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# COMPOSTING OF OPIUM POPPY PROCESSING SOLID WASTE WITH POULTRY MANURE: EFFECTS OF INITIAL C/N RATIO ON COMPOSTING LOSSES

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***Abstract***

In this study, composting of opium poppy processing solid waste with poultry manure and rough sawdust with five initial Carbon/Nitrogen (C/N ratio) ratio ranging from 20.45, 25.00, 29.03, 32.60 and 37.47 was carried out using fifteen-identical cylindrical stainless steel reactors, each of which has an effective volume of 100 L to determine the effects of initial C/N ratio on composting loss due to degradation (dry matter loss, organic matter loss, carbon loss, and nitrogen loss, and ammonia loss). The experiment lasted for 18.65 days. In the experiment, the temperature, electrical conductivity, pH, moisture, organic matter, total carbon (C) and nitrogen (N) contents and $NH_3$-N were monitored. Dry matter loss, organic matter loss, carbon loss, nitrogen loss, and $NH_3$-N loss were expressed as a function of initial C/N ratio. Results showed that the highest dry matter loss and organic matter loss existed at the CN ratio of 29.70 and 31.18, respectively. The highest carbon loss occurred at the C/N ratio of 30.83. Both nitrogen loss and $NH_3$-N loss decreased as the C/N ratio increased.

**Key words:** Composting, opium poppy processing solid waste, poultry manure, C/N ratio, loss

## INTRODUCTION

With the increasing amount of plant and animal production, the amount of waste increases day by day and causes environmental problems. In recent years, awareness of environmental problems related to wastes from agricultural production and agricultural-industrial processing has been increasing in Turkey. At the meetings held by the United Nations, 3R (Recycling, Reduce and Reuse) strategies have been adopted in the disposal of waste within the scope of the sustainability principle (Ekinci *et al*., 2010). In this context, it is important to valorise waste for the sustainable development of communities and the protection of the ecosystem (Bernal *et al*., 2009). Turkey has an important place in the world in the production of legal opium poppy. Afyon Alkaloids Factory in 2014 processed 16223 tons of poppy capsules (TurkStat, 2014) yielding approximately 40558 tons of solid opium poppy processing wastes (OPPSW). The OPPSW can used as an organic matter amendment for agricultural use. These kinds of waste disposal methods have resulted not only in ecological problems including: odour pollution, leaching of toxic elements, methane emissions, eutrophication of waterways, nutrient imbalances, phytotoxicity and dissemination of pathogens (Huang et al., 2004) but also in official complaints to environmental protection agencies (Onursal and Ekinci, 2015). Environmental damage by wastes existing during the poultry production is one of the important problems facing the poultry industry in Turkey. Improper management and utilization of manure may contribute to environmental degradation, and ultimately be detrimental for human and animal health. Poultry manure is a valuable by-product of the poultry industry and it has important utilization area in agriculture. Manure is usually considered as waste material and farmers seeks the empty area for dumping. However, if it is accepted as a valuable by-product of the poultry industry, it may be converted to a product which has value in market economy. OPPSW with poultry manure can be composted to produce a useful, economic and salable product. Composting is a decomposition of organic materials and a process of which physical, chemical, and biological factors interact simultaneously. Compost quality depends on the type of composting materials and good management of composting systems. If the composting process is managed well, the desired quality of compost is obtained within a short time and with the least environmental effects. Otherwise, compost will be bad in quality and it will be even toxic to plants. Initial C/N ratio is a controllable parameters which affects the management of the composting process. C/N ratio is one of the key component of a successful composting process (Hansen *et al*., 1989). Microorganisms use carbon for both energy and growth, while nitrogen is used for protein synthesis. Microorganisms use 30 parts of C per unit of N during active aerobic metabolism (Chowdhury *et al*., 2013). Excessive or insufficient amounts of carbon or nitrogen affect the composting process. Therefore, it is important for microorganisms to provide carbon and nitrogen at specific ratios for optimum composting. This study involves composting of opium poppy processing solid wastes with poultry manure and rough sawdust. The study was conducted to determine the effects of C/N ratio on composting loss due to degradation of dry matter (dry matter loss, organic matter loss, carbon loss, nitrogen loss, and ammonia loss).

## MATERIALS AND METHODS

This study involved OPPSW, Poultry Manure (PM) and Rough Sawdust (RS). The OPPSW was received from Afyon Alkaloids Factory in Afyon province. PM was received from Gürelli farm in Isparta province. RS was maintained from the local sawmill. The main characteristics of the three raw materials (OPPSW, PM, and RS) are reported in Table 1. Values reported are on a dry weight basis except for moisture content which is on a wet weight basis. The experiment was conducted at five different initial C/N ratios (20.45, 25.00, 29.03, 32.60 and 37.47) corresponding to mixes. The number of replication for each mix is 3. The proportions of OPPSW, PM, and RS in the compost mixtures based on dry weight basis are presented in Table 2. Initial chemical and physical properties (moisture content, organic matter content, electrical conductivity, pH, C, N and C/N ratios of compost mixtures with reactor assignment are presented in Table 3.

**Table 1.** Initial physical and chemical properties of feedstock and composting mixes used in the experiment

| | OPPSW | PM | RS |
|---|---|---|---|
| Moisture,% | 35.52±1.60 | 72.42±0.44 | 6.1±0.01 |
| Organic matter, % | 55.39±0.27 | 70.52±0.31 | 99.18±0.05 |
| EC*, dS/m | 2.21±0.01 | 11.48±0.02 | 3.9±0.14 |
| pH | 8.78±0.05 | 5.22±0.00 | 5.7±0.14 |
| Total C, % | 33.00±0.05 | 35.41±0.08 | 48.60±0.10 |
| Total N, % | 0.88±0.06 | 5.87±0.03 | 0.13±0.02 |
| C/N | 37.5 | 6.03 | 373.85 |

*: Electrical conductivity

Fifteen-identical cylindrical stainless steel reactors, each of which has an effective volume of 100 L with the inner diameter of 47.3 cm and height of 57.0 cm were used in the experiment (Figure 1). K type thermocouples with a diameter of 3 mm and 35 cm length are inserted into each composting reactor equipped with three ports to facilitate temperature at three levels of 10, 27, and 44 cm above the perforated floor. Control of aeration fans as well as data acquiring and logging was performed by a PLC (Schneider M258).

**Table 2.** The proportions of OPPSW, PM, and RS in the compost mixtures based on dry weight basis

| Materials | Mix-1 | Mix2 | Mix-3 | Mix-4 | Mix-5 |
|---|---|---|---|---|---|
| OPPSW (%) | 46.52 | 63.93 | 68.04 | 70.82 | 71.91 |
| PM (%) | 27.21 | 15.90 | 10.81 | 7.24 | 5.59 |
| RS (%) | 26.27 | 20.17 | 21.16 | 21.95 | 22.50 |

**Table 3.** Initial chemical and physical properties of compost mixtures.

| | Moisture (%) | Organic matter (%) | EC dS/m | pH - | C (%) | N (%) | C/N ratio - |
|---|---|---|---|---|---|---|---|
| Mix-1 (R1, R2, R3) | 64.69 ±0.02 | 72.82 ±1.56 | 6.93 ±0.25 | 8.21 ±0.22 | 33.64 ±0.71 | 1.65 ±0.02 | 20.45 ±0.69 |
| Mix-2 (R4, R5, R6) | 63.46 ±0.08 | 66.69 ±1.26 | 4.33 ±0.46 | 8.44 ±0.30 | 32.87 ±0.77 | 1.32 ±0.05 | 25.00 ±0.35 |
| Mix-3 (R7, R8, R9) | 63.83 ±2.56 | 66.49 ±1.25 | 2.52 ±0.32 | 8.51 ±0.32 | 34.81 ±0.00 | 1.20 ±0.04 | 29.03 ±1.03 |
| Mix-4 (R10, R11, R12) | 59.26 ±0.95 | 65.8 ±1.27 | 3.38 ±0.10 | 8.57 ±0.21 | 39.27 ±0.85 | 1.21 ±0.02 | 32.60 ±1.28 |
| Mix-5 (R13, R14, R15) | 59.49 ±0.12 | 67.12 ±0.17 | 3.12 ±0.17 | 8.80 ±0.25 | 39.10 ±0.71 | 1.05 ±0.05 | 37.47 ±2.45 |

**Figure 1.** Composting reactors

**Figure 2.** Ammonia sampling system

Air flow supplied into the reactors by fans (0.25 kW) is measured by a hot wire anemometer (QVM62.1 Siemens) and the results of measurement are transmitted to the PLC unit. Compost temperature was controlled through airflow manipulation based on temperature feedback control. Temperature is the controlled variable and aeration rate is the manipulated variable (Ekinci *et al*., 2004). Fans are operated with on/off mode when the compost temperature (T) is less than or equal to set point temperature ($T_{sp}$) of 60°C to regulate airflow and to allow temperature increase. This stage is characterized with on/off time (7.5 on-25 min off time) and volumetric airflow rate to meet minimum requirements for oxygen and air movement ($Q_{min}$=1.5 $m^3$/h). Air was continuously supplied by the controller to cool down compost mass when $T>T_{sp}$. Duplicate samples for physical and chemical analysis were taken from each reactor at the beginning, right after remixing, and at the end of experiment. Moisture contents of fresh samples were determined after the samples were dried at 70±5°C for 3 days, and organic matter content of dry samples was analyzed after incinerating the samples at 550°C as recommended by the US Department of Agriculture and the US Composting Council (USCC, 2002). pH and EC of the fresh samples were extracted by shaking at 180 rpm for 20 min at a solid:water ratio of 1:10 (w/v), and measured using pH and EC meters (Models WTW pH 720 and WTW Multi 340i), respectively (Data related to EC and pH was not presented here). Total C and N content were analyzed using the elemental analyzer (Vario MACRO CN Elemental analyzer). Air sampled for ammonia was bubbled through boric acid traps at the flow rate of 1 L/min (Figure 2). An air flow meter was used for monitoring flow. The flow meter is preceded by a trap containing Drierite as a desiccant. Airflow was controlled with a valve which was connected in series with a vacuum pump. The 200 mL flask contains 50 mL of indicating boric acid solutions. Solution was changed in the primary traps every 8-9 hours during the first three days of composting. For the remaining days, the sampling duration was based upon the color change of boric acid solution. The samples collected in boric acid solution were titrated with 0.02 N $H_2SO_4$ to determine the mass of $NH_3$-N that was collected during the sampling period.

Dry mass loss (DML), organic mass loss (OML), carbon loss (C-loss), and nitrogen loss (N-loss) were calculated based on initial and final values of dry matter and their corresponding concentrations.

$$\text{DML}\ (\%)=\left(1-\left[\frac{m_d(\theta)}{m_d(0)}\right]\right)100 \tag{1}$$

$$\text{OML}(\%)=\left(1-\left[\frac{m_O(\theta)}{m_O(0)}\right]\right)100 \tag{2}$$

$$\text{C-loss}\ (\%)=\left(1-\left[\frac{m_C(\theta)}{m_C(0)}\right]\right)100 \tag{3}$$

$$\text{N-loss}\ (\%)=\left(1-\left[\frac{m_N(\theta)}{m_N(0)}\right]\right)100 \tag{4}$$

Where $m_d(\theta)$, $m_O(\theta)$, $m_C(\theta)$, and $m_N(\theta)$ are the compost dry mass, organic mass, and total carbon mass, and total nitrogen mass (kg) at given time, respectively. $m_d(0)$, $m_O(0)$, $m_C(0)$, and $m_N(0)$ are the compost dry mass, organic mass, total carbon mass, and total nitrogen mass (kg) at the initial, respectively (Şevik *et al*. 2016).

## RESULTS AND DISCUSSION

### *Compost temperature*

Compost temperature as a function of time for Mix-1 (R1, R2, and R3) is presented in Figure 3. Temperatures were measured at three points from each reactor, but only midpoint temperatures were given. The trial lasted for18.65 days. In general, although the temperature values in all (R1-R15) reactors were similar and the time to reach the control temperature of 60°C, the residence time at the control temperature have changed. Mixing of reactors was performed at 3.87 days of composting. Similar result was obtained from the study of Onursal and Ekinci (2015). The spikes in the temperature profiles indicates the manual mixing and also sampling times. The close control of compost temperature at $T_{sp}$ of 60°C with the small standard deviation was maintained by the aeration system. The temperature values in all the reactors approached the ambient temperature at the end of the experiment. This may be due to the depletion of readily available nutrients (Sülük *et al*., 2017).

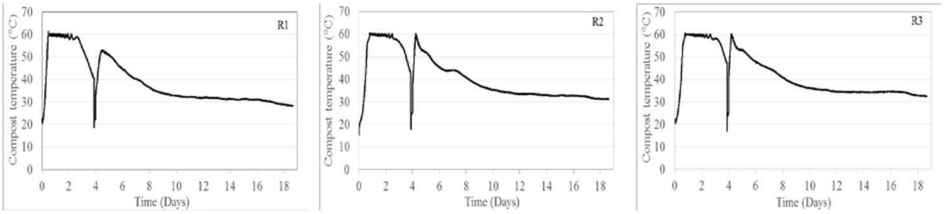


**Figure 3.** Compost temperature as a function time for R1, R2, and R3 for Mix-1

### *Compost moisture*

Change of the compost mixtures (wet basis, %) depending on the time is given in Table 4. Despite the fact that the initial starting moisture was planned to be 62% in the trial, different starting moistures were obtained due to the properties of the materials used. The moisture content of all the mixes decreased until the re-mixing. After mixing, the temperature development was weaker and this reflected the loss of moisture. After mixing, the loss of moisture was slight in some reactors and increased in some (R6, R8, R9, R10, R11, R12 and R15).

### *Organic matter*

The time-dependent change in compost organic matter (%) is given in Table 5. Initial organic matter contents of the mixes were measured as 72.82, 66.69, 66.49, 65.80, and 67.12% for Mix-1 through 5, respectively. The organic matter of compost mixes in all reactors decreased during the biodegradation process. Furthermore, studies showed that the highest organic matter degradation occurred during the thermophilic stage due to microbial activity (Ekinci *et al*., 2016).

**Table 4.** The change of compost moisture as a function of time

| Reactor | Composting duration (days) | | |
|---|---|---|---|
| | 0 | 3.87 | 18.65 |
| R1 | 64.69±0.02 | 60.53±1.32 | 52.81±0.83 |
| R2 | 64.69±0.02 | 60.93±1.30 | 52.05±0.07 |
| R3 | 64.69±0.02 | 58.93±1.22 | 52.92±2.21 |
| R4 | 63.46±0.08 | 58.67±0.89 | 53.53±1.59 |
| R5 | 63.46±0.08 | 59.48±0.23 | 58.21±1.07 |
| R6 | 63.46±0.08 | 58.85±0.31 | 59.21±1.70 |
| R7 | 63.83±2.56 | 58.75±0.93 | 55.26±1.03 |
| R8 | 63.83±2.56 | 59.07±1.16 | 59.98±1.43 |

| Reactor | Composting duration (days) | | |
|---|---|---|---|
| | 0 | 3.87 | 18.65 |
| R9 | 63.83±2.56 | 57.96±0.73 | 59.73±2.37 |
| R10 | 59.26±0.95 | 55.27±1.08 | 56.27±0.04 |
| R11 | 59.26±0.95 | 56.00±0.65 | 57.05±0.02 |
| R12 | 59.26±0.95 | 56.24±0.35 | 56.89±2.97 |
| R13 | 59.49±0.12 | 53.95±0.15 | 49.71±0.01 |
| R14 | 59.49±0.12 | 53.97±0.56 | 50.31±3.56 |
| R15 | 59.49±0.12 | 53.88±1.83 | 55.25±0.35 |

### *C/N ratio*

C/N ratio was measured at the initial and final stage of composting. The initial and final C, N and C/N ratio of compost mixtures is given in Table 6. The C, N and C/N ratios in all mixtures were found to decrease at the end of the experiment. The highest decrease in C/N ratio occurred for Mix-3 and Mix-4. The initial C/N ratios of Mix-3 and Mix-4 were 29 and 32.60, respectively. This ratio was within the range reported for ideal composting by Chowdhury *et al*. (2013).

**Table 5.** The change of compost organic matter (%) as a function of time.

| Reactor | Organic matter content (%) | | |
|---|---|---|---|
| | 0 (days) | 3.87 (days) | 18.65 (days) |
| R1 | 72.82±1.56 | 70.24±0.17 | 63.21±1.61 |
| R2 | 72.82±1.56 | 70.27±1.06 | 59.67±0.71 |
| R3 | 72.82±1.56 | 66.60±0.14 | 60.90±0.12 |
| R4 | 66.69±1.26 | 64.08±0.00 | 56.22±0.63 |
| R5 | 66.69±1.26 | 64.26±0.11 | 58.12±0.03 |
| R6 | 66.69±1.26 | 64.61±1.05 | 60.72±0.84 |
| R7 | 66.49±1.25 | 64.98±0.75 | 63.42±1.73 |
| R8 | 66.49±1.25 | 64.10±0.58 | 57.21±2.02 |
| R9 | 66.49±1.25 | 64.60±1.11 | 56.07±1.10 |
| R10 | 65.80±1.27 | 61.92±0.31 | 55.20±0.52 |
| R11 | 65.80±1.27 | 63.50±0.81 | 57.56±0.52 |
| R12 | 65.80±1.27 | 61.54±1.94 | 56.20±1.02 |
| R13 | 67.12±0.17 | 56.72±0.74 | 57.61±3.22 |
| R14 | 67.12±0.17 | 63.60±0.07 | 57.44±2.19 |
| R15 | 67.12±0.17 | 62.66±14.07 | 57.25±2.45 |

**Table 6.** The change of C, N, and C/N ratio of reactors

| Reactors | C (%) | | N (%) | | C/N ratio | |
|---|---|---|---|---|---|---|
| | 0 (days) | 18.65 (days) | 0 (days) | 18.65 (days) | 0 (days) | 18.65 (days) |
| R1 | 33.64±0.71 | 24.00±0.66 | 1.65±0.02 | 1.24±0.04 | 20.45±0.69 | 19.44±1.09 |
| R2 | 33.64±0.71 | 24.68±0.76 | 1.65±0.02 | 1.33±0.04 | 20.45±0.69 | 18.58±1.17 |
| R3 | 33.64±0.71 | 26.83±0.41 | 1.65±0.02 | 1.49±0.00 | 20.45±0.69 | 18.01±0.28 |
| R4 | 32.87±0.77 | 25.85±0.76 | 1.32±0.05 | 1.21±0.00 | 25.00±0.35 | 21.36±0.63 |
| R5 | 32.87±0.77 | 26.34±1.52 | 1.32±0.05 | 1.16±0.03 | 25.00±0.35 | 22.69±0.76 |
| R6 | 32.87±0.77 | 27.21±0.33 | 1.32±0.05 | 1.24±0.04 | 25.00±0.35 | 22.04±0.37 |
| R7 | 34.81±0.00 | 21.31±0.23 | 1.20±0.04 | 1.01±0.01 | 29.03±1.03 | 21.20±0.08 |
| R8 | 34.81±0.00 | 23.22±0.10 | 1.20±0.04 | 1.14±0.04 | 29.03±1.03 | 20.47±0.55 |
| R9 | 34.81±0.00 | 22.13±0.40 | 1.20±0.04 | 1.14±0.01 | 29.03±1.03 | 19.49±0.23 |
| R10 | 39.27±0.85 | 25.88±0.78 | 1.21±0.02 | 1.13±0.03 | 32.60±1.28 | 22.91±1.27 |
| R11 | 39.27±0.85 | 23.39±0.88 | 1.21±0.02 | 1.07±0.04 | 32.60±1.28 | 21.86±0.04 |
| R12 | 39.27±0.85 | 23.78±0.93 | 1.21±0.02 | 1.15±0.00 | 32.60±1.28 | 20.67±0.81 |
| R13 | 39.10±0.71 | 32.05±0.82 | 1.05±0.05 | 0.95±0.04 | 37.47±2.45 | 33.75±0.64 |
| R14 | 39.10±0.71 | 31.75±0.75 | 1.05±0.05 | 0.99±0.04 | 37.47±2.45 | 32.27±1.92 |
| R15 | 39.10±0.71 | 31.08±0.23 | 1.05±0.05 | 0.97±0.01 | 37.47±2.45 | 32.05±0.70 |

***Composting loss as function of C/N ratio***

The change of DML, OML, C-loss and N-loss as a function of mixes is presented in Table 7. DML and OML are an indicator of the overall composting success. Furthermore, the degradation of the organic matter during composting can be estimated by DML (Ekinci *et al*., 2002). Regression analysis using Gaussian curve was applied to experimentally determined DML at different C/N ratios. DML as a function of C/N was correlated and the resultant equation with $R^2$=0.97 (Eq.5) showed that the highest DML (15.81%) occurred at C/N ratio of 29.70. DML as a function of C/N ratio is given in Figure 4a.

$$DML = 15.81\, e^{-0.5\left[\frac{\left(\frac{C}{N}\right)-29.70}{9.88}\right]^2} \quad (5)$$

As for OML, regression analysis using Gaussian curve yielded an equation (Eq.6) with $R^2$=0.98. Based on the equation, it can be said that the highest OML existed at the C/N ratio of 31.18. OML as a function of C/N ratio is given in Figure 4b.

$$OML = 24.20 + 10.07\, e^{-0.5\left[\frac{\left(\frac{C}{N}\right) - 31.18}{0.99}\right]^2} \qquad (6)$$

**Table 7.** The change of DML, OML, C-loss and N-loss with mixes

| Reactor | $m_d(0)$ (kg) | $m_d(\theta)$ (kg) | $m_O(0)$ (kg) | $m_O(\theta)$ (kg) | $m_C(0)$ (kg) | $m_C(\theta)$ (kg) | $m_N(0)$ (kg) | $m_N(\theta)$ (kg) | DML (%) | OML (%) | C-loss (%) | N-loss (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | 14.84 | 12.45 | 10.80 | 7.87 | 0.24 | 0.15 | 4.99 | 2.99 | 16.10 | 27.17 | 40.15 | 37.01 |
| R2 | 13.74 | 13.18 | 10.00 | 7.86 | 0.23 | 0.18 | 4.62 | 3.25 | 4.05 | 21.37 | 29.61 | 22.42 |
| R3 | 14.65 | 13.17 | 10.67 | 8.02 | 0.24 | 0.20 | 4.93 | 3.53 | 10.10 | 24.82 | 28.30 | 18.57 |
| R4 | 16.95 | 15.65 | 11.31 | 8.80 | 0.22 | 0.19 | 5.57 | 4.04 | 7.72 | 22.20 | 27.41 | 15.08 |
| R5 | 18.73 | 16.07 | 12.49 | 9.34 | 0.25 | 0.19 | 6.16 | 4.23 | 14.20 | 25.22 | 31.25 | 24.32 |
| R6 | 19.01 | 15.52 | 12.68 | 9.42 | 0.25 | 0.19 | 6.25 | 4.22 | 18.36 | 25.67 | 32.40 | 23.32 |
| R7 | 17.08 | 15.31 | 11.36 | 9.71 | 0.20 | 0.15 | 5.95 | 3.26 | 10.39 | 14.52 | 45.16 | 24.95 |
| R8 | 15.29 | 12.18 | 10.17 | 6.97 | 0.18 | 0.14 | 5.32 | 2.83 | 20.33 | 31.45 | 46.86 | 24.65 |
| R9 | 15.35 | 12.85 | 10.20 | 7.21 | 0.18 | 0.15 | 5.34 | 2.84 | 16.24 | 29.36 | 46.76 | 20.77 |
| R10 | 17.61 | 15.08 | 11.59 | 8.32 | 0.21 | 0.17 | 6.92 | 3.90 | 14.37 | 28.16 | 43.58 | 19.70 |
| R11 | 18.05 | 14.60 | 11.88 | 8.41 | 0.22 | 0.16 | 7.09 | 3.42 | 19.11 | 29.24 | 51.83 | 28.17 |
| R12 | 17.21 | 14.86 | 11.32 | 8.35 | 0.21 | 0.17 | 6.76 | 3.53 | 13.61 | 26.22 | 47.70 | 17.56 |
| R13 | 14.02 | 13.23 | 9.41 | 7.62 | 0.15 | 0.13 | 5.48 | 4.24 | 5.68 | 19.04 | 22.68 | 14.25 |
| R14 | 14.49 | 12.32 | 9.73 | 7.08 | 0.15 | 0.12 | 5.67 | 3.91 | 14.99 | 27.26 | 30.97 | 19.87 |
| R15 | 13.56 | 11.91 | 9.10 | 6.82 | 0.14 | 0.12 | 5.30 | 3.70 | 12.17 | 25.09 | 30.19 | 18.48 |

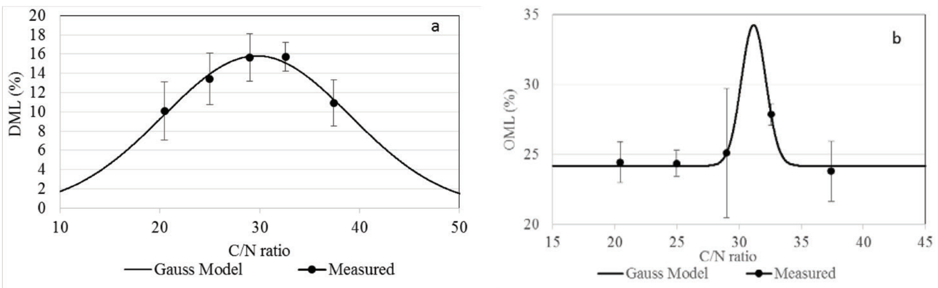


**Figure 4.** The change of DML (a) and OML (b) as a function of C/N ratio

Larney *et al.* (2006) reported that composting leads to higher C and N-losses compared to stockpiling or a direct application to soil. Hao *et al.* (2004) added that the major concern of manure composting is to control C and N-losses since they reduce the agronomic value of compost and contribute to greenhouse gas emissions. Manipulation of C/N ratios in composting reduces nitrogen volatilization substantially during manure composting (Ekinci *et al*., 2002). Gaussian curve was applied to C-loss at different C/N ratios. C-loss as a function of C/N ratio was correlated and the resultant equation with $R^2$=0.97 (Eq.7) showed that the highest C-loss occurred at the C/N ratio of 30.83. C-loss as a function of C/N ratio is given in Figure 5a.

$$\text{C-loss} = 30.33 + 71.17\, e^{-0.5\left[\frac{\left(\frac{C}{N}\right)-30.83}{1.05}\right]^2} \quad (7)$$

As for N-loss, regression analysis yielded a linear equation with $R^2$=0.68 (Eq.8). The result showed that N-loss decreased with increase in C/N ratio. N-loss as a function of C/N ratio is given in Figure 5b.

$$\text{N-loss} = -0.39\,(C/N) + 33.33 \quad (8)$$

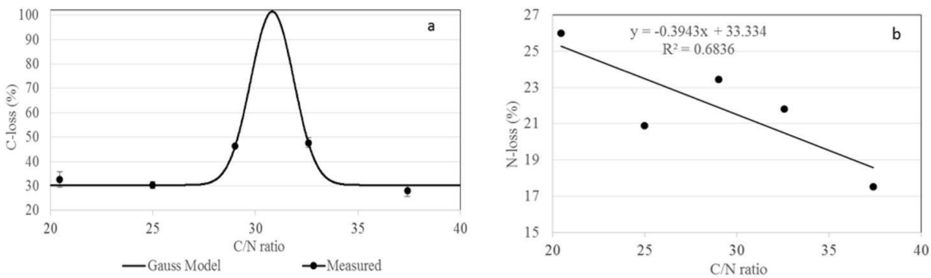


**Figure 5.** The change of C-loss (a) and N-loss (b) as a function of C/N ratio

### *$NH_3$-N loss as a function of C/N ratio*

Initial C/N is an important process factor in terms of ammonia emission and rate of decomposition of material in the initial phase of composting. At low C/N ratios, ammonia emission can occur if the amount of nitrogen in the composting media is more than what the microorganisms needs. On the other hand, C/N >30 may slow down the composting process because of lack of nitrogen. Figures 6 show $NH_3$-N loss as a function of C/N ratio. The regression analysis using exponential decay curve (Eq.9) for $NH_3$-N loss and C/N ratio with $R^2$ of 0.86 showed that increasing C/N ratio from 20.45 to 37.45 would reduce ammonia loss by 88.82%.

$$NH_3 - N = 57768.83\, e^{-0.11\,\left(\frac{C}{N}\right)} \quad (9)$$

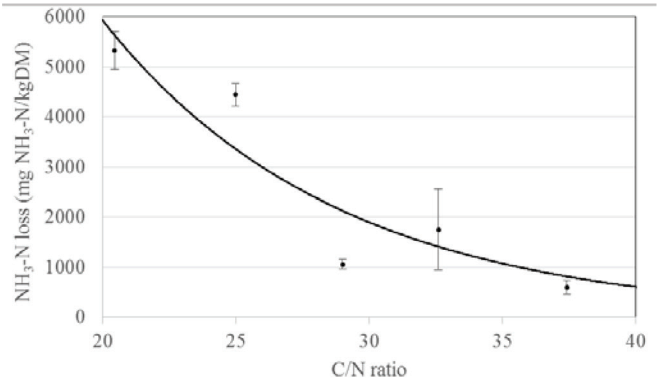


**Figure 6.** Cumulative $NH_3$-N loss as a function of C/N ratio

## CONCLUSIONS

Composting of opium poppy processing solid wastes with poultry manure and rough sawdust was carried out at five different initial C/N ratio of 20.45, 25.00, 29.03, 32.60 and 37.47 to determine the effects initial C/N ratio on composting loss due to degradation (dry matter loss, organic matter loss, carbon loss, nitrogen loss, and ammonia loss). Fifteen-identical cylindrical stainless steel reactors, each of which has an effective volume of 100 L were used for the experiment. Compost temperature was controlled through airflow manipulation based on temperature feedback control at the set point temperature of 60°C. The process was monitored for temperature, moisture, organic matter, electrical conductivity, pH, C/N ratios, and $NH_3$-N. Results showed that the highest DML and OML existed at the CN ratio of 29.70 and 31.18, respectively. To reduce nitrogen loss during composting, a C/N ratio of > 30 is preferred because of the exponential decay curve relation between initial C/N ratio and N-loss. The initial C/N ratio of compost mixtures affected N-loss significantly implying that the lower initial C/N led to higher N-loss. The highest C-loss occurred at the C/N ratio of 30.83. To avoid high C-loss and N-loss composting operation should be optimized.

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