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# VEGETABLE WASTE COMPOSTING: A CASE STUDY IN KUNDASANG, SABAH

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**ABSTRACT**. *Composting is considered agronomically, ecologically, and practically beneficial, with the end product being an organic fertilizer or soil conditioner rich in nutrients for the soil. This study aims to investigate the effects of adding chicken manure (CM) to vegetable waste (VW) and rice husk (RH) composting. This is a pioneering study on Kundasang composting, as well as addressing the vegetable waste problem in the community. The composting process was studied for 20 days in a 37-L laboratory composter reactor box with passive aeration. Four mixtures were investigated, each with a VW: RH (1:2) ratio and a different additive of CM (0%, 1%, 2.5% and 5%). The composting process's performance shows that Mix-3 (2.5 % CM) is ideal compared to other mixtures, with the highest temperature achieved at 41ºC as early as day 1, resulting in a 28.12% organic matter (OM) loss. The OM loss value results show that Mix-3 (28.12%) > Mix-2 (26.14%) > Mix-1 (16.55%) >Mix-4 (13.33%). The maximum temperature reached was 41ºC, and the Mix-3(41.3ºC)>Mix-1(41.1ºC)>Mix-2(41.0ºC)>Mix-4(40.7ºC) and decreasing near to ambient. The reduction percentage shows Mix-3 (13.92%) > Mix-2 (13.45%) > Mix-4 (9.24%) > Mix-1 (8.93%). Thus, with the optimum addition of chicken manure, the degradation is reflected in the high moisture content reduction rate. In conclusion, using CM as an additive has a significant impact on composting VW.*

## INTRODUCTION

The vegetables are perishable but inexpensive commodities [1]. In Kundasang, the total agricultural area is 18,085.2 hectares, serving 235 seller stalls selling only vegetables and fruits [2], boosting economic activities and tourism. However, it also produced almost 13 tonnes of organic waste with a waste generation rate of 6.35kg/day [2]. Plazzotta et al. [3] defined vegetable waste (VW) as the inedible parts of vegetables, including the peels, rotten, scraped and, shells of vegetables, and usually, more than 30% are discarded during collection, handling, transportation, and processing [4]. Lui et al. [5] stated that the inevitably high level of organic content (>95% dry basis), water content (>80%), and biodegradability of VW resulted in hazards such as the abundant formation of leachate from landfills and erratic combustion during incineration [6].

The primary production of vegetables in Asia is 879 million, and Malaysia contributed 1.29 million tonnes in 2019 [7]. A projection of 9.05 billion tonnes per year estimated global agricultural waste (VW primarily) production, at least one-third are disposed of environmentally unsafe [8]. Accelerated population growth and environmental issues [9] with inclining global demands for food, energy, and chemicals have driven research on developing renewable raw materials through technologies with minor environmental impacts [10]. Thus, composting is a simple and efficient method for treating and stabilizing organic wastes [11] such as vegetable and food waste, animal manures, and biosolids [12].

Composting could effectively convert livestock manure into fertilizer [13,14] or amendments used to promote plant growth and improve soil fertility [15], [16]. The addition of bulking materials and organic matter sources such as organic residues like rice husk (RH), sawdust, wood shavings, [17] and dried leaves is added to promote porosity, structural support, air movement in the mixture, and control moisture [18]. Most previous studies, such as Hwang et al. [19], Abubakari et al. [20], and Rawoteea et al. [21], have focused on composting vegetable waste and adding single additives or bulking agents to improve the composting effect [22]. Although this approach has its beneficial effects, some problems always exist, such as secondary pollution and high cost [23,24]. Successful optimization of these parameters may shorten the process and result in products of high quality [25]. Thus, this study highlights the efficiency of co-composting on the different dosages of additives.

Vegetable waste composting with rice husk and chicken manure has been studied elsewhere [23-27], but none of it was in Malaysia. There has been little research on co-composting with vegetable waste on a pilot scale in Malaysia. Malakahmad et. al. [23] study aims to evaluate the applicability of converting vegetable waste and yard waste generated in the Cameron Highlands, Malaysia into high-quality and fast compost via an in-vessel method. Malakahmad et. al. [23] study uses vegetable waste as feedstock but not rice husk and chicken manure as the bulking agent. Thus, this study composts vegetable waste (VW) composting with rice husk (RH) and a variant dosage of chicken manure (CM). This study could be the pioneer study on composting, specifically in Kundasang, as it was one of the most significant vegetable waste production areas in East Malaysia. The Fresh Market in Kundasang town, Sabah, is a significant contributor to the increase in organic waste generated in the Ranau district. As such, it has the potential to implement effective composting practices. This study could also initiate composting behavior and awareness about proper and practical waste management in this community.

The co-composting method is said to have the advantages of higher efficiency and better composting products due to rich compositions [24]. As Tratsch et. al., [30] study in Brazil for 95 days shows that VW, RH and CM with a ratio of 1:1:1 (T1-2:1:0, T2-1:1:1, T3-1.5:1:0, T4-1.2:1:0) improved C/N ratio, TOC, pH and moisture content (MC) %. Although the highest temperature of 70ºC, pH of 8.55, EC of 11.66 mS/cm, MC of 45.34, and organic matter (OM) loss rate of 34.59% were achieved, they do not illuminate the effects of different percentages of CM on VW and RH, despite the fact that the goal is to produce compost from various ratios. Similar data presented by Bhatia et al. [26] included the highest temperature of 56.2ºC, OM loss of 62.8%, pH value of 7.8, EC value of 3.31, and MC at 40%, but they were only comparing non-reactor (windrow) and reactor (rotary drum) composting in India for 30 days.

Research by Ajmal et al. [28] in China uses reactor studies on variant temperatures with various time incubations using VW, RH, and CM. The ratio used is fixed at 1.57:1:0.29, and the results presented lack organic matter loss and electrical conductivity. Research by Dayananda et al.

[24] in India uses a variant of % of vegetable waste as feedstock in rector composting for 21 days; however, the data also lacks OM loss % and EC. Another study by Bian et al. [29] in China took 18-hour composting using a ratio of 6:3:1 (CM:VW:RH) by a reactor. The research's objective is to evaluate the effects of thermal phases and transformation time on performance and lacing on electrical conductivity data. EC values are essential as they project the nutrients available in the compost by its soluble salt level. Thus, this study is going to provide data on organic matter loss and electrical conductivity to evaluate the parameters of maturity on compost quality produced besides optimum temperature, moisture content, and pH value.

Therefore, in this study, the goals are to: 1) study the effect of chicken manure dosage on rice husk addition in composting vegetable waste; and 2) evaluate parameters of temperature, moisture content, pH value, electrical conductivity and organic matter loss with the enhanced passive aerated reactor.

## MATERIALS AND METHOD

The composting raw materials consist of vegetable waste, rice husks, and chicken manure collected at Kundasang, Sabah. The vegetable waste was collected from vegetable sellers at Kundasang Vegetable Fresh Market, while the rice husks were collected near Kundasang Vegetable Farm and locally produced. The chicken manure was obtained from the nearest chicken farm to Kundasang town. All raw materials are obtained in Kundasang town to reduce transportation costs and create an efficient environment for the composting process.

### *Reactor design*

The composting process took about 20 days cycle inside a 37-liter rectangular form container (length×width×height×thickness = 36×36×34×0.5cm). Each container's backside has three layers of five holes inline (3×1.5cm) with perforated pipe instilled in the middle of the box, so oxygen was available via natural ventilation. All reactors are then covered with a plastic cover with a hole in the middle to place the perforated pipe as venting holes to provide aerobic conditions and keep moisture content constant. Besides, a five-hole at the bottom was dug below the reactor to remove the leachate.

### *Methodology*

Table 1 shows the initial physio-chemical parameters for all raw materials used. Table 2 shows four different mixtures of raw composting materials consisting of a 2:1 ratio of vegetable waste (VW) and rice husk (RH) with various % of chicken manure (CM) were studied.

**Table 1:** Initial physico-chemical parameters of raw materials.

| Parameters (unit) | Vegetable waste, VW | Rice husk, RH | Chicken manure, CM |
|---|---|---|---|
| pH | 4.5-4.8 | 7.1–7.3 | 6.2 |
| MC (%) | 58–89 | 8–11 | 71.8 |
| EC (mS/cm) | 1.9 | 0.6 | 3.4 |
| Particle size (cm) | 1-2 | 1-3 | NA |

*Abbreviations: MC: Moisture content, EC: Electrical conductivity, C/N: Carbon-nitrogen ratio, OM loss: Organic matter loss, NA: Not Available.

**Table 2:** Combinations of vegetable waste (VW) and rice husk (RH) with various in % of chicken manure (CM) in samples

| | Vegetable waste, VW | Rice husk, RH | Chicken manure, CM |
|---|---|---|---|
| **(Mix-1)** | 8.00 | 4.00 | 0.00 (0% CM) |
| **(Mix-2)** | 8.00 | 4.00 | 0.12 (1% CM) |
| **(Mix-3)** | 8.00 | 4.00 | 0.30 (2.5% CM) |
| **(Mix-4)** | 8.00 | 4.00 | 0.60 (5% CM) |

*Unit weight : kilogram (kg)

### *Physcio-chemical analysis*

Each reactor produced a compost sample and was collected on days 0, 10, and 20. Samples collected at three points, namely the upper, middle, and lower points of the mass of about 250g, are then blended homogeneously to form an integrated sample [30]. The temperature profile is measured daily while changes in pH, electrical conductivity (EC), and moisture content (MC) are analysed on the $0^{th}$, $10^{th,}$ and $20^{th}$ day of the analysis period. Compost was collected and tested for pH, EC, MC, and organic material (OM) loss, with each test replicated three times.

The determination of pH and EC used distilled water to add to the sample of 10g of compost per 100ml of water and then shaken for 2h to obtain 10ml of extract. For each pH and EC value determination, the pH and EC indicator meters were immersed in the extract [31], [32]. MC was determined by drying the samples to a constant weight at 105ºC for 24 hours in an oven. OM loss can be calculated from ash contents after a 4h dry combustion at 550ºC [33]. The OM loss % difference between the mixtures is defined using the Student T-Test [36] to indicate no significant difference with $P > 0.05$.

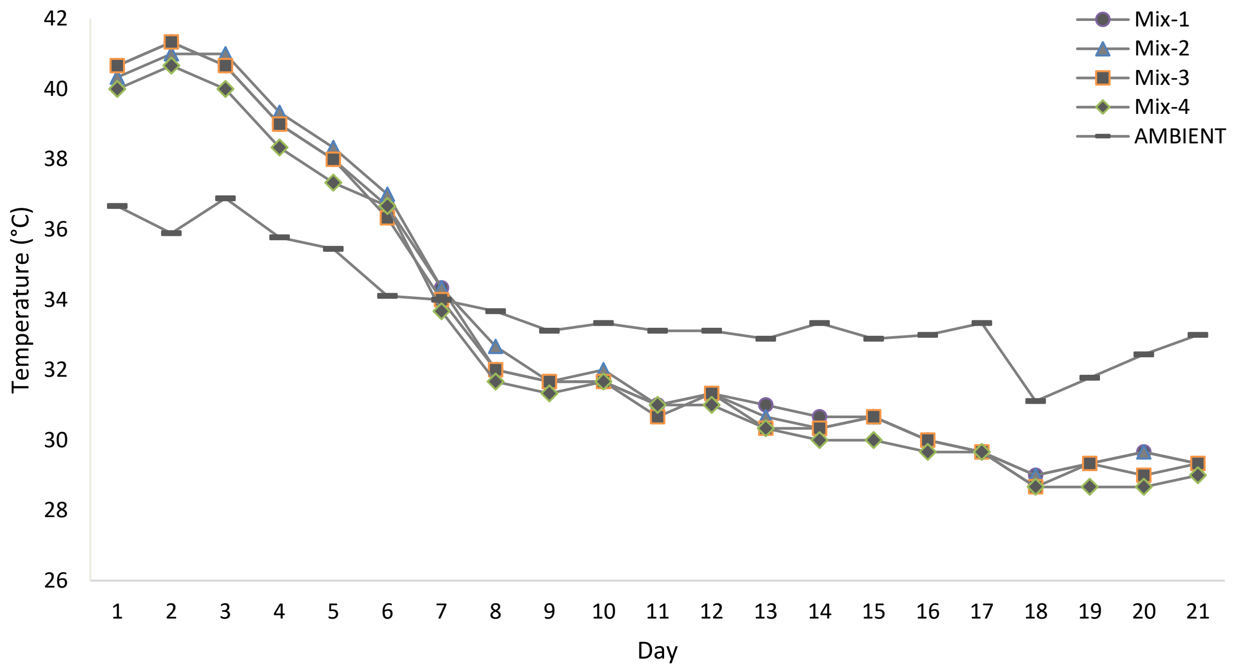
## RESULTS AND DISCUSSION

### *Evolution of temperature*

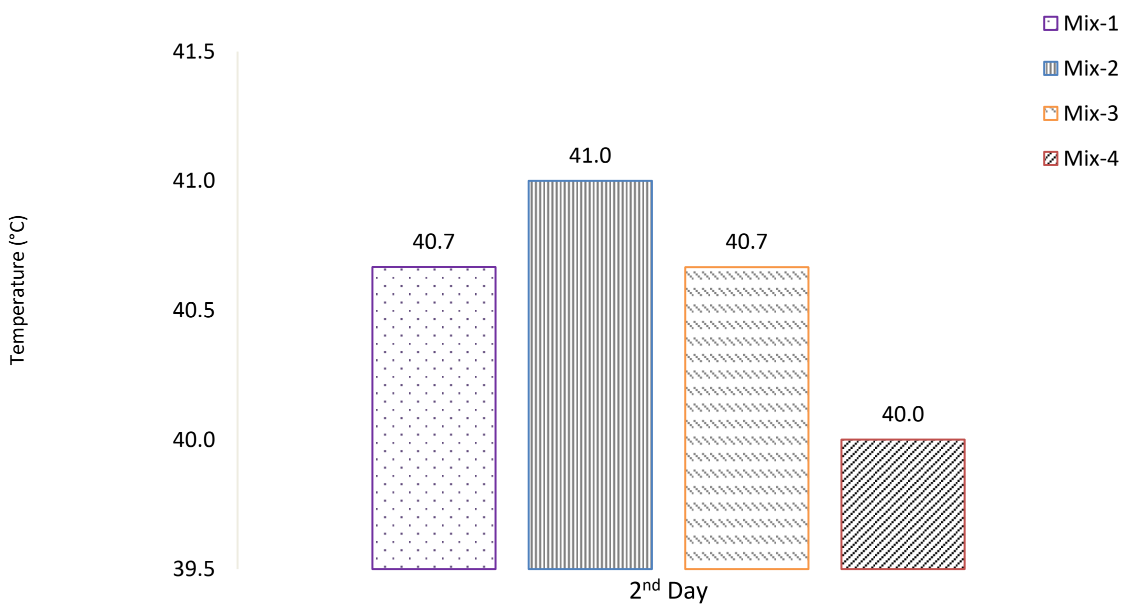
The composting temperature profile is presented in Figure 1 to investigate the effect of chicken manure addition. The temperatures increased quickly in all mixtures and reached their maximum on day 2, except for Mix-2 (on day 3). The temperature began to increase from day 1 and reached a maximum of41ºC during composting. The first 1-3 days are the initial activation where simple organic compounds such as sugars are mineralized by microbial communities, producing $CO_2$, $NH_3$, organic acids, and heat [34].

After the initial activation phase, comes the thermophilic phase [35] where the temperature can reach greater than 40 ºC [39,40]. Amid the thermophilic phase, microorganisms degrade cellulose, lignin, and fats [34]. Rice husk functions as an amendment that enhances composting [37] by enhancing water-holding capacity, controlling the moisture content of the composting mass [29] and increasing the ventilation [38] or aeration due to its high capillarity [39]. This results in the temperature increment through this composting period.

Finally, through the mesophilic phase of maturation, the temperature is slowly declining due to microbial activity slowing down and stabilizing, resulting from the decline of biodegradable compounds [44,45]. The differences between Mix-2 and Mix-3 were calculated using the Student's t-test. The t-test that was conducted indicates that there is a significant difference ($p = 0.044$, $p < 0.05$) between Mix-3 and Mix-2. The t-test indicates that Mix-3 and Mix-2 have the highest temperatures on day 1 of the composting process and should be taken into account.




(a)




(b)

Figure 1. Temperature profile during (a) the whole process of composting, (b) the peak of composting

***Moisture content***

The heat created through the composting process initiates vaporization [42] and moisture. Shou et al. [43] state that moisture stimulates the heap porosity, oxygen transfer, and microorganism metabolism [49-50], which influences the conversion of organic material and then projects the consequences through the fluctuations of the heap temperature [14, 51].

Moisture content is an important parameter in determining the success of composting [48]. The physical and chemical properties of the waste material change with moisture, which acts as a transport medium for nutrients for microbial activity [49]. Lack of preliminary MC causes water unavailability from early composting stages, obstructing microbial digestion. It causes composting to lose heat due to high porosity, consequently reducing end products tremendously [54,55]. Elevated MC can decrease the compost porosity as it compresses the heap effortlessly, thus preventing mass oxygen transfer, resulting in a drop in heap decomposition and increased odour production [52].

Figure 2 shows MC during composting declines until day 10, and Mix-3 decreases the fastest. Equation (1) can be used to calculate the MC reduction rate. MC's quickest decrease was spotted before the end of the high-temperature period (as in figure 1), from start until day 2. MC reduction in treatments displayed the metabolic activity of microorganisms for protein degradation and the influence of water absorption capacity of rice husk to assist in the composting process, primarily to balance the VW moisture [53].

$$Reduction\ \% = \frac{(initial - final)}{initial}\ x\ 100\% \qquad \dots (1)$$

The reduction percentage from initial to day 10 shows Mix-3 (13.92%) > Mix-2 (13.45%) > Mix-4 (9.24%) > Mix-1 (8.93%). The reduction percentage shows Mix-3 and Mix-2 reach up to a 13% reduction due to rapid decomposition compared to Mix-4 and Mix-1. This shows that the optimum addition of chicken manure portrays optimum degradation reflected in the high moisture content reduction percentage.

During the cooling period, the MC gradually increased, and it occurred after day 10 of composting. The persistent incline in MC as composting continued was due to temperature decrement, which corresponds to a lower evaporation rate as biological activity becomes relatively stable [54].

Compost stability is evident as all results show an MC value greater than 60% [59,60]. The differences between Mix-2 and Mix-3 were calculated using Student's t-test. The t-test that was conducted indicates that there is no significant difference ($p=0.208$, $p > 0.05$) between Mix-3 and Mix-2. The t-test indicates that Mix-3 and Mix-2 moisture content were lost at almost the same rate during the composting process.

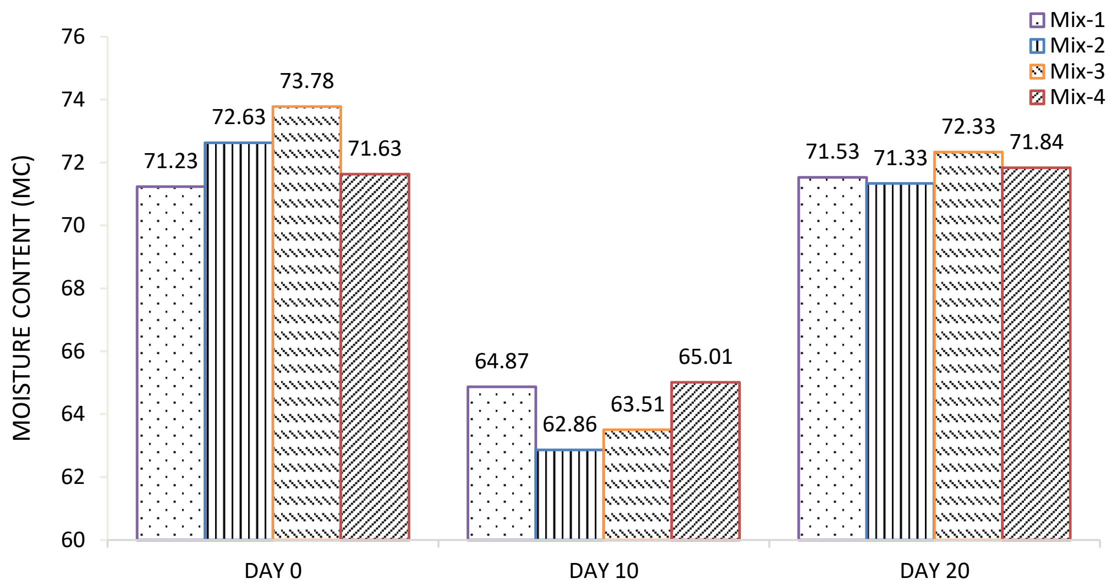



Figure 2: Changes of moisture content (MC) in composting vegetable waste with different chicken manure dosages.

***pH value***

The applicable pH range for preserving high microbial activity through composting is 7–8, tangent to organic matter (OM) biodegradation. An apparent decrease in the pH was observed as the degradation progressed [61]. During composting, the complex components were degraded to organic acids and then to $CO_2$ [18,59]. Figure 3 shows the pH value in all the treatments oscillate between 7.60-7.95, signifying biodegradation process. The pH reduction % also can be calculated using equation (1). pH reduction % from initial to day 20 shows Mix-3 (4.67%) > Mix-2 (3.3%) > Mix-4 (3.51%) > Mix-1 (3.27%) conclude Mix-3 has the most reduction. The differences between Mix-2 and Mix-3 were calculated using Student's t-test. The t-test that was conducted indicates that there is a significant difference ($p=0.048$, $p > 0.05$) between Mix-3 and Mix-2. The t-test indicates that Mix-3 and Mix-2 pH values on day 20 during the composting process were significantly different and should be taken into account.

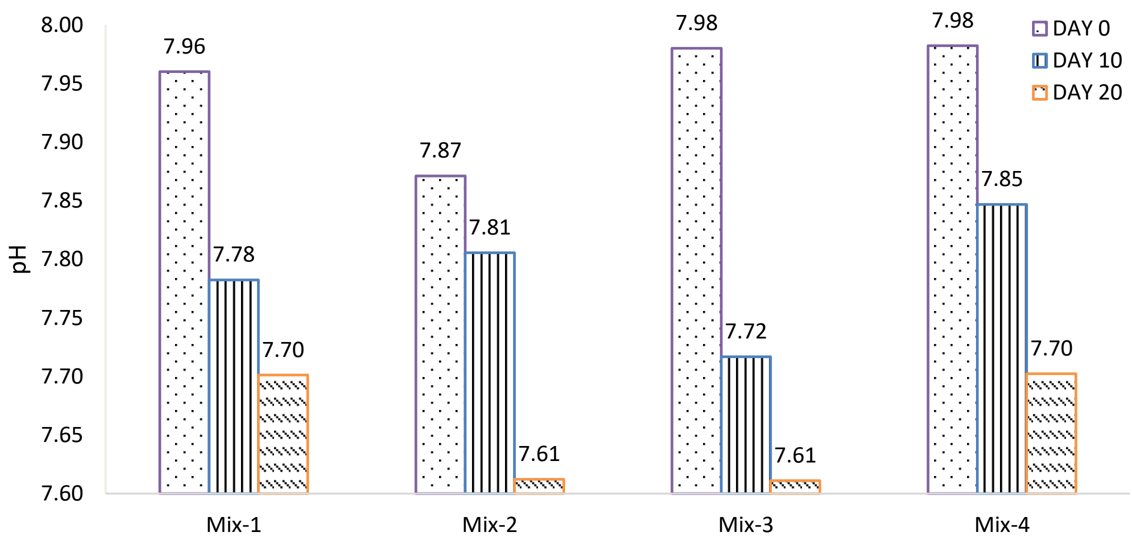



Figure 3: pH value changes during the composting with the addition of chicken manure.

### *Electrical conductivity*

The electrical conductivity (EC) value reflected the degree of salinity of composting material or compost, indicating its possible phytotoxicity effects on plant growth if applied to the soil. It was interesting to note that, the initial EC results in Figure 4 show the additional effect of chicken manure on EC readings as observed in Mix-1 to Mix-4. Then the EC profile shows a declining trend in all reactors after composting for 20 days, and the highest recorded decreasing rate was at treatment for Mix-4, followed by Mix-3, then Mix-1, and lastly Mix-2, from the initial reading. The reason for decreasing EC during composting is caused by the release of mineral salts such as phosphate, potassium, and ammonia ions [62] through the decomposition of organic matter into soluble components [63].

The EC profile increased from day 10 to day 20 for Mix-2 to Mix-4 due to rapid decomposition from the initial until day 10. Mix-1 decreased accordingly from the initial until day 20 because the soluble salt is solubilized and passed out through leachate.

Gao et al. [64] stated a limit of 3.0 mS/cm for stable composts, as supported by Rowateea et al. [21]. It was concluded that the final composts produced in this study were stable. The differences between Mix-2 and Mix-3 were calculated using the Student's t-test. The t-test that was conducted indicates that there is no significant difference ($p=0.78$, $p > 0.05$) between Mix-3 and Mix-2. The t-test indicates that during the composting process, the electrical conductivity of Mix-3 and Mix-2 is almost the same.

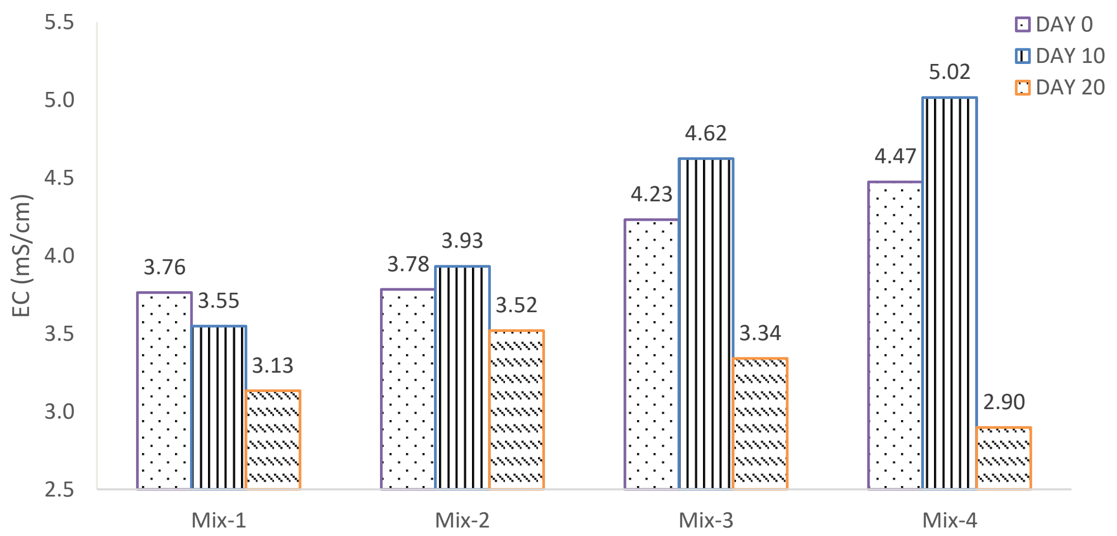



Figure 4: Electrical conductivity (EC) changes during the composting with the addition of chicken manure.

### *Organic matter loss*

Organic matter (OM) loss results show trends for the organic matter indicated reduction value after a 20-day composting period as in Figure 5. The degradation of OM was calculated through the contents of ash to evaluate the composting performance. Decreasing trends on the whole during composting processes indicate that OM is rapidly broken down by microorganisms.

The highest OM loss obtained for the compost was Mix-3, followed by Mix-2, Mix-1, and Mix-4. Decomposition and mineralization of organic matter cause an increment in organic matter loss, leading to maximum carbon loss and increased nitrogen concentration [65,66].

The differences between Mix-2 and Mix-3 were calculated using the Student's t-test. The t-test that was conducted indicates that there is no significant difference ($p=0.32$, $p > 0.05$) between Mix-3 and Mix-2. The t-test indicates that Mix-3 and Mix-2 lost organic matter at almost the same rate during the composting process.

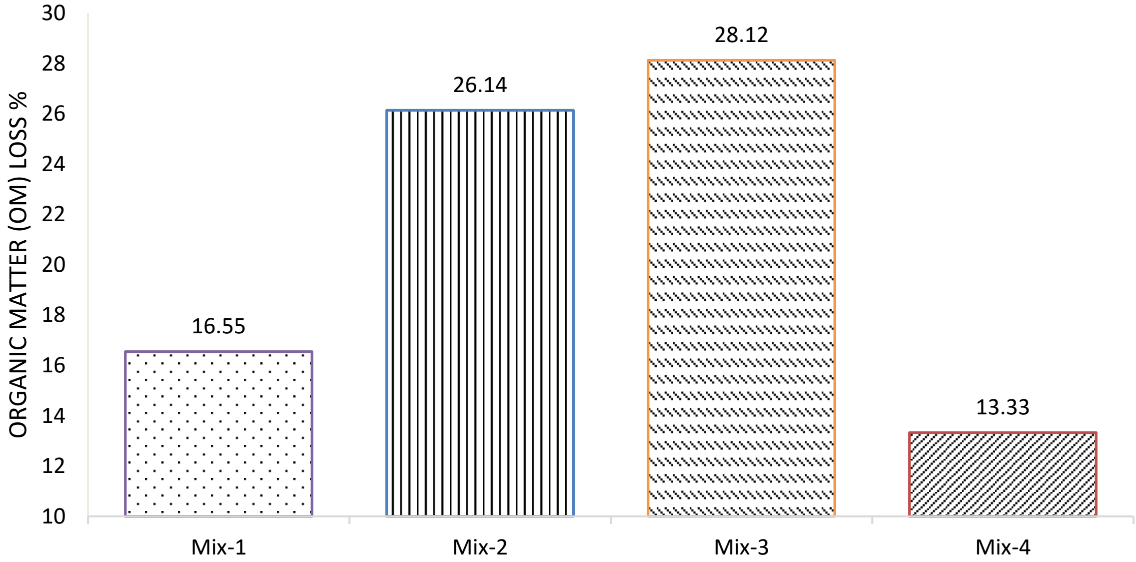



Figure 5: Effects of chicken manure application on organic matter (OM) loss.

**Table 3:** Comparison research using vegetable waste, chicken manure, and rice husk

| Ratio | | | Condition-Aeration-Duration | | Initial | | | | Performance | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VW | RH | CM | | **Parameter (unit)** | pH | MC (%) | EC (mS/cm) | PS (cm) | pH | MC (%) | EC (mS/cm) | Opt. Temp. (ºC) | OM loss (%) | PS (cm) | |
| 1.0 | 0.5 | 2.0 | R-100L-Active-18 Hr | | 8.5 | 68 | NA | NA | 8.1 | 44 | NA | 75 | NA | 2 | [29] |
| 1.0 | 1.0 | 1.0 | R-10L-Active-20 Dy | | 4.5 | 50-60 | NA | NA | 6-6.5 | 45 | NA | 60 | NA | NA | [67] |
| 0.0 | 3.0 | 1.0 | R-7L-Active-12 Wk | | 8.5 | 60 | 2.9 | NA | 6.9 | | 0.6 | 50 | NA | NA | [19] |
| 1.0 | 0.3 | 1.6 | R-100L-Active-22 Hr | | 7.5 | 55 | NA | NA | 8.3 | 26 | NA | 55 | NA | 2 | [27] |
| 1.0 | 1.0 | 1.0 | NR-15m$^2$- Active-30 Dy | | 4.4 | 84 | 5.7 | NA | 8.6 | 45 | 2.8 | 70 | 50 | NA | [25] |
| 1.0 | 2.0 | 0.3 | R-37L-Passive-20 Dy | | 7.9 | 72 | 4.2 | >2 | 7.6 | 72 | 3.3 | 41 | 28 | >1 | This study |

*Abbreviations: VW: Vegetable waste, RH: Rice husk, CM: Chicken manure, MC: Moisture content, R: Reactor; NR: Non-Reactor; EC: Electrical conductivity, Opt. Temp: Optimum temperature, OM loss: Organic matter loss, PS: Particle size; NA: Not Available; Hr: Hour; Dy: Day; Wk: Week.

## CONCLUSION

Vegetable waste (VW) composting with rice husk (RH) and chicken manure (CM) as bulking agents and amendments enhanced organic matter loss in compost produced. This study shows the effect of chicken manure and rice husk additions on composting vegetable waste. The results show that compost produced with a mixture of 2.5% chicken manure is ideal. As shown in Figure 4, Mix-3 with 2.5% CM amendment stimulated organic matter degradation by the highest amount. Conversely, Mix-4 with 5% CM amendment obstructed the deprivation and humification of organic matter, leading to slower degradation. This research pH value is leaning more towards neutral, thus projecting the OM loss rate to be relatively high. The EC is lower in this research due to the CM and RH additions, thus enhancing microbial activity.

The result (as shown in Table 3) stated that the Mix-3 with 2.5% chicken manure amendment was the optimum condition to be used as an ideal mixture based on its highest temperature (41ºC) achieved at the shortest time, which led to the highest organic matter degradation in VW composting.

This study proposes green and practical waste management of organic waste produced in Kundasang. This study achieved optimum conditions at the highest temperature of 41ºC as early as day 1 and 70% moisture content with the energy-free reactor in only 20 days, thus achieving its objective.

This study was also conducted to propose community waste management of organic waste generated by agriculture activities in Kundasang. The current solution for this organic waste is to dump it in landfills; thus, this study use composting as a cost-effective and environmentally safe waste management method. Besides, the compost produced could be used as a soil conditioner or fertilizer to sustain the environment. The community is now producing the compost through the composter design proposed by composting with different dosages of chicken manure while managing the vegetable waste to achieve the study objective.

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