Composting process of Dipterocarpus alatus and kitchen waste (vegetables and fruits) at isolated military units

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Received 20 Sep. 2025; Revised 5 Nov. 2025; Accepted 6 Nov. 2025; Published 25 Dec. 2025.

DOI: https://doi.org/10.54939/1859-1043.j.mst.108.2025.91-97

ABSTRACT

Dipterocarpus alatus *is widely planted in military units due to its strong adaptability to various soil types, high drought tolerance, and deep root system, which enhances stability and minimizes wind damage, thereby ensuring the safety of military infrastructures. At present, the fallen leaves of this species are mostly collected and burned, causing environmental pollution because they contain 50 - 70% essential oils and 30 - 40% resin, which release toxic compounds during combustion. This study aimed to develop and evaluate a composting process utilizing Dipterocarpus leaves combined with kitchen waste. The composting mixture consisted of 60% dried D. alatus leaves, 15% rice husk, and 25% kitchen waste (vegetables, tubers, and fruits) by weight. The application of the Bima bio-agent effectively accelerated the decomposition process. The resulting compost product met the Vietnamese industry standard 10TCN 526:2002 for microbial organic fertilizer derived from household waste, with the following characteristics: 97.1% of particles passing through a 5 mm sieve, moisture content of 32.26%, pH of 7.58, total organic matter content of 34.16%, total nitrogen content of 2.61%, and absence of Salmonella spp.*

Keywords: Dipterocarpus alatus; Kitchen waste (vegetables and fruits); Compost; Organic humus; Enzyme (Bima).

1. INTRODUCTION

Isolated military units currently face significant challenges in managing their municipal solid waste (MSW). The majority of these units lack standard waste treatment systems, leading to prevalent unsanitary disposal methods such as burying waste in open fields or nearby forests. This practice poses severe risks of soil, water, and air pollution. Organic waste, in particular, has high pollution potential; its decomposition releases toxic gases and foul odors. Direct discharge into water sources can deplete dissolved oxygen, leading to eutrophication and degradation of aquatic ecosystems. Furthermore, leachate from unsanitary landfills contains high concentrations of pollutants, threatening groundwater, soil, and surrounding water bodies, while also posing risks of harmful microbial contamination. Improper waste management not only causes environmental pollution but also negatively impacts the health of military personnel. Independent military units are often located far from residential areas (typically 10 - 20 km from the nearest civilian settlement), making it impossible to utilize public waste collection services due to their military zoning. The solid waste generated at these units primarily consists of garden waste (leaves, dry branches), food scraps, pre-processed vegetable waste, paper, plastic bottles, and plastic bags. Different types of solid waste are typically collected, sorted, and often disposed of through burning and unsanitary landfilling (including leaves, paper, and plastic bags). Recyclable plastic waste is collected through youth initiatives, while food scraps are gathered in large buckets after each meal and then cooked for animal feed at the end of the day. Composting municipal solid waste is considered the best solution for waste management, offering not only economic benefits but also contributing to environmental protection.

Several studies on composting from household waste in the period 2023 - 2025 focus on (i) home/community composting, (ii) improvement with additives (biochar, inoculated-biochar), (iii) optimization of bulking agents and (iv) vermicomposting as an alternative/pairing option. Results from studies indicate that the optimal process thermophilic temperature is around 45 - 65°C, Stable incubation time: 30 - 90 days (household & community), ~ 45 - 90 days wind; adding probiotics shortens incubation time. The advantages of recent studies are high applicability, the quality of products after composting is improved. The biggest disadvantage is poor waste classification → impurities are still high, lack of long-term socio-economic analysis.

This study focuses on developing and evaluating a composting protocol to effectively utilize the abundant supply of Dipterocarpaceae leaves and domestic kitchen waste. The primary objective is to minimize the organic waste generated at these autonomous military units and to produce a quality organic fertilizer for use in agricultural production or soil remediation efforts. The research methodology involved testing various composting parameters to determine the optimal mixing ratio between carbon-rich material (Dipterocarpaceae leaves) and nitrogen-rich material (kitchen waste) to ensure a suitable Carbon-to-Nitrogen (C/N) ratio for efficient decomposition.

2. RESEARCH METHODOLOGY

2.1. Research materials

- Dipterocarpus alatus were collected and transported from the military barracks.
- Organic waste was collected from the kitchen waste generated by military messes/kitchens.
- Trichoderma biofertilizer from Biotechnology Center, Ho Chi Minh City.
- Rice husk for composting.

2.2. Experimental equipment

- Crusher YE2: High efficiency three-phase asynchronous motor; Speed: 1.400 rpm; Voltage: 380 V, frequency: 50 Hz.
- Cutting machine: 12 mm pillow block bearing, aluminum material; 304 stainless steel shaft L = 50 cm, Ø = 12 mm.
- Humidity meter: Model: TK-100W; Measuring range: 0 - 84%; Dimensions: 460 x 75 x 5 (mm).
- Compost bin: HDPE, V= 5l; the barrel is perforated around the sides and bottom to allow air to flow through the small holes.

2.3. Experimental setup

2.3.1. Prepare the materials for composting

- Dipterocarpus Alatus: Grind Dipterocarpus alatus leaves with YE2 grinder, the size after grinding is 4 - 8 mm, humidity 7,8%.
- Organic kitchen waste (vegetables, tubers, fruits): Cut kitchen waste (vegetables, tubers, fruits,etc.) into small pieces with a cutter, size after cutting 8 - 10 mm, humidity 78,3%.
- Filler (rice husk): humidity 8,2%.
- Probiotic solution: Dissolve 20 g of Bima probiotic (Trichoderma strains: ≥ 5×106 spores/gram, Organic: 50%, Humidity < 30%) in 1 liter of water to create a probiotic solution.

2.3.2. Experimental setup

a) The experimental composting models were cylindrical, hollow plastic containers with dimensions of diameter × height = 201 mm× 240 mm (Volume = 5 liters).

These containers were perforated with circular holes of 5 mm around the sides and on the bottom, and were situated indoors in a dry location. The bottom of each container was designed with a grid layer and a drainage system for collecting and recirculating (moisture irrigation) the leachate.

The composting raw materials were gently loaded into the containers to preserve their initial porosity and texture at the start of the incubation period. For each batch, the raw materials were prepared with a total mass of 5 kg per treatment.

b) Survey of the mixing ratio between Dipterocarpus Alatus and Organic kitchen waste

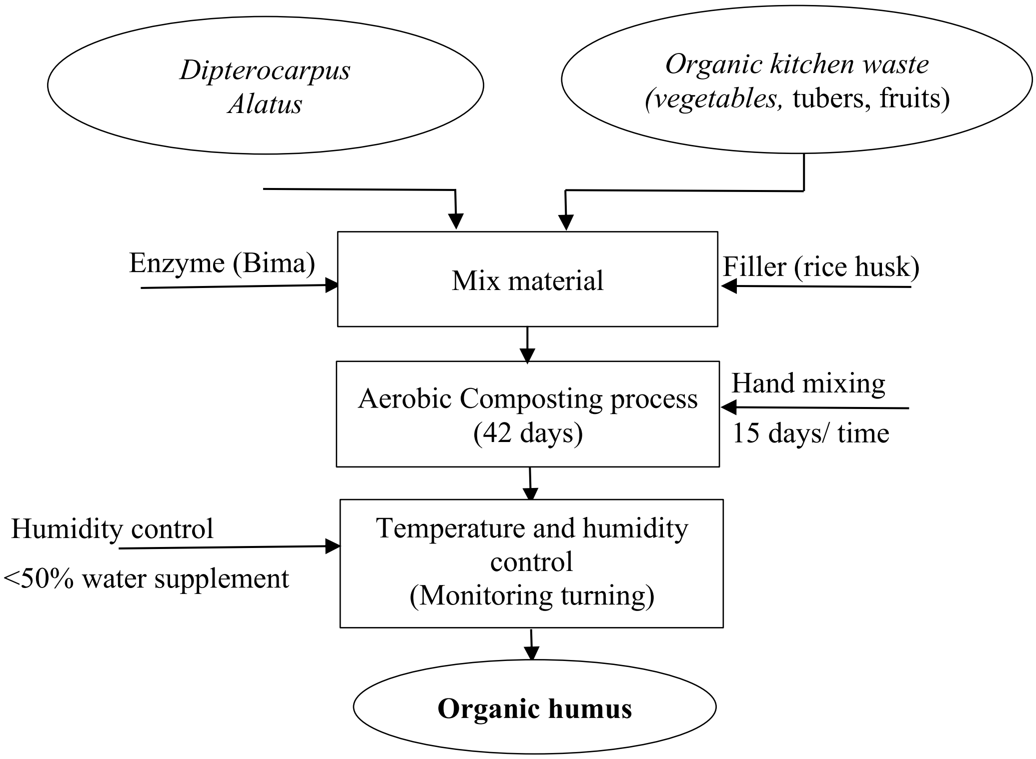
Mixing municipal solid waste with garden waste, predominantly from Dipterocarpus Alatus (DL). Five experimental treatments (TT) were applied in this study.

Table 1. *The mixing ratio of raw materials.*

Mixing ratio (% mass)	TT1	TT2	TT3	TT4	TT5
Organic kitchen waste	0	25	50	75	100
Dipterocarpus Alatus	100	75	50	25	0

c) Monitoring and turning process of composting parameters: the method for monitoring composting parameters involves using an IoT technology with a soil moisture probe sensor and a DS18B20 temperature sensor to measure the compost sample parameters. An ESP32 microcontroller is then used to read the sensor data and directly upload the results to a server for storage.

Composting protocol



The composting process has 4 steps:

- Step 1: Pre-processing ingredients for the compost batch.
- Step 2: Weigh ingredients according to the mixing ratio. Put the weighed ingredients into the container. Mix the ingredients well, then pour the yeast solution evenly into the mixture and continue mixing.
- Step 3: Put the mixed ingredients into the compost bin (5 liter, HDPE, perforated).
- Step 4: Composting: After the first 7 - 10 days, stir the mixture to increase oxygen and promote decomposition. Temperature and humidity are automatically monitored by IOT devices throughout the composting period (mixture humidity is maintained at 50-65%, if humidity < 50%, add more water during the mixing process).

d) Monitoring and sample analysis procedures

Temperature and moisture content were measured and recorded daily via an IoT (Internet of Things) system. The system transmitted the sensor data to a cloud platform for storage and real-time monitoring visualization.

Table 2. *Methods for analyzing physical, chemical, and biological parameters/indicators.*

Order	Parameters	Methods for analyzing
I	**Material**	
1	Moisture material	Determination of moisture content by the drying method
II	**Monitor the incubation process**	
1	Temperature	Thermometer
2	Moisture	Hygrometer TK-100W
3	pH	pH meter
4	Mass reduction	Measure the mass before and after the composting process
III	**Organic humus**	
1	Particle size through sieve 5 mm	TK TCVN 251:2018
2	Moisture	TCVN 9297:2012
3	pH	TCVN 13263-9:2020
4	Total organic matter content	TCVN 9294:2012
5	Total Nitrogen Content	TCVN 8557:2010
6	Salmonella ssp bacteria	Ref. TCVN 10780-1:2017

3. RESULTS AND DISCUSSION

3.1. Investigation of factors affecting the composting process

3.1.1. Temperature and moisture

Temperature evolution is a critical factor in the aerobic composting process, reflecting the microbial activity. This process typically proceeds through three main phases, determined by the changes in temperature and the predominant microbial community [4, 5].

Reaction mechanism of the composting process:

Organic matter + O_2 + Microorganisms → CO_2 + H_2O + Heat + Organic humus + Mineral nutrients (N, P, K, etc.)

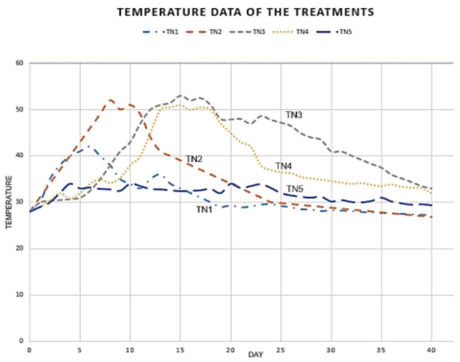


Figure 1. *Temperature variation during composting process.*

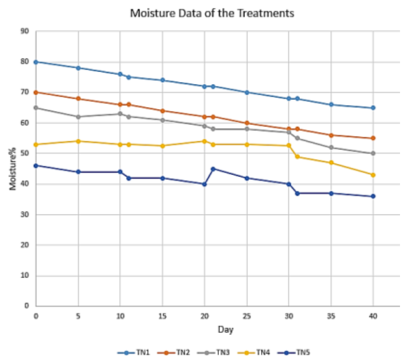


Figure 2. *Moisture variation during composting.*

Temperature is one of the most important factors in the composting process, as it reflects microbial activity, the rate of organic matter decomposition, and the safety and stability of the final product.

Temperature increased during the first 20 days after incubation. TN1 and TN5, negligible temperature variation. TN2, TN3, TN4: The highest temperature reached is about 50 °C. High temperature promotes the activity of decomposing enzymes secreted by thermophilic microorganisms, which helps accelerate the decomposition of complex organic substances (such as Lignin and Cellulose), shortening the incubation time. TN3, The temperature remained around 50 °C for 3 consecutive days.

In this experiment, the moisture content changed significantly with the mixing ratios between dried euphorbia hirta leaves and kitchen waste. The more kitchen waste, the higher the moisture content. In TN5, the moisture content gradually decreased from 80% to about 65%. In contrast, in TN 1, the moisture content was low, about 35 - 48%. The moisture content gradually decreased during the composting process. The ideal moisture content for the compost pile is from 40% to 65%, with the optimum level usually falling between 50% and 60%.

3.1.2. pH

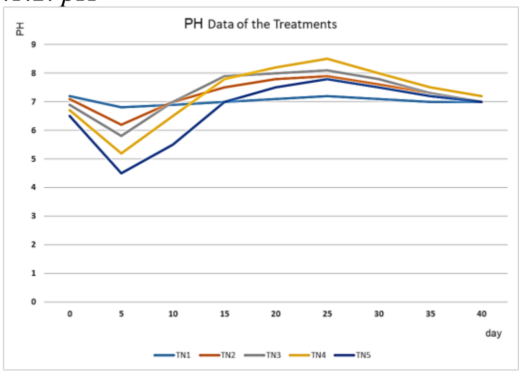


Figure 3. *Temperature variation during composting process.*

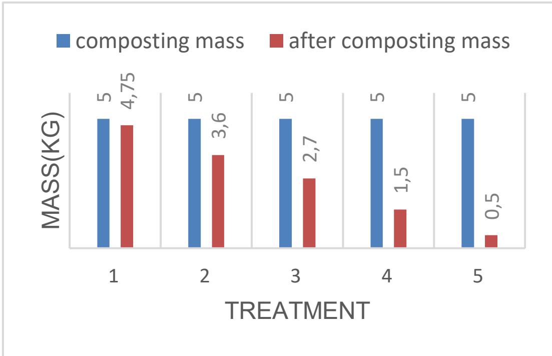


Figure 4. *Mass loss during composting.*

In the early stages, when microorganisms (mainly bacteria) begin to decompose the rapidly soluble organic acids present in fruits and vegetables (such as citric acid, lactic acid), the pH tends to decrease and can reach levels lower than 6.0. During the growth phase, pH increases and stabilizes: When the temperature increases (up to 55 - 65 °C), thermophilic microorganisms become more active, and continue to decompose, releasing more alkaline compounds. pH will gradually increase and usually stabilize between 7.0 and 8.0. This is an important stage for eliminating pathogens. This is also consistent with the appropriate pH range for organic matter decomposition, ranging from 5.5 to 9.0.

3.1.3. Mass reduction

The compost volume decreases sharply when the kitchen waste ratio is high. Because kitchen waste (vegetables, tubers, fruits) has high humidity, the longer the compost time, the more water is lost. The higher the proportion of euphorbia hirta leaves, the smaller the mass loss. Specifically, in TN1, the mass loss is 5%, and in TN5, the mass loss is 95%.

Through monitoring the factors affecting the composting process with different mixing ratios between dry otter leaves and household waste, it shows that the ratio in TN 2 (25% kitchen waste, 75% Dipterocarpus Alatus) achieved suitable temperature, humidity, and pH for the composting process.

To improve the quality of organic humus, increase porosity and reduce odor; add rice husk as filler. The filler is a carbon-rich material, similar to the composition of the Dipterocarpus Alatus. However, the hollow structure of the rice husk is added to the compost to improve the physical, chemical and biological properties of the compost material.

Composting experiment with mixing ratio according to the volume of raw materials is: 25% kitchen waste (vegetables, tubers, fruits), 60% Dipterocarpus Alatus and 15% filler (rice husk).

The results of temperature and humidity measurements are as follows:

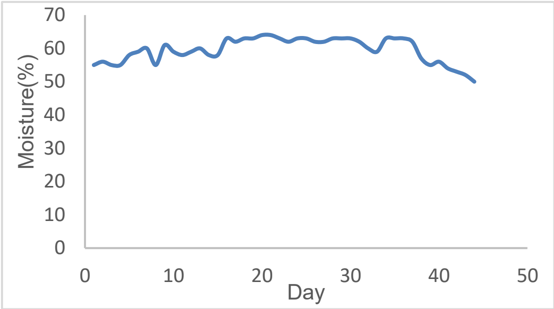


Figure 5. *Moisture monitoring with composting with added bulk.*

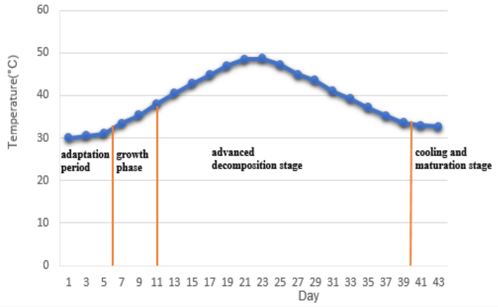


Figure 6. *Temperature monitoring with composting with added bulk.*

The filler helps the composting process maintain optimal humidity of 50 - 65%, temperature: 30 - 45 °C in the first 20 days, strong decomposition stage at 48,7 °C on the 24th day of composting.

3.2. Results of organic humus quality analysis

After 42 days of incubation with a mixing ratio according to the volume of raw materials is: 25% kitchen waste (vegetables, tubers, fruits), 60% Dipterocarpus Alatus and 15% filler (rice husk), the resulting product is organic humus (decomposed) that is dark brown, porous, and odorless. The organic humus is analyzed for parameters according to the standard 10TCN 526:2002 on microbial organic fertilizer from household waste. The results are presented in table 3.

The analysis results show that all organic humus parameters meet the standards. This product can be used as a direct base fertilizer for the soil, improving soil structure, increasing water and nutrient retention or mixed with other ingredients to increase efficiency. Organic humus from the composting process of Dipterocarpus Alatus and kitchen waste (vegetables, tubers, fruits) has average nutritional content, rich in micronutrients; suitable for growing: Vegetables, flowers, urban plants. Economic efficiency of composting: Reduce organic waste treatment costs, reduce landfill volume; Reduce the need to buy chemical fertilizers; Increase crop productivity; Compost can be sold as a product.

Table 3. *Results of organic humus quality analysis.*

Order	Parameters	Measurement value limit	Measurement results
1	Particle size through sieve 5 mm	Particle diameter (not larger than): 4 - 5 mm	97,10%
2	Moisture	Humidity (not greater than): 35%	32,26%
3	pH	pH: 6,0 - 8,0	7,58
4	Total organic matter content	Total carbon content not less than: 13%	34,16%
5	Total nitrogen content	Total nitrogen content not less than: 2.5%	2,61%
6	Salmonella ssp bacteria	Salmonella density in 25 grams of sample: 0	Not detected

4. CONCLUSIONS

The composting process from Dipterocarpus Alatus and kitchen waste can be used to create organic humus. The optimal mixing ratio according to the volume of raw materials is: 60% Dipterocarpus Alatus, 15% filler (rice husk) and 25% kitchen waste (vegetables, tubers, fruits).

The proposed process helps to effectively treat waste and reduce environmental pollutants. The resulting product is dark brown, loose, odorless, and nutritious compost, which helps improve soil and enhance plant health. The investment cost for the composting process is low, easy to implement and highly applicable. Replicating the composting model is a practical solution to reduce waste, improve soil and promote sustainable agriculture.

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TÓM TẮT

Quy trình ủ compost giữa lá dầu rái khô và rác thải nhà bếp (rau, củ, quả) tại các đơn vị đóng quân độc lập

Cây dầu rái (Dipterocarpus alatus) được trồng phổ biến trong các đơn vị quân đội nhờ sinh trưởng tốt trên nhiều loại đất, chịu hạn và có rễ ăn sâu giúp cây đứng vững, hạn chế gãy đổ trong gió bão, đảm bảo an toàn công trình. Hiện nay, lá khô của cây chủ yếu được thu gom, đốt bỏ, gây ô nhiễm do chứa 50 - 70% tinh dầu và 30 - 40% nhựa dầu, phát thải nhiều chất độc hại. Nghiên cứu này xây dựng, đánh giá quy trình ủ compost nhằm tận dụng nguồn lá cây họ Dầu kết hợp rác thải nhà bếp. Với tỷ lệ 60% lá dầu rái khô, 15% bã trấu và 25% rác nhà bếp (rau, củ, quả) theo khối lượng, sản phẩm thu được là mùn hữu cơ đạt chuẩn. Chế phẩm sinh học Bima được dùng để thúc đẩy phân hủy. Kết quả cho thấy mùn hữu cơ đạt tiêu chuẩn 10TCN 526:2002 về phân hữu cơ vi sinh từ rác sinh hoạt, với các chỉ tiêu: hạt qua rây 5mm đạt 97,1%; độ ẩm 32,26%; pH 7,58; chất hữu cơ 34,16%; nitơ tổng 2,61%; không phát hiện Salmonella spp.

Từ khoá: Lá khô cây dầu rái; Rác thải nhà bếp (rau củ quả); Ủ compost; Mùn hữu cơ; Enzym Bima.