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Broiler Litter Reutilization Applying Different Composting Concepts

Technical Note

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ABSTRACT

Broiler litter reutilization consists in using the same bedding material to cover the house floor for several broiler flocks. This requires the litter to be treated in order to reduce the amount of microorganisms, according to international recommendations. The aim of this study was to evaluate two methods of broiler litter fermentation based on composting concepts and their effect on litter and the air quality during fermentation in small-scale broiler houses. The experiment was carried out in the Environmental Laboratory I of the School of Agricultural Engineering of the State University of Campinas, utilizing six small-scale houses. Litter from the same grow-out (one, two or three) was distributed in two experimental houses, where it was either piled or spread. Before beginning the treatment, six litter samples were collected from each house and analyzed for total nitrogen content, humidity, pH and microbial counts. Litter humidity, gas emission (NH_3 and CO_2), environmental temperature, air relative humidity, and air velocity were determined during and after composting. Bacterial population, especially of *Salmonella* sp, was higher when the litter was piled compared with spread litter. However, fungi population showed a different pattern, decreasing after composting. Nevertheless, both treatments were not able to significantly reduce bacterial counts, specifically *Salmonella* sp, when the population before and after fermentation were compared.

INTRODUCTION

The poultry industry is one of the fastest growing sectors of global agribusiness because of the increasing demand for animal protein, including meat and eggs. However, one of the main challenges of modern poultry production is the disposal of waste, particularly of broiler litter (Bolan *et al.*, 2010). At the same time, the poultry industry also faces litter availability problems because of the increasing demand. Therefore, different substrate types and qualities available in the market need to be used (Bigili *et al.*, 2009).

Litter is used to provide comfort to the birds and to maintain carcass quality, as it reduces the incidence of breast and footpad lesions, as well of lesions in other less commercially important parts (Oliveira *et al.*, 2002).

According to Kelleher *et al.* (2002), litter and waste predominantly consist of water, carbon (C), nitrogen (N) and phosphorus (P), and lower levels of chlorine (Cl), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and arsenic (As). These levels vary among broiler houses and regions, depending on the substrate, number of flocks reared, drinking systems, hygiene status, cleaning method, and storage (Edwards & Daniel, 1992; Jacob *et al.*, 1997; Dao & Zhang, 2007).

Due to economic reasons, litter is often reutilized for several flocks. However, excessive reutilization impairs house disinfection, worsening the microbiological quality of the production system (Walter, 2000). This may increase the prevalence of pathogens, such as *Salmonella* sp., in the environment (Chernaki-Leffer *et al.*, 2002), and therefore, management practices that reduce broiler house contamination need to be developed. For instance, Abreu *et al.* (2011) evaluated different litter substrates (soybean stubble and rice husks) and two ventilation systems (fixed and oscillating) and observed a reduction in enterobacteria levels in the litter.

Some methods to reduce the microbiological load in reused litter are mentioned in literature, such as anaerobic digestion, composting (aerobic fermentation) and direct combustion (Kelleher *et al.*, 2002). In a review on litter utilization, Turnell *et al.* (2007) define composting as the collapse of a microbial population contained in the organic matter of the substrate in a thermophilic phase, which is the phase when the temperature of the pile is between 45 and 70 °C (Miller, 1996; Sundberg *et al.*, 2004). Those authors also stress that composting systems seem to be interesting for the treatment of broiler farming waste because it reduces waste volume. During composting, organic material is broken down, which improves waste storage characteristics and management, reducing its volume, weight, pathogenic load, and undesirable odors, as well as stabilizing nutrients and organic matter (Tiquia & Tam, 1998; Tiquia *et al.*, 2000). However, this requires providing optimal conditions for microbial growth, such as temperature, aeration, humidity, nutrients, and optimal carbon to nitrogen ratio (Costa *et al.*, 2005). However, the trade and use of composted broiler litter is still under discussion, due to health and environmental reasons (Peigne & Giradin, 2004; Tiquia & Tam, 2002).

In the study of Kwak *et al.* (2005) on the effect of composting of broiler litter by piling (1.2m high) in the elimination of *Escherichia coli, Salmonella enteritidis* and *Shigella sonnei*, it was observed that these pathogens were eliminated between day 2 and 4 of composting, and that the highest temperature recorded was 62°C on day 6 of fermentation.

On the other hand, when animal waste is composted, nitrogen is lost due to ammonia volatilization, but this negative effect may be minimized by controlling the humidity and the pH of the substrate used for composting (Kelleher *et al.*, 2002; Tiquia & Tam, 2002; Delaune *et al.*, 2004). Another potential problem of composting systems is the emission of greenhouse gases which may contribute for global warming and acid rain (Ginting *et al.*, 2003; HAO *et al.*, 2004; Peigne & Girardin, 2004; Sharpe *et al.*, 2004).

Therefore, we hypothesized that the use of adequate broiler litter fermentation methodologies may improve its quality and allow it to be reutilized. The objective of this study was to evaluate the effects of two composting methodologies on litter and air quality of broiler houses.

MATERIALS AND METHODS

The experiment was carried out at the Environment Laboratory I of the School of Agriculture Engineering of the State University of Campinas on June 10-22, 2010.

Six reduced-scale broiler houses were used to reproduce the litter fermentation treatments. Houses were built in the east-west direction and were 3.0 m long, 1.4 m wide, and 1.1 m high, made of bricks and covered with cement-fiber tiles.

Broiler litters were obtained from three different commercial broiler houses from a farm located in Capivari, SP, Brazil. One house was equipped with conventional environmental control system and litter was used for only one flock, and the houses two and three were dark houses and the same litter was used for two and three flocks, respectively. All broiler flocks were reared until 42 days of age, and litter substrate was sawdust.

The commercial broiler houses from which litter was collected were divided in six quadrants and 94 kg of litter was removed from the geometric center of each quadrant, totaling 560 kg of litter collected per house. The collected litter from each house was homogenized and distributed in two experimental broiler houses (280 kg each).

A completely randomized experimental design in a 2 x 3 factorial arrangement was applied, with two different litter dispositions for composting (piled – P or spread – S) and three different litter utilization times (1, 2, or 3 flocks).

Six samples were collected from each experimental house for the analyses of total nitrogen content, humidity, pH, and microbiological status before fermentation. These samples were considered treatment replicates, and each parameter was individually analyzed.

Litter from the same grow-out (one, two or three) was distributed in two experimental houses, where it

was either piled (Treatment P) or spread (Treatment S), allowing the simultaneous analysis of litters reutilized for different grow-outs.

The first methodology was composting in piles in the center of the house. The piles were 2.25m long, 0.80m wide and 0.60m high (Treatment P). The second methodology was to spread the litter throughout the experimental house at 20cm height (Treatment S). It is known that the differences in litter arrangement may affect the speed of the composting process due to changes in aeration and temperature inside piles.

In both treatments, humidity was homogenized in 50-55% and the litter was aerated every three days, being stirred with the aid of a hoe, which objective was to maintain biological activity by keeping the desired temperature of 60-80°C. The disposition of the litter in the experimental house (pile and spread) as well as litter fermentation for 12 days, were chosen to simulate the litter management practice commonly applied in commercial broiler houses during downtime between broiler flocks. Both methodologies are adapted from Silva *et al.* (2007).

During composting, litter humidity, gas emission (NH_3 and CO_2), environmental temperature, air relative humidity, and air velocity were determined in the experimental houses. After the composting period, these parameters were analyzed to compare the periods before and after fermentation.

Data were submitted to the F-test to verify the equality of variances, and means were compared by the T test ($p<0.05$).

RESULTS AND DISCUSSION

Table 1 presents mean and standard deviation values of nitrogen, humidity and pH of the litters used for one, two or three flocks compared with the values obtained before and after composting. Piling significantly reduced total nitrogen percentage and increased pH and humidity ($p<0.05$) when litter had been used once

Table 1. Litter parameter obtained before and after being submitted to the different composting treatments.

Method	Parameters								
	Litter used once								
	Before	After		Before	After		Before	After	
	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value
	Nitrogen (%)			Humidity (%)			pH		
P	1.49 (0.0031)a	0.66 (0.0002)b	0.0013	15.71 (0.0100)a	42.92 (0.0244)b	0.0000	8.25 (0.0757)a	8.90 (0.0486)b	0.0000
S	2.46 (0.0027)a	0.68 (0.0006)a	0.0000	15.00 (0.0174)a	38.00 (17.733)b	0.0000	7.80 (0.2490)a	8.88 (0.0509)b	0.0003
Method	Parameters								
	Litter used for two grow-outs								
	Before	After		Before	After		Before	After	
	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value
	Nitrogen (%)			Humidity (%)			pH		
P	1.69 (0.0018)a	0.85 (0.0003)b	0.0001	13.72 (0.0152)a	41.44 (0.0100)b	0.0000	8.01 (0.2422)a	8.89 (0.0376)b	0.0005
S	2.36 (0.0057)a	0.75 (0.0003)b	0.0010	13.21 (0.0050)a	42.45 (0.0279)b	0.0000	7.92 (0.2661)a	8.80 (0.0234)b	0.0005
Method	Parameters								
	Litter used for three grow-outs								
	Before	After		Before	After		Before	After	
	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value
	Nitrogen (%)			Humidity (%)			pH		
P	1.35 (0.0016)a	0.61 (0.0002)a	0.0000	16.12 (0.0078)a	19.00 (0.0434)b	0.0000	8.38 (0.0349)a	8.89 (0.0417)b	0.0000
S	1.48 (0.0024)a	0.65 (0.0002)b	0.0004	14.12 (0.0103)a	38.24 (0.0450)b	0.0000	8.04 (0.2194)a	8.87 (0.0242)b	0.0003

Legend: P Piled; S: Spread
Means followed by the same letter in the same row are statistically similar by the T test ($P<0.05$).

and twice. When the litter was used for three grow-outs, humidity and pH also increased, but total nitrogen level remained similar (Table 1). This behaviour can be explained by how the substrate was arranged, because when the litter is piled, the microenvironment is kept constant, resulting in optimal temperatures for the fermentation process. When litter was spread (Table 1), pH and humidity increased ($p<0.05$), while nitrogen levels were not different before and after treatment when the litter had been used only once and were reduced when litter had been used for two and three grow-outs. As the exposed surface of the spread litter was larger, it is possible that the nitrogen released was able to be captured more rapidly by the sensors.

According to Orrico Jr. *et al.* (2009), adequate temperature (>50ºC) and humidity between 40 and 60% are required to allow bacterial fermentation during composting. After fermentation, organic matter biodegradable solids remain stable, and the compost can be then managed, stored, and used as organic fertilizer with no negative effects on the environment if the correct dose is applied.

Table 2 presents mean and standard deviation of the counts of the main microorganisms found in the three different litters before and after composting (P or S). Total bacteria and *Salmonella* sp counts before and after fermentation were not different ($p>0.05$) among litters used for one, two or three grow-outs in none of the treatments (P or S), as shown in Table 2. On the other hand, fungal counts were reduced only when litters used two and three times were spread.

According to Oliveira *et al.* (2003), higher litter humidity promotes higher activity of ammonia-producing bacteria, consequently increasing substrate pH. Nitrogen losses, according to Orrico Jr. *et al.* (2004), are caused by an imbalance in the carbon:nitrogen ratio in the substrate, and nitrogen is then lost by volatilization as ammonia. Ammonia (NH^+_4.-N) is produced by microorganisms that hydrolyze nitrogen compounds, a process called ammonification. The

Table 2. Microbial counts in the litter obtained before and after being submitted to the different composting treatments.

Method	Parameters								
	Litter used for one grow-out								
	Before	After		Before	After		Before	After	
	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value
	Total bacteria (CFU/g)			Salmonella sp (CFU/g)			Fungi (CFU/g)		
P	663.83 (247.62)a	812.17 (606.42)a	0.5913	13267.17 (4952.45)a	16233.83 (12129.25)a	0.5913	2733.83 (1636.66)a	1433.83 (163.30)a	0.1736
S	681.33 (531.72)a	304.67 (41.88)a	0.1442	13617.17 (10634.36)a	6083.83 (837.66)a	0.5913	2733.83 (1887.50)a	1433.83 (991.30)a	0.1736
Method	Parameters								
	Litter used for two grow-outs								
	Before	After		Before	After		Before	After	
	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value
	Total bacteria (CFU/g)			Salmonella sp (CFU/g)			Fungi (CFU/g)		
S	277.17 a (215.80)	839.67 (606.26)a	0.0579	5533.83 (4315.86)a	16783.83 (12125.25)a	0.0579	15800.50 (17558.13)a	600.50 (1027.62)a	0.0879
S	424.67 (572.34)a	279.67 (127.96)a	0.5712	8483.83 (11446.82)a	5583.83 (2559.23)a	0.5712	1933.83 (1121.90)a	733.83 (588.78) b	0.0428
Method	Parameters								
	Litter used for three grow-outs								
	Before	After		Before	After		Before	After	
	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value	Mean (standard deviation)	Mean (standard deviation)	P value
	Total bacteria (CFU/g)			Salmonella sp (CFU/g)			Fungi (CFU/g)		
P	872.17 (232.22)a	659.67 (195.71)a	0.1173	17433.83 (4644.42)a	13183.83 (3914.29)a	0.1173	13933.83 (6826.61)a	0.50 (0.0000)b	0.0041
S	739.67 (497.71)a	545.50 (379.09)a	0.4647	14783.83 (9954.18)a	10900.50 (7581.82)b	0.4657	6200.50 (4705.74)b	133.83 (326.57)a	0.0254

Legend: P Piled; S: Spread
Means followed by the same letter in the same row are statistically similar by the T test ($P<0.05$).

NH^+_4.-N produced is used either for microbial growth or for nitrification, which is the conversion of ammonia in nitrates. When there is more nitrogen than the microorganisms are capable of assimilating, it is lost in the atmosphere as nitrogen oxide and ammonia, which represents the larger fraction of nitrogen losses. Tiquia & Tam (2000) asserted that pH is one of the main factors influencing N losses, because alkalinity favor ammonia formation, leading to further reduction in N content in the compost. In the present study, pH was maintained higher than 8.6, therefore favoring the formation of ammonia.

Costa *et al*. (2006) studied N concentrations during composting of dead broilers using different aeration systems, and obtained 3.85% at the start and 2.45% at the end of the process. Tiquia & Tam (2000), when composting broiler house waste, observed a 50% reduction in NH^+_4.-N between days 1 and 7 of composting, and stable ammonia concentrations only after day 35. Those authors also determined a 59% N reduction in the mass relative to the initial N content and attributed these nitrogen losses to the low C/N ratio of the material, high temperature of the piles, and pH higher than 7.

Orrico Jr. *et al.* (2010) evaluated the efficiency of composting for the treatment and recycling of broiler litter and broiler carcasses using as parameters total and heat-tolerant coliform counts, total solids, temperature, pH and N, P, K, Ca, Na, Mg, Fe, Zn, and Cu contents. The authors observed significant reduction in total solids and particularly in nitrogen, which accounted for 71.6% of the losses during composting. In that study, there was 100% reduction in the presence of total and heat-resistant coliform counts, possibly due to the longer fermentation period of 60 days.

The thermophilic phase is critical to reduce pathogens in waste. In the study of Costa *et al.* (2006) on the composting of broiler carcasses, there was a progressive reduction in total and thermotolerant coliforms, as well as elimination of bacteria of the genus *Salmonella*, which were isolated from the initial material and were no longer detected in the final compost.

In their study, Orrico Jr. *et al.* (2010) found that composting was efficient to eliminate total thermotolerant coliforms during the piling period, which was not found in the present study. Those authors observed 100% reduction, with numbers of 1.1×10^8 NMP g^{-1} in the beginning and 0 NMP g^{-1} at the end of composting for total and thermotolerant coliforms. Other studies, such as those of Curci *et al.* (2007), Torres *et al.* (2007), and Orrico *et al.* (2007), also observed that composting was efficient to eliminate pathogenic microorganisms. The maintenance of bacterial counts in the present study may have been due to shorter fermentation time, favoring further nitrogen reduction.

The reduction of pathogen counts in the final product of litter composting that will be utilized again in the broiler house has extreme importance. As well as the high coliform counts in drinking water, this factor may result in higher incidence of diseases, and consequent increase in mortality and production losses (Salminen & Rintala, 2002).

CONCLUSIONS

Based on the obtained results, it is concluded that neither of the composting methods (piled or spread) significantly reduced bacterial populations, particularly of *Salmonella* spp., in litters used for one, two or three broiler grow-outs. However, piling the litter was more effective in reducing its N content, humidity and pH. In addition, the period of 12 days of composting seemed not be sufficient to reduce litter microbial populations. When carrying out studies on different composting methods to treat litter used for different number of broiler grow-outs, longer fermentation times and substrate humidity control are suggested.

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