CHEMICAL ENGINEERING TRANSACTIONS

VOL. 72, 2019

A publication of
AIDIC
The Italian Association
of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Jeng Shiun Lim, Azizul Azri Mustaffa, Nur Nabila Abdul Hamid, Jiří Jaromír Klemeš

ISBN 978-88-95608-69-3; **ISSN** 2283-9216

DOI: 10.3303/CET1972037

Enhancement of Pineapple Residue Composting by Food Waste Addition

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The common practice to clear pineapple residues (leaves and stems) in the Mekong Delta, Vietnam for land preparation for cultivations is by burning or even by spraying herbicide that results in environmental pollution. In addition, management of food waste has also become an essential concern in recent years. In this study, co-composting of pineapple residues and food waste was investigated. The co-composting process was conducted in 120 L plastic buckets. Two composting Runs were conducted, either without (A) or with (B) food waste. The composting temperatures were monitored daily using a digital thermometer. The composting mixture was withdrawn, mixed thoroughly, and then re-distributed into the composting bucket every three days. The sample was subjected to measure pH and cell density of mesophilic and thermophilic microorganisms. Temperature of composting pile in the Run B increased sharply to 60 – 65 °C just after the first day. In contrast, that in the Run A increased slowly to 40 – 42 °C for the first 15 d. It implied the food waste addition promoted pineapple residues composting. The compost was subjected to phytotoxicity test and also analysed other important parameters such as organic content, useful microorganisms, and heavy metals.

1. Introduction

Pineapple (*Ananas comosus*) is one of the most widely planted fruit bearing tree in the Mekong Delta, Vietnam with the area of about 40,000 ha. After two fruit harvests, approximately 90 to 150 t of pineapple residues (leaves and stems) are discarded per ha (Liu et al., 2013). There are two common ways to clear the pineapple residues on the field.

The first one is to shred and incorporate directly in the soil. The first way is shredding and incorporating pineapple residues directly in the soil. However, a long period of up to 35 weeks is required for the complete decomposition of pineapple residues (Tam and Magistad, 1936).

The second way is burning the pineapple residues in situ prior to being returned to the soil. But, this process cause haze and pollutes the environment (Heard et al., 2006). It also does not enhance pineapple fruit yield (Ahmed et al., 2002). In the Mekong Delta, Vietnam with the area of about 40,000 ha, farmers even spray herbicides in situ to clear rapidly pineapple residues. This way much negatively affects the soil and water sources of the region. Food waste includes a percentage average of 55 % of total municipal solid waste in developing countries (Troschinetz and Mihelcic, 2009).

In Vietnam, management of food waste has also become an essential concern in recent years since most of food waste is disposed in landfills which result in odours and water contamination (Ngoc and Schnitzer, 2009). Therefore, these wastes need to be treated properly.

Composting is one of the most desirable methods for treating wastes to produce organic fertiliser (Sanadi et al., 2018). The wastes returned to the soil as compost can improve soil condition by providing nutrients and useful microorganisms that will improve plants growth rate, crops quality and yield (Liu, 2013). Composting mainly involve biological degradation reactions, carbon to nitrogen ratio (C/N ratio) plays an essential role (Guo et al., 2012). Pineapple residues usually have high content of cellulose resulting in a high C/N ratio (Ch'ng et al., 2013),

Paper Received: 30 March 2018; Revised: 10 September 2018; Accepted: 23 November 2018

Please cite this article as: Hoang H.A., Luu Q.H., Le P.T., Tran V.T., 2019, Enhancement of pineapple residue composting by food waste addition, Chemical Engineering Transactions, 72, 217-222 DOI:10.3303/CET1972037

while food waste often has a low C/N ratio (Cerda et al., 2018). Therefore, mixture of pineapple residues and food waste may be a suitable raw material for the co-composting. To the best of our knowledge, there is no study on co-composting of these two organic wastes. The objective of this study was to investigate the suitability of co-composting of pineapple residues and food waste.

2. Materials and methods

2.1 Composting materials

Pineapple residues (leaves and stems) were harvested from pineapple farms in Tan Phuoc, Tien Giang province, Vietnam. Their C/N ratio was analysed by the Quality Assurance and Testing Center 3 (QUATEST 3), Vietnam.

Pineapple residues were cut into pieces of 2-3 cm length and then dried under sunlight until the moisture content of approximately 70 % was attained. Food waste was collected from the university canteens. Seeding food-waste-derived compost was purchased from Tay Ninh Environmental JSC, Tay Ninh province, Vietnam. Molasses was purchased from local markets and diluted three time by distilled water. It was then treated by sulfuric acid.

2.2 Composting operation

Composting process was conducted in 120-L plastic buckets. A total of 27 holes on the side and 9 holes at the bottom with 1.0-cm diameters were drilled to allow a good aeration during the process. Two composting Runs were conducted.

In the Run (A), pineapple residues, seeding compost, and molasses were mixed in a ratio of 10:1:0.01 on weight basis. In the Run (B), pineapple residues, food waste, seeding compost, and molasses were mixed in a ratio of 10:1:1:0.01 on weight basis. The initial moisture content of the composting mixture was adjusted to approximately 75 %.

2.3 Physicochemical and microbial cell density analysis

The ambient and composting pile temperatures were monitored daily at 2 p.m. using a digital thermometer (REOTEMP Backyard Compost Thermometer). The composting temperature was measured at the centre and the outermost of the pile.

The composting mixture was withdrawn, mixed thoroughly, and then re-distributed into the composting bucket every 3 d. The sample was subjected to measure pH, moisture content and cell density of microorganisms. A dilution plating method using trypticase soy agar (TSA) medium was used to determine the cell density of the mesophilic and thermophilic microorganisms.

The incubation temperature was set to 30 and 60 °C for the mesophiles and thermophiles. The incubation period for both groups was set to 3 d. The composting ended upon the temperature at the pile centre was nearly equal to the ambient temperature.

Compost sample was tested by the Quality Assurance and Testing Center 3 (QUATEST 3) in terms of organic content, useful microorganisms, pathogenic bacteria (*E. coli* and *Salmonella spp*.) and heavy metal contents (Cd, As, Pb, and Hg). Maturity of the compost was examined by phytotoxicity test.

2.4 Phytotoxicity test

A phytotoxicity test based on germination bioassay was carried out using the method described by Zucconi et al. (1981). Compost sample was shaken in distilled water at a ratio of 1:10 for 1 h. The solution was centrifuged for 10 min at 13,000 rpm, then filtered through No. 2 Whatman filter paper (Merck KGaA, Darmstadt, Germany). 9 mL of extract was filled into the 9-cm sterilized, disposable petri dishes containing 10 Mung bean (*Vigna radiata*) seeds.

One filter paper (No. 2 Whatman) was placed under germination sheet. Distilled water was used as a control. Each petri dish was sealed by Parafilm to avoid water loss while allowing air penetration. The petri dishes were kept in the dark for four days at 25 °C. All experiments were performed in triplicate. The number of seeds germinated was obtained every day and the root lengths were measured after 4 d. The germination index (GI) was calculated as follow:

$$GI = \frac{seed\ germination\ of\ treatment}{seed\ germination\ of\ control} \times \frac{mean\ root\ length\ of\ treatment}{mean\ root\ length\ of\ control} \times 100 \quad (1)$$

3. Results and discussion

3.1 Time course of composting temperature

Time course of composting temperature of both Run A and Run B is shown in Figure 1. During the composting process, the ambient temperature was recorded at 30 - 33 °C. In Run A (without food waste), temperature at the outmost of the pile was 2-3 °C higher than the ambient temperature (data not shown). Temperature at the centre slightly increased to approximately 40 °C during the first day and then was almost constant for the next 12 d. The highest temperature was at approximately 42 °C.

After the day 13, the temperature began to decrease to approximately 35 °C at day 15. Disruption of the temperature increase normally occurs during the initial stage of the composting process at 40 - 45 °C (Nakasaki et al., 2013). It indicated the mesophiles was inhibited whereas the thermophiles had not necessarily established. It also implied the failure of Run A. Therefore, Run A was ended at day 15 and no parameter other than temperature was recorded.

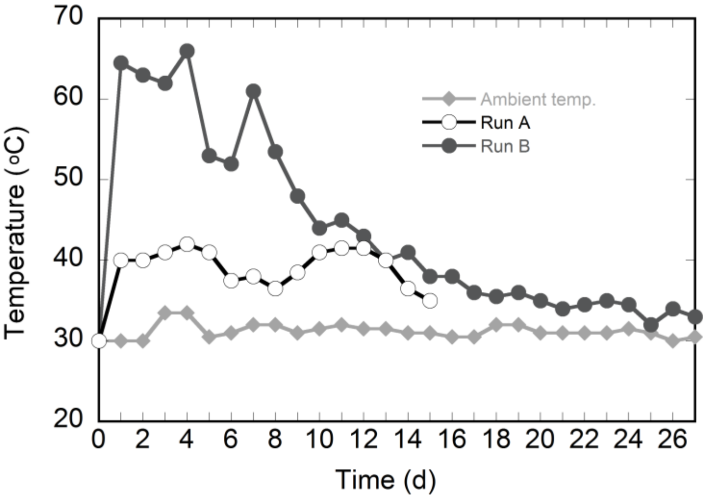

Figure 1: Temperature readings during the composting process of Run A (without food waste) and Run B (with food waste). Ambient temperature was also recorded.

In Run B (with food waste), temperature at the centre sharply increased to approximately 64 °C during the first day and then maintained higher than 60 °C for the next 7 d. On every turning day, the temperature decreased but then re-increased on the next day.

The turning process involved pooling, mixing, and redistributing the materials from composting pile. It brought the composting materials from low temperature zone to higher temperature zone and resulted in rapid degradation of organic matters (Kuok et al., 2012). Temperature at the outmost of the pile was 2-8 °C higher than the ambient temperature (data not shown).

The temperature evolution is used as a direct and convenient parameter to determine the status of composting processes (Tang et al., 2011). Degradation of organic materials by microorganisms resulted in accumulation of metabolic energy and caused the temperature increase (Horvath, 1972).

It can be considered that microbial activity was improved by adding food waste to the raw composting materials. During the first 7 d, the temperature increased sharply and maintained high indicated the success of transition from mesophiles to thermophiles. After day 7, the temperature decreased gradually but still kept higher than 40 °C until day 14. At day 27, the pile temperature was nearly equal to ambient temperature. It indicated the composting could be ended and mature compost was derived.

3.2 Time course of composting pH

The initial pH of composting materials was 6.77 (Figure 2). The value increased to 9.26 on day 3 and 9.31 on day 6. pH increased since the organic acids in the materials were degraded (Kumar et al., 2010). The pH increase was consistent with the temperature increase during the composting. The temperature increase promoted microbial activity and resulted in a high degradation rate of organic materials. After day 6, the pH decreased gradually to neutral with value on the last day was 8.39.\

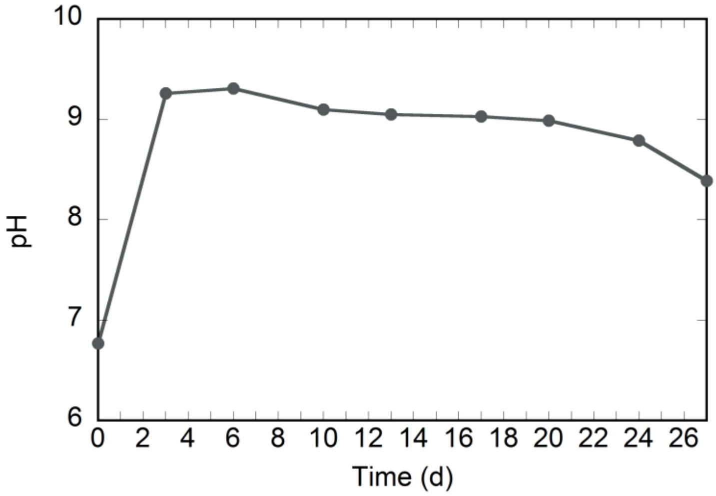

Figure 2: The change of pH during the composting process of Run B.

3.3 Time course of microbial concentrations

During the early stages of composting, the total count of both mesophilic and thermophilic microorganisms increased dramatically but the thermophiles count was higher (Figure 3). The thermophilic microorganism count peaked at approximately 11 log CFU/g on day 6. It was then decreased gradually to 8.86 log CFU/g on the last day. In case of mesophilic microorganisms, their number increased slowly on the first 10 d but increased strongly at later stage and peaked at 11.41 log CFU/g on day 13. It was consistent with temperature pattern (Figure 1) when temperature of the pile decreased to approximately 45 °C at day 10. The final mesophiles count was 9.08 log CFU/g on the last day.

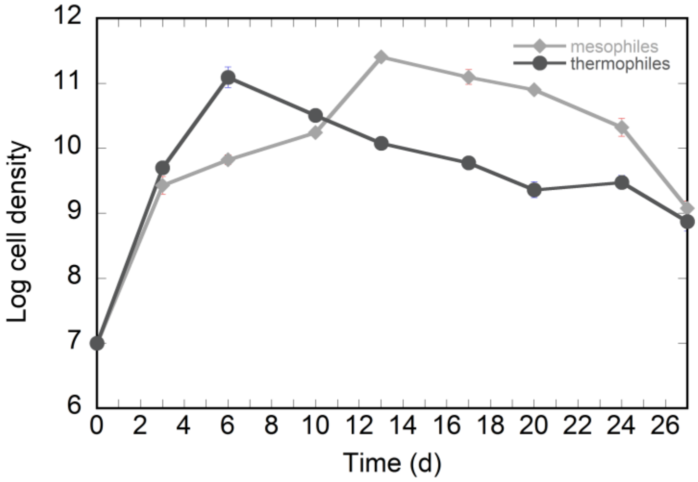

Figure 3: The courses of cell density of mesophilic and thermophilic microorganisms during composting of Run B. Error bars indicating 95% confidence intervals for the averaged values (n = 3) are not graphically detectable as the intervals are too narrow.

The increase of microorganism counts resulted in the increase of temperature since the microorganisms' activity generated heat. When the temperature increased above 45 °C, composting process reached thermophilic phase and thermophilic number increased faster than mesophilic one. After composting temperature dropped below 40 °C, mesophilic number became more competitive than thermophilic one. The mesophilic number increased sharply after 10 d of composting and reached its peak at day 13. After that, the degradable resources were low to sustain the microorganisms' activities so both the thermophilic and mesophilic numbers decreased during the rest of the composting process.

The final compost was subjected to determine useful microorganisms and pathogenic bacteria counts by the QUATEST 3. The useful microorganisms such as the nitrogen fixation, phosphate solubilising and cellulolytic microorganisms were approximately 1.1 x 10^8, 6.4 x 10^6 and 8.0 x 10^6 CFU/g. Temperature increase and turning also enhance destruction of pathogenic bacteria during composting (Kuok et al., 2012). The analysis showed that *E. coli* count was 2.4 x 10^1 MPN/g while *Salmonella spp*. counts per 25 g was negative. It satisfied the Vietnam Standard for Compost (No. 108/2017/NDCP) in terms of useful microorganisms and pathogenic bacteria.

3.4 Maturity and quality of the compost

Seed germination index is a sensitive parameter to detect toxicity affecting root growth and seed germination (Tiquia and Tam, 1998). Germination index for the mung bean was 113.69 % higher than 80 %. It indicated that the final compost was mature (Zucconi et al., 1981). In Vietnam, quality of the compost is evaluated based on the Vietnam Standard for Compost (No. 108/2017/NDCP). The compost in the current study had organic, and humic acid contents of 30.1 % and 4.82 %, which were higher than the required values of 15 % and 3.5 % in the standard. Heavy metal contents of Cd, As, and Pb were lower than the approval limits as shown in the standard. However, the Hg content of 2.6 mg/kg was higher than the approval limit of 2.0 mg/kg. The high Hg content might come from un-classified food wastes. Heavy metals may delay compost maturation (Wu and Ma, 2001).

Composting is one of the most common methods to properly treat organic wastes (Bernal et al., 2009). However, lonely composting of pineapple residues (leaves and stems) is challenging due to two main reasons. First, they are mainly composed of macromolecules such as cellulose, hemicellulose, and lignin that are hard to be degraded (Upadhyay et al., 2010). Second, they are poor in themselves-microorganisms that prolong the composting or even result in the failure. Therefore, co-composting the pineapple residues with other wastes is essential for the success (Ch'ng et al., 2013). The current study is the first preliminary successful report about co-composting of pineapple residues and food waste. This approach enables handling an abundant agricultural waste in the Mekong Delta Vietnam and also food waste via an environmental friendly manner. The study confirmed the failure of composting pineapple residues without food waste when the highest composting pile temperature of 42 °C did not reach thermophilic phase.

In the Run with food waste, temperature, pH, and microorganisms of the composting pile increased strongly at the first days. It indicated the addition of food waste enhanced degradation of the pineapple residues during the composting. Composting mainly involve biological degradation reactions, C/N ratio plays an essential role (Guo et al., 2012). The pineapple residues used in the composting had an initial C/N ratio of 37.4. The high C/N ratio is similar as reported by Ch'ng et al. (2013). Whereas food waste often has low C/N ratios (Adhikari et al., 2008). Therefore, addition of food waste to pineapple residues will result in a more suitable C/N ratio contributing to the success of composting. In the future studies, possibility of co-composting of pineapple residues and food waste will be investigated at larger scales.

4. Conclusions

Management of pineapple residues and food waste has become an essential concern in recent years in Vietnam. In this study, the suitability of co-composting of pineapple residues and food waste was investigated. Temperature of the composting pile with food waste significantly increased to 60 – 65 °C while that without food waste failed to reach a sufficiently high temperature of a successful composting. It was indicated that pineapple residue composting was promoted by addition of food waste. The final compost was obtained after 27-day composting. By analysing phytotoxicity, organic content, useful microorganisms, and heavy metals, the final compost was demonstrated to be mature and almost satisfied the Vietnam Standard for Compost. To the best of our knowledge, there is the first study on co-composting of these two organic wastes. It is then expected to contribute to reduce environmental pollution and enhance a sustainable farming of pineapple in the Mekong Delta, Vietnam.

Acknowledgments

This research was funded by Vietnam Government through the project “Improvement of quantity, quality, product diversification and biomass utilisation from Cayenne pineapple Ananas comosus farming in the Mekong Delta, Vietnam, KHCN-TNB.DT, 2018 – 2020.

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