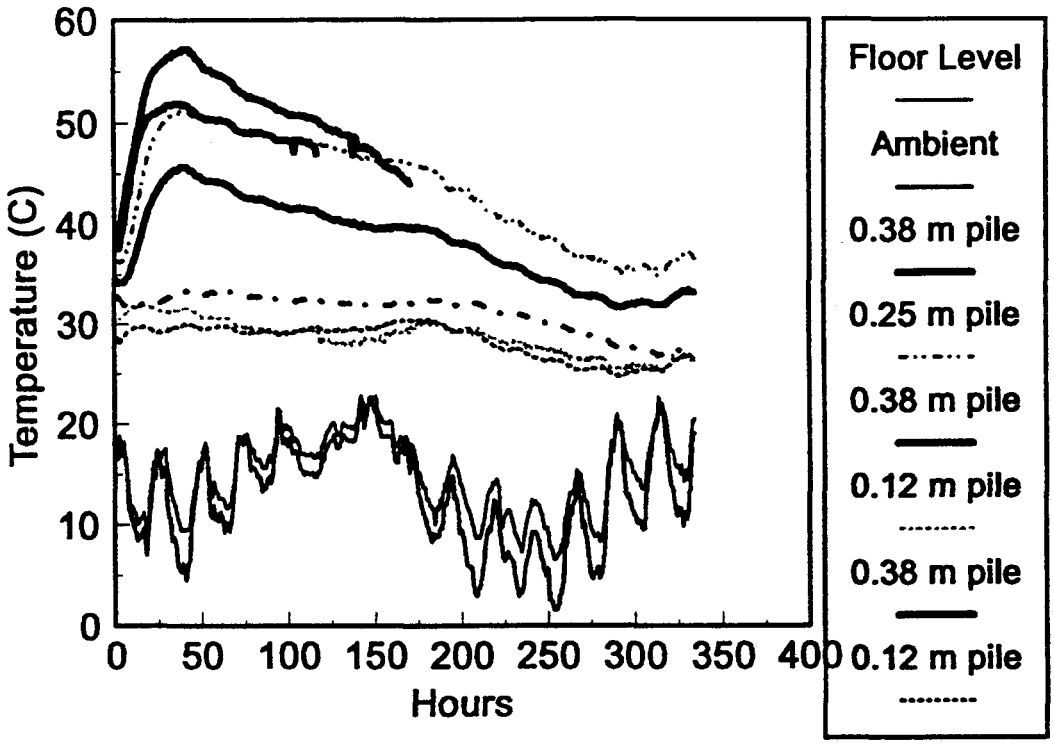


Figure 7. Temperatures within the layer house and the treatment piles between March 2 and March 16, 1998.

Patterson did not actually calculate any reduction in weight, this 47.4% loss in manure weight would correspond well with that reported by Patterson. It should be expected, since only natural ventilation was used in the house in this study, a somewhat smaller amount of manure reduction would be observed.

In Figure 7 are shown the temperatures measured within the layer house over a two-week cycle between March 2 and March 16, 1998. Temperature measurements were taken on an hourly basis using thermocouples placed in the manure treatments and throughout the house. Hour zero represents the time immediately after turning of the woochip piles by the mechanical turner, while hour 340 would be the time just prior to the next turning Two thermocouples failed during these experiments, therefore, the temperatures plots for these two thermocouples do not extend over the entire time period. Ambient (approximately 2 m above floor level) and floor temperatures were measured in the manure storage area and are shown in the figure as the two lowest curves within the figure. Ambient temperatures ranged between approximately 0 and 20 °C over this time period. Temperatures above 45 °C, which would be sufficient for composting (Haug, 1993), were observed to occur in both the 0.25 m and 0.38 m compost, while temperatures in the 0.12 m woodchip treatment remained at approximately 30 °C throughout this time period. Temperatures of the 0.12 m pile were by this time in the experiment not that much different than that of the raw manure. The low temperatures observed in the 0.12 m pile were believed caused by the high moisture content of the material which were greater than those normally associated with good composting conditions. In regions within the 0.25 m and 0.38 m piles where excess moisture existed, caused by leaking drinkers, very little increase in pile temperature was observed after turning. This manure management system is very moisture sensitive, as are other composting systems, and if a grower cannot control drinker problems within a house then this system should probably not be considered.

Ammonia (NH_3), carbon dioxide (CO_2) and hydrogen sulfide (H_2S) was monitored before, during and after turning of the material. It was difficult to get an accurate estimate of the zone of influence which turning had on the gas concentrations

within the house, since this house depends on natural ventilation within the downstairs manure storage area. Because of this, wind direction plays an important part in how the gases disperse within the house. Gas measurements were made before turning, during the Winter months, with the sidewall curtains raised. Turning of the litter treatments was always performed with the sidewall curtains lowered. Concentrations of H_2S were negligible throughout the house during these experiments. The only time when noticeable values of H_2S occurred was when the machine became bogged down during the turning process in regions in which moisture had been a problem. CO_2 concentrations were measured on the outer borders of the test region and also in the upstairs of the house. With the curtains raised average CO_2 concentrations of 800 to 900 ppm were measured in the manure storage area of the house, with a maximum CO_2 concentration within this region of 1500 ppm. In the upstairs of the house, where the birds were caged, CO_2 concentrations were very similar to those measured downstairs with a maximum CO_2 concentration of 1400 ppm. Before turning, background levels of NH_3 were measured in the manure storage area with the curtains raised. In the manure storage area of this house background concentrations of ammonia of from 5 to 47 ppm were measured in the test area with the curtains raised. These tests were conducted on one end of the house. At the very end of the house very little ventilation occurred and the concentration of background NH_3 were normally higher in this region than in the center of the house. In the upstairs portion of the house background concentrations of NH_3 were not greater than 10 ppm. NH_3 was noticeable during the turning process with a maximum concentration of 400 ppm observed during January (day 69) of these experiments. On that same day concentrations of NH_3 of 68 ppm were measured 5 m behind the turner. Between days 97 and 208 of these experiments the concentration of NH_3 has not reached levels comparable to those observed in January. As the manure accumulated within the house the speed at which the mechanical turner could move through the piles decreased. Under ideal conditions the machine could go as fast as 1.5 m per minute on day 208 (May 24) while in January with little accumulated manure the turner was moving through the pile at speeds almost twice that fast. During the early parts of this experiment the tines of the turner were also operating as close to the floor as possible. The concentration of ammonia might be related to the operation of the machine and to these two parameters. However, the concentration of NH_3 measured during turning could also be influenced by the properties of the compost, which may have changed over this time period. While NH_3 was noticeable during the turning process around the machine, after the turning process was completed enough ventilation existed within the manure area such that the concentration of NH_3 returned to its background level shortly thereafter. This was similar to experiments performed under controlled conditions at the UGA Poultry Farm. In totally enclosed conditions in which ventilation fans were used, the concentration of NH_3 returned to approximately that of the background concentration 5 to 10 minutes after turning was completed.

Fly pans were placed at the base of each pile to determine if some fly control was provided by the compost treatments. Analysis of the material collected from the pans has not yet been done. Based on the temperatures measured during the two-week cycle, temperatures were achieved which should kill any fly eggs which were mixed back into the piles during the turning process. It is believed that some fly control is achieved by using this system, however, this has not been experimentally determined at this time. During the latter stages of these experiments, large quantities of darkling beetles were observed on the surface of the woodchip litter treatments after turning. The beetles were assumed to live in the piles. However, it is not known if these treatments provide an environment conducive for the beetles to live within and some control should be provided, or if they just live on or near the surface of the piles where the fresh manure is deposited and the turning process brings them to the surface.

In Table 1 is shown the nutrient density of the raw manure and the three different woodchip treatments after 181 days of testing. Also shown is the nutrient density for a manure and leaf compost made from yard wastes. Turning of the 0.12 m woodchip and manure mixture had ceased by this time and the moisture content of this treatment was much higher than either the 0.25 m or 0.38 m treatments. By in-house composting the product will leave the house with a dry basis nutrient density of approximately 2% N, 8% P_2O_5 and 4% K_2O. This product is much like that of the manure and leaf compost with very little odor and improved handling properties over that of the raw manure. Patterson (1994) reported the nutrient density of commercial layer manure for samples taken from a 8 different flocks of birds, housed in fan-ventilated commercial layer houses, during long term manure storage. Values for samples reported to have a high and low nutrient density are shown in Table 2. The values reported in this experiment are between those reported by Patterson for high and low nutrient density, with the percent N closer to those reported for the low sample while the percent P_2O_5 and K_2O were more towards the middle of the reported range. Patterson reported that the variation in nutrient density of layer manure could be traced to the age of the birds, bird diet and the management of the waste materials. While the nutrient density of the raw layer manure and the woodchip treatments are not significantly different, the moisture content of the raw manure is much higher than that of any of the other treatments. Obviously, this decrease in moisture content within the 3 woodchip treatments is related to the decrease in manure weight and manure volume which were previously reported in this study.

SUMMARY

The in-house composting system under commercial conditions produced a significant reduction in both weight and manure volume over conventional methods in which the manure is only stacked under the house. A 34.5% reduction in manure volume was observed in the 0.38 m woodchip treatment when compared to raw manure. This particular treatment started with 0.18 m^3 of woodchips and increased in volume by only 41% over 208 days of testing. Both the 0.25 m and 0.38 m woodchip treatment showed a significant reduction in manure weight with a 24% reduction in weight on average when compared to the raw manure. The 0.12 m woodchip treatment does not appear to provide enough carbon source to keep the compost process working over a long period of time. For this particular treatment tests were only conducted over less than 125 days because of excessive moisture in the manure deposited by the birds and leaking waterers within the cage system. The success of this system is dependent on the control of water, therefore, monitoring of the drinking system by the grower for leaking drinkers must be done on a regular basis. The woodchips layer manure mixture has many of the same properties as a leaf manure compost. The layer manure compost has a dry basis nutrient density of approximately 2% N, 8% P_2O_5 and 4%K_2O. From a material standpoint, the composted material is an improvement over that of raw layer manure, in that it has a decreased moisture content, improved handling properties and less odor.Gas concentrations of ammonia, carbon dioxide and hydrogen sulfide were monitored. Levels of carbon dioxide were not excessive and hydrogen sulfide was not detected, except where particularly wet section of manure compost was encountered during turning. Ammonia was much more noticeable during the in-house composting process. . During the actual turning of the litter ammonia was noticeable adjacent to and sometimes 5 m behind the machine. However, the zone of influence of the machine was difficult to determine since the area within which the manure was stored was ventilated using natural ventilation. During the early stages of this experiment the concentration of ammonia was higher. This may be related to the speed at which the turner moved through the piles as well as the properties of the compost during these early stages. However, as the compost matured the level of ammonia produced during turning appeared to decrease. After turning, the concentration of ammonia decreased quickly to that of the background levels.

Table 1. Nutrient density of the manure and compost after 181 days (Oct. 28 to April 27) of testing.

	N	P_2O_5 (%db)	K_2O	M.C. (%wb)
Manure and Leaf Compost	1.7	7.5	4.2	41.2
Raw Layer Manure	1.8	8.1	3.5	69.0
0.12 m Woodchips and Manure	1.9	8.5	3.7	57.7
0.25 m Woodchips and Manure	2.1	8.3	3.6	49.0
0.38 m Woodchips and Manure	2.0	8.6	3.5	46.7

Table 2. Nutrient density of layer manure. (Patterson, 1994).

	N	P_2O_5 (%db)	K_2O
High Nutrient Density	9.42	11.73	5.72
Low Nutrient Density	1.98	3.71	2.16

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