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Nutrient composition and nutrient losses during composting of chicken manures as affected by addition of sawdust

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Abstract
This study was conducted to determine the effects of sawdust application on nutrient composition and losses during composting of chicken manures, waste chicken feed, and feathers. It was hypothesised that addition of sawdust to compost piles would reduce nutrient losses during the composting process, and therefore would improve compost quality. Sawdust was applied at three sawdust-to-organic material ratios, as follows: 20:80, 40:60, and 50:50 (%, by volume), respectively. The organic materials were subject to physico-chemical analyses using standard laboratory procedures from samples taken from the piles during the composting process. Compost piles were irrigated during turning, and physico-chemical properties were routinely monitored. Results showed that temperature and pH changes recorded in the pile were significantly correlated with the amount of sawdust applied ($P<0.05$). These changes induced losses of nutrients and total C, and therefore affected dry matter composition. The rate of losses was correlated with the sawdust-to-organic material ratio ($P<0.05$). Narrower ratios showed proportionally higher nutrient losses compared with wider ratios. Maturation was observed at about 126 days after composting had been initiated. There were no differences between-treatments in the time required to reach maturity ($P>0.05$). The maturation point was established when the temperature in the pile was stable at around 25±1°C. Nitrogen losses were mainly attributed to volatilisation of ammonia, and occurred primarily within the first two weeks. Such losses were caused by the addition of sawdust, even at relatively low rates, and increased significantly when temperature and pH of the pile were at or above 50±1°C and 8.10±0.5, respectively.

Keywords: *Ammonia volatilization, Chicken manure, Compost quality and composition, Nutrient recovery.*

1 Introduction
Recycling of organic materials to land is regarded as the best practicable and environmental option. However, routine application of chicken manures at rates that exceed nutrient requirements by crops may lead to build-up of soil nutrients, such as nitrogen and phosphorus, or increased risk of pathogens contamination, and therefore potential for transport to surface or underground water [1]. Despite this, application of composted materials to agricultural land is a preferred option compared with fresh manures, as it is safer in terms of pathogens, odour, and risk of weed-seeds contamination [1]. Composting is mentioned in several studies as an effective method to mitigate pathogens incidence from organic materials applied to land. Both pathogens and the weed-seed bank are significantly reduced when compost windrow temperatures reach 60–70°C for at least 4 days [2-4]. During the composting process soluble nutrients, such as nitrogen and phosphorus, may be lost by leaching, and subsequently runoff [5]. Nutrient losses from compost piles are known to be one of the main disadvantages of aerobic composting methods. At high temperatures, nitrogen may also be lost by volatilization of ammonia (NH_3^+) [6]. Research (e.g., Martins and Dewes [7], Jiang et al. [8]) has shown that as much as 75% of total nitrogen in manures can be lost through volatilization during composting. Other pathways losses for nitrogen include N_2O emissions, which may be up to 1.5-7.3% relative to pre-composting (total) nitrogen content in the material. Nutrient losses are affected by temperature and pH in the compost pile, with approximately 40% to 90% of total nitrogen losses occurring within the first 28 days, depending on the conditions [6]. The C:N ratio also has a significant effect on nitrogen dynamics within the pile, and losses may increase at low (e.g., <20) C:N ratios.
Phosphate lost by leaching is mentioned in Seymour and Bourdon [9] to be significant, depending on the conditions. The aim of our study was to demonstrate that increased C:N ratios in the material may reduce the risk of nutrient losses from compost piles during the composting process. To achieve this objective, nutrient losses from chicken manures, treated with sawdust and subject to aerobic composting, were quantified during the process using different sawdust-to-compost ratios.

2 Materials and Methods

2.1 Compost pile construction and management

Fresh chicken manure was collected from a commercial farm located in southern Queensland, Australia, after cleaning of sheds had been completed. Samples were collected prior to treatment, and contained broken eggs (membrane and eggshell) as well as pellets and feathers. Subsequently, the material collected underwent composting and samples were taken at different stages of decomposition. Three windrows were constructed at a facility located in Pittsworth (QLD, Australia). Windrows were mechanically constructed using specialised equipment, which also enabled mixing of the material. All piles were trapezoidal in shape, 100-m long, 2-m wide, and 1.5-m height. Different ratios of sawdust (wood chops) were applied at three sawdust-to-organic material ratios, as follows: 20:80, 40:60, and 50:50 (%, by volume), respectively. These mixtures resulted in the following C:N ratios: 7:1, 8:1, and 9:1, respectively. All piles were irrigated during turning, and pH, electrical conductivity (EC), and temperature were routinely monitored until the pile reached maturity. The temperature inside the compost pile was measured by using a 1.2-m long thermometric probe, which recorded readings on a daily basis. Turing of the pile was performed when the inside temperature reached 70°C. Figure (1) shows the average pile temperature during aerobic composting process in classic phases, namely: mesospheric and thermophilic phases, respectively. Initially, the temperature in the pile was about 28°C (mesospheric) and after a week it increased to about 55°C. The thermophilic phase started on day 21, and it continued through day 90. Subsequently, temperatures in the pile decreased gradually as the material approximated maturity at about 110 days.

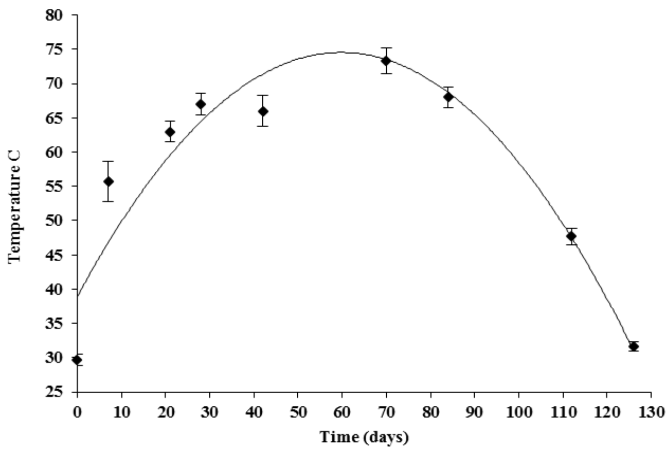

Figure 1: Changes in temperature recorded in the compost pile during composting. Error bars denote SE of means (n=3).

2.2 Chemical and biological properties

The compost pile was subjected to chemical and biological analyses during the composting process following standard analytical procedures, and included the following determinations: moisture content and dry matter (DM), total C and total N (MAFF, 1986), total P and total K, and available nutrients N, P and K determined by extraction solution (1:10) (compost: water) [10, 11]. Pathogens (*Escherichia coli* O157:H7 and *Salmonella enterica*) were determined in compost using a selective media [12]. Table (1) summarises the characteristic of fresh chicken manure.

Table 1: Chemical and biological properties determined on chicken manure.

Parameter	Moisture (%, w w^{-1})	$pH_{1:10}$	$EC_{1:10}$ dS/m	Total C, %	Total N, %	Total P, %	Total K, %	Pathogens log_{10} CFU g^{-1}	
								E.coli	*Salmonella. spp*
Value	52.3 ±2.5	8.33	12.01	57.5	9.53	8.24	13.35	6.2	5.01

2.3 Statistical analyses

The study used a randomized complete block design in which each pile was block. Data are expressed as the mean of five replicated values for each of the parameters measured (n=5). Statistical analyses were undertaken using One-Way ANOVA to determine the effect of sawdust ratio on nutrient losses. The least significant difference (LSD) was used to compare means with a probability level of 5%.

3 Results and Discussion

Figure 2 shows changes in pH of chicken manures during composting as affected by sawdust addition when different manure-to-sawdust ratios are used. Initial pH of chicken manure was alkyne (pH =8.33), but it decreased to near-neutrality (range: 6.83 to 7.66) after the composting period. Increased sawdust-to-manure ratio generally reduced pH, and it reached 6.75 in the $R_{50:50}$ treatment. The increase in pH was due to increased ammonia concentration in compost. Addition of sawdust promoted the conversion of ammonia-N into organic-N forms through microbial immobilization. This process produces CO_2, which during composting, reacts with water to carbonic acid thus lowering pH [13].

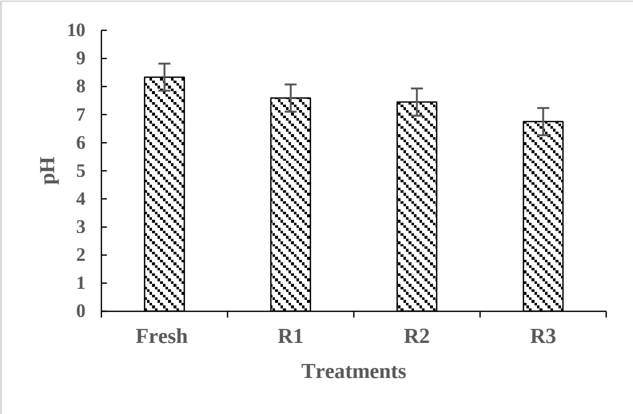

Figure 2: Compost pH in fresh and sawdust-treated manure. Ratios are R1: 80:20, R2: 60:40, and R3: 50:50 (manure-to-sawdust, by volume), respectively. Error bars denote LSD at 5% level.

Electrical conductivity (EC) values decreased with increasing amount of sawdust added to the mix (P<0.05). At the end of the composting period, EC values ranged from 6.72 to 9.77 dS m^{-1} (Figure 3). This decrease was attributed to the release of soluble salts (i.e., nitrates, ammonium, and phosphates) through compositing of manure and sawdust [14]. Research (e.g., Wong et al. [15]) suggests that as decomposition progresses, EC of compost can decrease due to volatilization of ammonia, and precipitation of mineral salts. Although EC values decreased, they did not exceed the suggested limit value of 3 dS m^{-1}, considered to be typical in stable composts [16]. High EC values in compost may suggest risk of phytotoxicity and may affect plant establishment (e.g., poor germination rate, withering) [17].

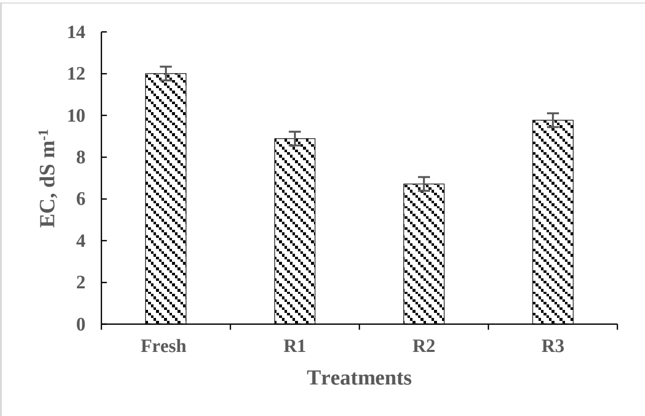

Figure. 3. Electrical conductivity (EC) of fresh and sawdust-treated manure. Ratios are R1: 80:20, R2: 60:40, and R3: 50:50 (manure-to-sawdust, by volume), respectively. Error bars denote LSD at 5% level.

There were significant differences in NPK compositions in all treatments at the end of composting period. Nutrient contents decreased significantly comparing with levels determined in the fresh manure. Addition of sawdust to the mix maintained or mitigated nutrients losses during the composting process. The 60:40 ratio manure-to-sawdust mixture was found to be effective as it reduced NPK losses from 52%, 78%, and 80% to 48%, 38%, and 33%, respectively, compared to the fresh material (Table 2).

Table 2: Total nutrient composition of chicken manure recorded after a composting period of 120 days.

Total Nutrients	Nitrogen	Phosphorus	Potassium
	-------%-------	-------%-------	-------%-------
Fresh chicken manure	9.53	8.24	13.35
80:20 (Manure:sawdust)	4.60	1.82	2.70
% change	51.74	77.95	79.77
60:40 (Manure:sawdust)	4.92	5.09	8.89
% change	48.39	38.18	33.38
50:50 (Manure:sawdust)	4.18	3.15	7.60
% change	56.15	61.77	43.04

Relatively higher nutrient concentrations were generally observed in fresh manure compared with mature compost, which was recorded in all treatments. This was possibly due to both addition of sawdust (dilution of bulk nutrient source) and nutrient leaching during composting, which agrees with observations made in related studies investigating the fate of nutrients and their transformation in organic materials used for compost (e.g., [18-20]).

The population of *Escherichia (E.coli* O157: H7) and *Salmonella. ssp* in chicken manure and compost found in fresh manure and compost is shown in Table 3. The number of colonies decreased significantly (P<0.001) after one week of composting in all treatments. Both *E.coli* and *Salmonella. ssp* colonies were observed in fresh manure whereas there were no pathogens detected after 18 days of composting (Table 3). This result was consistent with other studies, which showed that well-constructed piles maintained at elevated temperatures are able to control pathogens to large extent. The temperature of the compost pile in our experiments exceeded 70°C after 2 weeks of composting (Figure. 1) as a result of organic matter breakdown caused by aerobic microbial activity [2, 3, 21].

Table 2: Total nutrient composition of chicken manure recorded after a composting period of 120 days.

Material	Log_{10} CFU g^{-1}	
	Salmonella. ssp	E. coil
Fresh chicken manure	6.20 (±0.3)	5.01 (±0.1)
80:20 (Manure:sawdust)	n.d*	n.d
60:40 (Manure:sawdust)	n.d	n.d
50:50 (Manure:sawdust)	n.d	n.d

* n.d = below lower limit of detection of this method.

4 Conclusions

This study was conducted to determine the effects of sawdust addition on nutrients loss and pathogens during windrow composting. The pH and EC of the compost mixtures showed changes during the composting period. Compost pH decreased as result of organic matter breakdown whereas EC decreased due to leaching of salts. Addition of sawdust at a rate required to achieve 40% (by volume) in the mixture was shown to significantly reduce nutrient losses compared with addition of 20% or 50%, respectively. In all piles, temperatures reached 55°C within 2 weeks, which was effective to eliminate pathogens. Pathogens count after a composting of 120-day period showed values below detection limits.

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