Effect of Poultry Litter Amendment on Hatchery Waste Composting

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Primary Audience: Researchers, Hatchery Managers, Poultry Industry Environmental Managers, Extension Agents, Health Officials, Regulators

SUMMARY

Continuous growth of the poultry industry is accompanied by a need to manage large quantities of by-products such as hatchery wastes. Hatchery wastes contain nonfertile eggs, dead chicks, and broken eggshells. Although rendering plants currently use a portion of hatchery waste, large amounts are sent to landfills, which cost the poultry industry millions of dollars each year. As a potential alternative to landfilling, composting was investigated as a method to convert the nutrient rich waste into a stable product for beneficial use.

Hatchery waste was amended with sawdust and yard trimmings and in one treatment with poultry litter (broiler) to determine the feasibility of composting hatchery wastes. Hatchery waste co-composted with poultry litter maintained higher temperatures during the experiment resulting in higher dry matter and volatile solids and greater losses of nitrogen by the end of the composting process. The composted product containing poultry litter had higher levels of plant nutrients such as P, K, and many of the other micronutrients than the product without poultry litter. Both treatments were effective in eliminating 99.99% of *Escherichia coli*; however, more *Salmonella* reduction was observed in the treatment containing poultry litter than the treatment without poultry litter.

Key words: compost, pathogen reduction, hatchery waste, waste management

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DESCRIPTION OF PROBLEM

Broiler chick production in the United States has increased to new highs every year since 1975. In 2001, 9.01 billion total chicks were hatched in the United States [1], including 1.33 billion in the state of Georgia. This increase in hatchery production has resulted in increasing amounts of hatchery wastes that have to be managed appropriately. It is estimated that annual hatchery waste generated in the United States amounts to 140,000 tons [2]. In most cases, more than 65% of these hatchery wastes end up in landfills [3].

Hatchery wastes consist of nonfertile eggs, eggshells, egg membranes, and dead embryos and chicks. Traditional methods of hatchery waste disposal include landfill, land application, rendering, and egg wringing. Egg wringing is a process of centrifugally separating the liquid proteins, representing 40% by weight, from the eggshell and dehydrating and converting it into an animal protein feed additive [4]. The remaining solid fraction has no bene-

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TABLE 1. Properties of ingredients used for composting hatchery waste[A]

Ingredient	Moisture content (%)	Volatile solids content (%)	N (%)	C (%)	C:N Ratio	Bulk density (kg/m^3)
Hatchery waste	32.5 (2.25)	20.2 (3.56)	1.90 (0.45)	15.5 (3.05)	8.1:1	971 (15.4)
Sawdust	46.5 (4.14)	99.8 (1.85)	0.12 (0.03)	52.6 (1.29)	438:1	290 (20.6)
Yard trimmings	29.9 (3.30)	75.9 (3.56)	0.61 (0.05)	31.7 (0.27)	52.4:1	262 (10.4)
Poultry litter	23.0 (1.35)	83.6 (5.65)	3.82 (0.37)	39.0 (1.35)	10.2:1	422 (23.7)

[A]Values in parentheses are standard deviations.

ficial use and is typically sent to landfills. Land application of the hatchery waste, which used to be a common disposal practice [5] has been recently banned in Georgia because of problems with odors and inability to routinely incorporate the material into the soil [6].

Composting has successfully been used to dispose of and convert agricultural and animal wastes, such as poultry mortalities and litter, into a useful product [7]. Therefore, composting technology may be a feasible alternative to convert hatchery waste that is rich in nitrogen and calcium into a stable product for use as a soil amendment and organic fertilizer. Before composting technology can be commercially adopted, it is necessary to determine the organic matter decomposition rate, or time required to compost, and the quality of the composted product in terms of nutrient content and pathogen reduction. In order to evaluate composting as a feasible treatment option, a research project was conducted to 1) assess the rate of decomposition of hatchery wastes, 2) determine the effect of the use of poultry litter (obtained from broiler chicken houses) as an amendment in the composting process, 3) evaluate the pathogen reduction capability of the composting process, and 4) determine the nutrient content of the composted product.

MATERIALS AND METHODS

Materials and Procedure

Because hatchery wastes have a low C to N ratio (C:N) value of 8.1:1, they were composted with sawdust having a high C:N ratio of 438:1 (Table 1). Because of the high bulk density of hatchery waste (971 kg/m^3), yard trimmings (bulk density of 262 kg/m^3) were added to increase the porosity and reduce the bulk density of the composting material thus facilitating airflow into the compost matrix that is required for microbial respiration and heat removal.

A pilot-scale field experiment (two treatments × three replicates) was conducted using 3 × 2.5 × 2-m enclosed bins serving as compost bioreactors. The bins were built on a concrete base that was inclined to one side to prevent accumulation of any leachate at the bottom of the bin. The bins were constructed with treated lumber with the side boards stacked on top of each other leaving small gaps between the boards to allow air to enter the compost matrix.

The first treatment was prepared by mixing hatchery waste with sawdust and yard trimmings to provide a ratio of 3:2:1 by volume (1:6:11 dry weight). The second treatment was prepared by blending hatchery waste with sawdust, yard trimmings, and poultry litter (PL) to provide a ratio of 2:1:1:2 by volume (1:8:7:2 dry weight). Treatments were designed to contain the same content of hatchery waste (6.0% dry weight) in the completed mix. This recipe was developed to maximize the use of hatchery waste while maintaining optimum conditions to initiate microbial activity (C:N above 10:1, volatile solids content above 40%, and bulk density around 600 kg/m^3).

Water was added to both treatments to increase the moisture content (MC) by 10 to 15% in order to enhance microbial activity. Passive aeration and mixing (once every week for the first 2 wk and once every 2 or 3 wk for the following weeks) were the only mechanisms of oxygen supply to the composting matrix. Mixing was conducted by removing the compost from the bins, and then adding water and homogenizing the compost with a loader, and reloading the compost back into the bins.

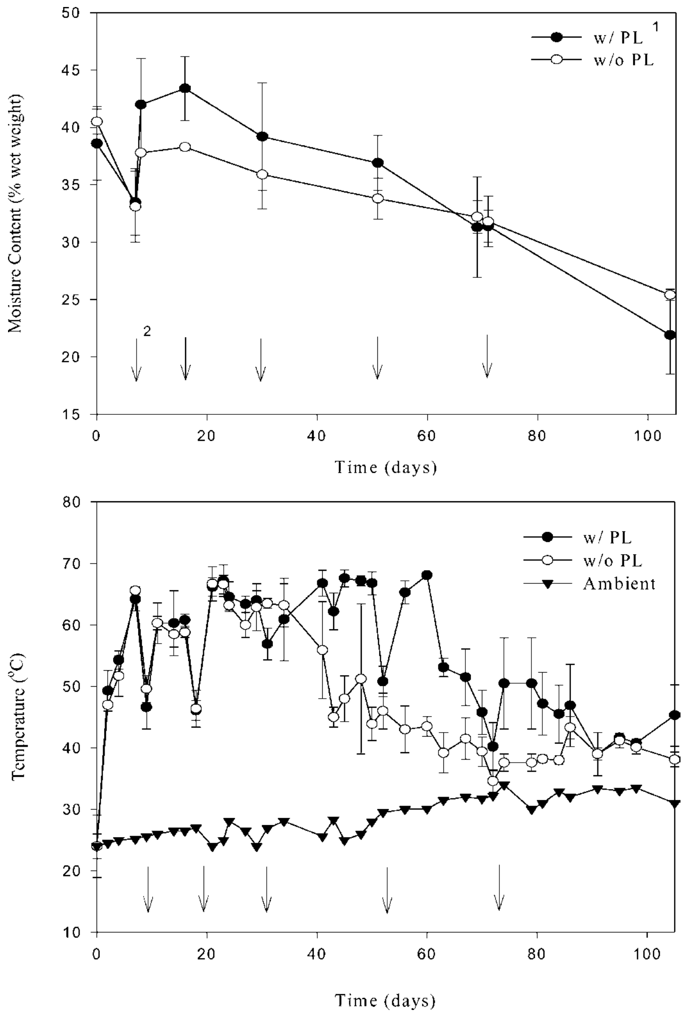

FIGURE 1. Moisture level (above) and temperature (below) in hatchery waste mixes during composting. PL = poultry litter. Arrows indicate days when compost was homogenized and water was added.

Experimental Design and Analytical Methods

Experimental design and data analysis was based on a completely randomized design of two treatments with three replicates each. Compost temperature was measured three times a week using type T thermocouples positioned at the middle of each bioreactor. Oxygen concentration within the composting matrix was measured three times each week using a portable oxygen analyzer [8].

Compost samples from each bioreactor were taken at the start of composting and at the end of five mixing events during composting. Samples were analyzed for moisture, volatile solids (VS), total C, total N, pH, stability index (i.e., oxygen uptake rate), and bulk density. Total counts of *E. coli* and the presence of *Salmonella* were measured in samples obtained at the start and the end of composting. Average elemental concentrations (nutrients and metals) of the three replicates in each treatment were determined at the end of the composting period.

A 250-g sample of wet compost was placed in a forced-draft oven (104°C) for 72 h or until no change occurred in weight to measure the

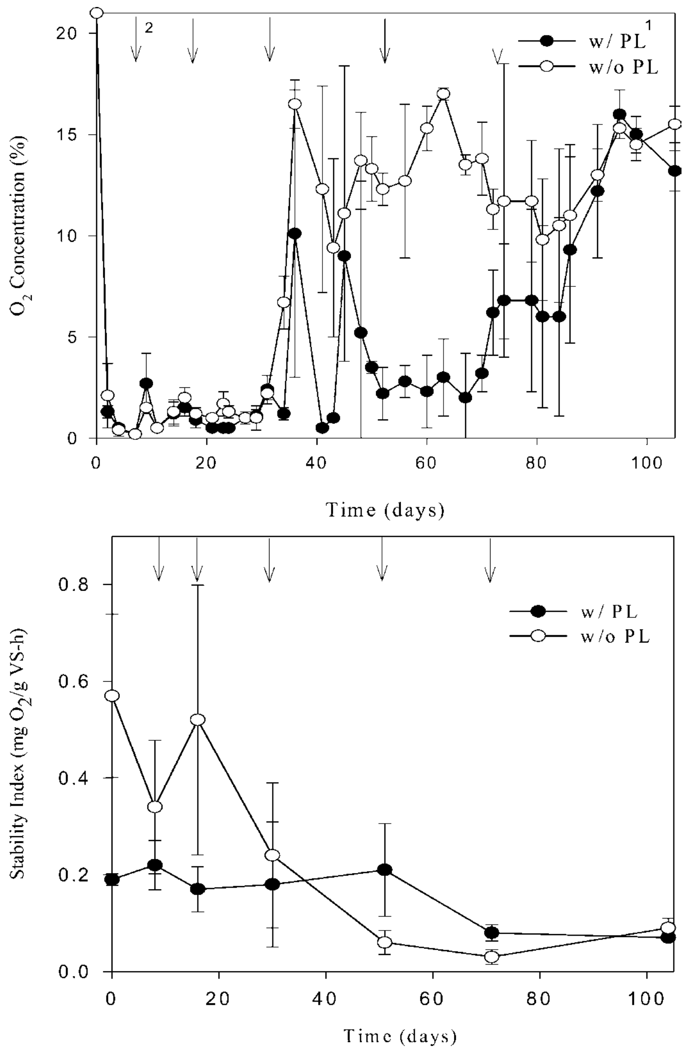

FIGURE 2. Oxygen concentration (above) and stability index (below) in hatchery waste mixes during composting. PL = poultry litter. Arrows indicate days when compost was homogenized and water was added.

moisture content [9]. The dry sample was then ground thoroughly (150 mesh), mixed, and stored in airtight bags for further analysis. Approximately 5-g subsample was combusted at 550°C for 6 h to determine VS concentration [10]. A water extract of 1:2 (mass basis) of compost to water was used to determine pH [11].

Approximately a 250-mg dried compost subsample was used for C, S, and N determinations by a combustion analyzer [12]. Micronutrients and metals were measured in a 250-mg dried compost sample after microwave digestion by using the EPA Method 3052 [13] with 10 mL of trace metal grade nitric acid and then analyzed based on the EPA Method 200.8 [14] by using an inductively coupled plasma mass spectrometer.

Plasma Mass Spectrometer

The stability index (SI) of the compost was measured using the procedure described by Iannotti et al. [15]. The sample was standardized for particle size (<9.5 mm) and moisture content (50%) and incubated (37°C) for 16 h under aerobic conditions to build the microbial populations

TABLE 2. Initial and final properties of hatchery waste composted with or without poultry litter (PL) as an amendment

	Treatment with PL		Treatment without PL	
Property	Initial	Final	Initial	Final
Moisture content, %	38.6 (3.17)[A]	21.9 (3.44)	40.2 (1.10)	32.0 (0.52)
Volatile solids content, %	59.9 (2.28)	34.2 (1.27)	46.5 (1.24)	25.4 (0.81)
Bulk density, kg/m^3	548 (19.4)	538 (36.3)	612 (26.4)	645 (6.91)
N, %	2.70 (0.43)[a]	0.95 (0.09)	1.84 (0.07)[b]	0.63 (0.15)
C, %	30.2 (2.05)	21.2 (1.19)	26.4 (2.81)	16.9 (2.44)
C/N Ratio	12.3:1	17.7:1	12.4:1	23.6:1
PH	7.4 (0.10)	8.8 (0.14)	7.1 (0.03)	7.4 (0.09)
E. coli, mpn/g[B]	40,504 (3,187)	13.2 (0.44)	42,303 (1,162)	9.7 (14.6)
Salmonella[C]	+++	− − −	+ + +	− + +
Total solids losses, %	N/A[D]	33.5 (5.19)[a]	N/A	17.3 (2.98)[b]
Volatile solids losses, %	N/A	62.1 (1.97)[a]	N/A	54.8 (0.84)[b]
N Losses, %	N/A	63.2 (5.99)	N/A	55.2 (3.00)

[a,b]Means within a row with different superscripts are significantly different $P < 0.05$).
[A]Values in parentheses are standard deviations.
[B]mpn/g = Most probably number per gram of dry weight of sample.
[C]+ = presence of *Salmonella* in one sample; − = absence in one sample (number of samples = 3).
[D]N/A = not applicable.

to an active standard level. A 120-g sample of the incubated material was placed in an aerated respirometric flask at constant temperature in a water bath (37°C) for 1 h. The aeration source was removed, and oxygen concentration inside the flask was monitored every 5 min for 1 h. The change in oxygen concentration in the flask was used to calculate a consumption rate in milligrams$_{oxygen}$/grams$_{volatile\ solids}$ per h. This rate of oxygen consumption under standard conditions of particle size, moisture, temperature, aeration, and incubation is dependent only on the amount of substrate availability. Greater substrate availability results in higher oxygen demand, indicating that the sample is biologically unstable. Organic compost with a SI less than 0.5 mg/g per h is considered stable and 1.0 to 1.5 mg/g per h is moderately stable. Unstable composts typically exhibit SI greater than 2.0 mg/g per h [16].

Fecal coliform counts were measured using the IDEXX Quanti-Tray system [17] following the manufacturer's recommended procedure and Method 9223B [18], and *Salmonella enteritidis* was analyzed using Method 998.09 described by AOAC [19].

RESULTS AND DISCUSSION

Process Parameters

For best results, it is recommended that the MC of materials being composted remain between 50 and 65% [20]. In this experiment, because of the presence of eggshells that do not absorb water, MC of both treatments was below 45% during the composting process (Figure 1). In some cases, further addition of water generated leachate. Although moisture remained at this low level, there was no limitation on microbial activity as could be observed from the temperature profile (Figure 1). Average MC of the two treatments throughout the experiment was not significantly different and therefore should not have had any effect on the progress of the composting process.

The two treatments maintained similar temperature profiles, until after the third mixing (34 d). Initially, rapid increases in temperatures to 65°C were observed followed by reductions in temperature around the 7th d, possibly due to oxygen limitations, which remained below 2% for the first 30 d. After each event of homogenizing the compost, there was a slight increase in oxygen concentration and a significant increase in temperature (Figures 1 and 2). Temperatures were maintained around 65°C for 30 d in both treatments and for 60 d in the treatment with PL. This high temperature for long durations is required for elimination of pathogens.

The SI measured at each mixing event showed that, initially, the SI was higher for the treatment without PL (Figure 2). Average SI throughout the composting process remained be-

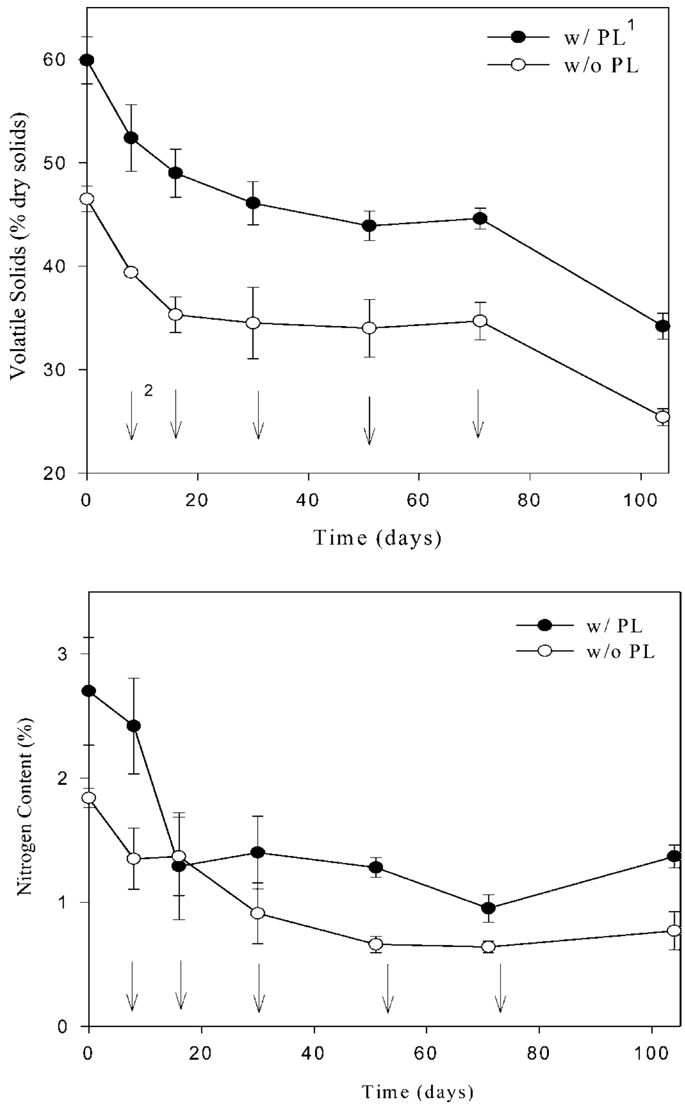

FIGURE 3. The changes in volatile solids (above) and total nitrogen (below) contents in hatchery waste mixes during composting. PL = poultry litter. Arrows indicate days when compost was homogenized and water was added.

low 0.60 mg/g per h for the treatment without PL and at or below 0.20 mg/g per h for the treatment with PL. When composting poultry manure amended with municipal solid waste, average SI is about 2.0 mg/g per h and decreases to about 0.50 mg/g per h by the end of the composting process [15]. An SI value of approximately 0.10 mg/g per h reached after 70 d of composting indicates that a highly stable composted product can be achieved in 10 wk of composting in a bin system as used in this research.

Pathogen Reduction

The presence of *E. coli* and *Salmonella* was considerable in both of the initial treatment groups (Table 2). *E. coli* in the initial samples was greater than 40,000 mpn/g at the start of composting in both treatments. By the completion of composting, a high percentage (99.9%)

of *E. coli* was eliminated, with the reduction possibly due to a combination of the high temperatures that were observed and the microorganisms degrading organic matter competing for food sources with the pathogens. Temperatures greater than 55°C for several days during composting can result in significant reduction in the counts of *E. coli* and other pathogens [21].

Although *Salmonella* was present in all three initial replicates of each treatment, after composting it was not found in the treatment containing PL but was present in two of the three replicates not containing PL. The PL treatment maintained a temperature greater than 60°C for more than 60 d and greater than 45°C for the rest of the composting period, whereas a temperature of 60°C was only maintained for 30 d or less in the treatment without PL. Apparently this shorter period of high temperature was not sufficient to completely inactivate the *Salmonella* in this treatment. It has been reported that when composting municipal solid wastes *Salmonella* is absent after 27 d of composting while temperature is maintained between 54 and 66°C; however, organisms reappeared at 57 d when temperature declined to 28.3°C, probably due to the absence of competing microorganisms and the abundance of *Salmonella* in the substrate [22].

Degradation during Composting

The quantity of VS (volatile solids) in hatchery waste was the lowest among all the ingredients used in the compost mixture (Table 1). Therefore, the majority of degradable volatiles in the mixes could be attributed to the amendments (sawdust, PL, and yard trimmings). The treatment with PL contained more VS (Table 2) because of the higher quantity of these solids in poultry litter (83.6%) and because this treatment contained a higher ratio of sawdust to hatchery waste (8:1) than the treatment without PL (6:1). VS contents were reduced from 59.9 and 46.5% to 49.0 and 35.3% within 16 d for the treatments containing PL and no PL, respectively (Figure 3). A second reduction in VS content was observed after the fifth mixing (71 d), when VS content was reduced to 34.2 and 25.4% for the PL and no PL treatments, respectively. This second phase of VS content reduction is probably due to microbial population successions and the presence of secondary organic substrates that

TABLE 3. Nutrient and metal concentrations in final compost product of hatchery waste[A,B]

Element	Treatment with PL	Treatment without PL
	Major plant nutrients (g/kg)	
P	6.6 (0.5)[B]	1.8 (0.4)
K	10.8 (0.4)	1.4 (0.3)
Ca	155.6 (0.2)	180.0 (29.4)
Mg	4.2 (0.4)	2.6 (0.4)
Mn	0.4 (0.0)	0.1 (0.0)
Fe	2.2 (0.3)	1.3 (0.3)
Al	2.6 (0.3)	0.9 (0.3)
S	1.5 (0.4)	0.3 (0.2)
Na	3.6 (0.1)	1.3 (0.2)
	Regulated heavy metals (mg/kg)	
As	18.4 (1.6)	5.7 (2.7)
Cd	0.0 (0.0)	0.1 (0.0)
Cu	232.0 (26.0)	60.0 (14.7)
Pb	5.2 (0.6)	7.2 (6.3)
Hg	BDL[C]	BDL
Mo	2.2 (0.2)	0.3 (0.2)
Ni	6.3 (1.3)	5.9 (5.8)
Se	0.8 (0.1)	0.2 (0.2)
Zn	158.0 (19.2)	13.5 (3.7)

[A]Hatchery waste compost with or without poultry litter (PL) as amendment.
[B]Values in parenthesis are standard deviations.
[C]BDL = Below detection limit.

become more available for biodegradation. Total VS loss over the composting process was greater (P = 0.004) for the treatment containing PL (62.1%) than the treatment without PL (54.8%). Similarly, the total loss in dry mass was greater (P = 0.004) for the treatment containing PL (33.5%) than for the treatment without PL (17.3%).

The presence of PL provided higher (P = 0.046) initial N content in this treatment (2.7%) than the treatment without PL (1.84%); however, the initial C:N ratios were comparable (Table 2). N content was reduced throughout the composting process for both treatments (Figure 3). The N content was reduced gradually over the experimental time for the treatment without PL, whereas a rapid decrease was observed in a short period (first 16 d) for the treatment with PL. This more rapid loss can be attributed to the mineralization of organic N and its loss into the environment as ammonia. The final N content in the treatments with and without PL were 0.95 and 0.63%, respectively, corresponding to an average N losses of 63.2 and 55.2%.

Compost Product Quality

Hatchery waste compost contained substantial concentrations of plant essential nutrients (Table 3). Both final products contained high concentrations of Ca due to the presence of eggshells (15.56 and 18.00% for treatment with PL and without PL, respectively). The PL hatchery waste compost contained higher quantities (two to eight times) of most nutrients (except Ca) than the compost without PL. The PL hatchery waste product had nutritional values equivalent or in some cases exceeding other compost products such as animal manure and biosolids based compost [23, 24]. Also, hatchery waste compost contained lower levels of heavy metals than allowed by regulators for biosolids for land application [25], therefore making hatchery waste compost suitable for use as a soil amendment at generous application rates.

CONCLUSIONS AND APPLICATIONS

This paper reports results from pilot-scale research in which hatchery wastes were composted with poultry litter (PL) as an amendment compared to a control with no poultry litter. The important conclusions derived from this work are as follows

1. Treatment of hatchery waste by composting with sawdust, yard trimmings, and PL produced a stable compost product that is rich in plant nutrients.
2. Stability was achieved in 10 wk by using a bin composting system.
3. Oxygen limitations were observed throughout the initial 35 d of composting, which could have been a result of the type of bin used in this research or a lack of sufficient porosity in the matrix. Future work could use a mix with greater porosity or use forced aeration to prevent extremely low oxygen levels during composting.
4. Use of PL as an amendment resulted in greater losses of organic and dry matter and more efficient elimination of *Salmonella*.
5. Both treatments were successful in reducing *E. coli* counts by more than 99.99%, suggesting that the presence of poultry litter did not provide any additional benefits in *E. coli* reduction.
6. Composting can effectively be used to reduce and eliminate pathogens in hatchery waste through heat inactivation and substrate consumptions by competing microorganisms.
7. Hatchery waste can be diverted from landfills through composting to produce a value-added product that is agronomically attractive and can be used as a soil amendment and source of plant nutrients.

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