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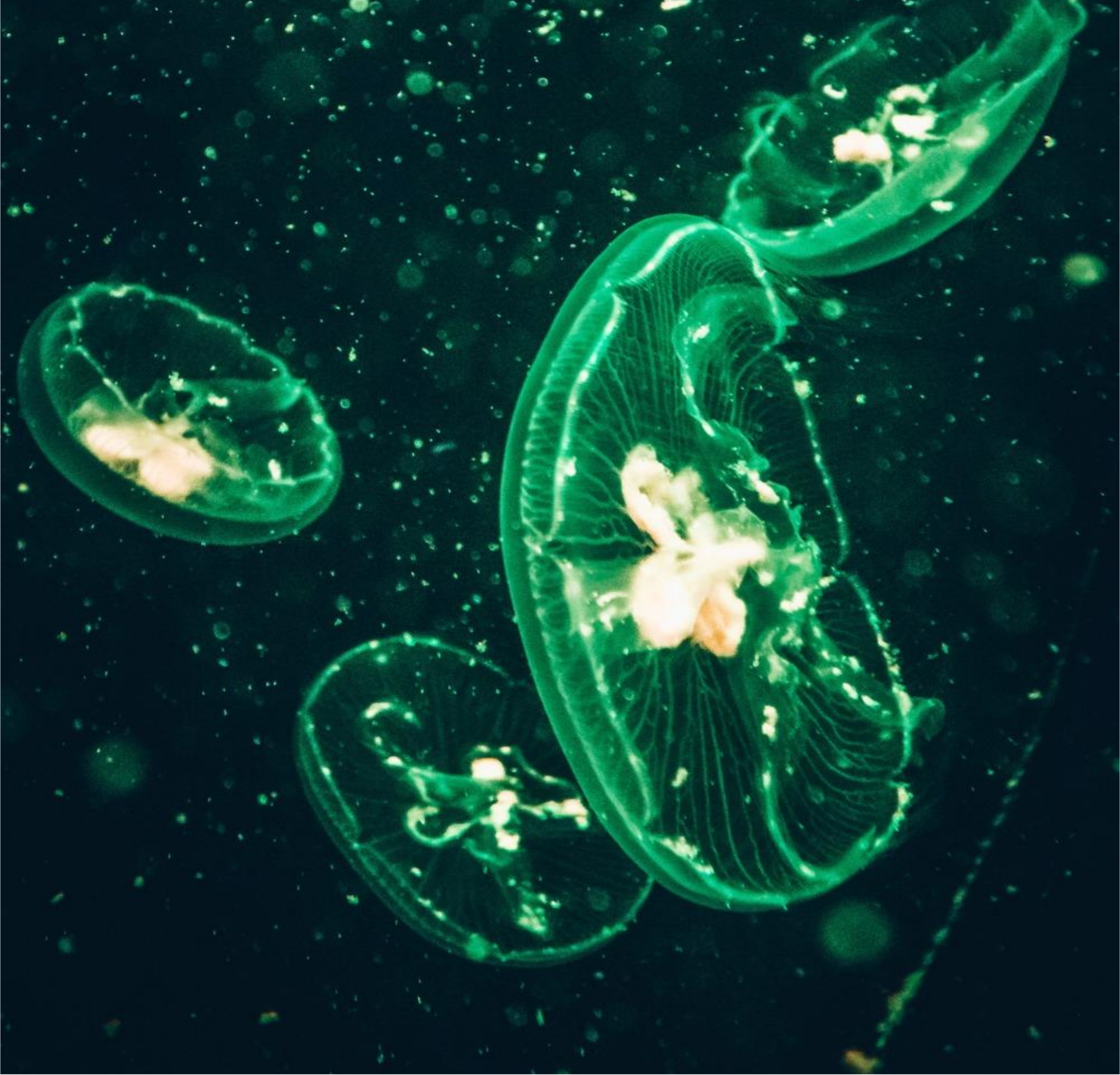

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VEGETABLE WASTE COMPOSTING: A CASE STUDY IN KUNDASANG, SABAH

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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 $P > 0.05$.

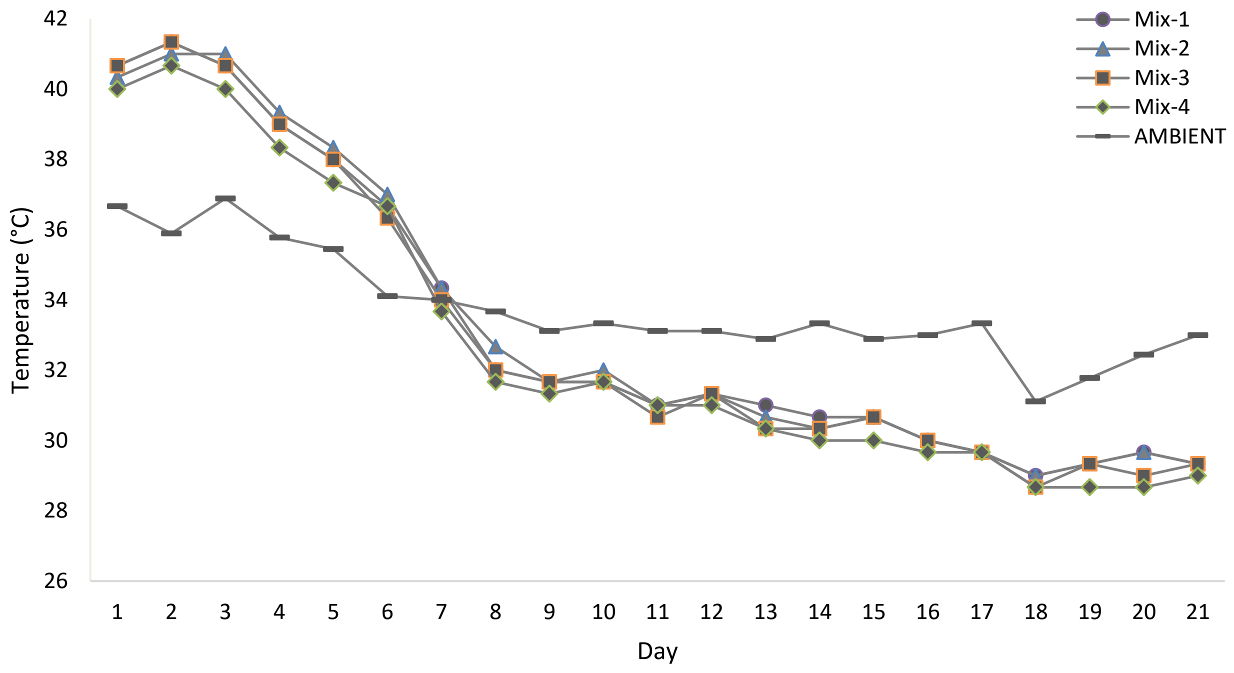
RESULTS AND DISCUSSION

Evolution of temperature

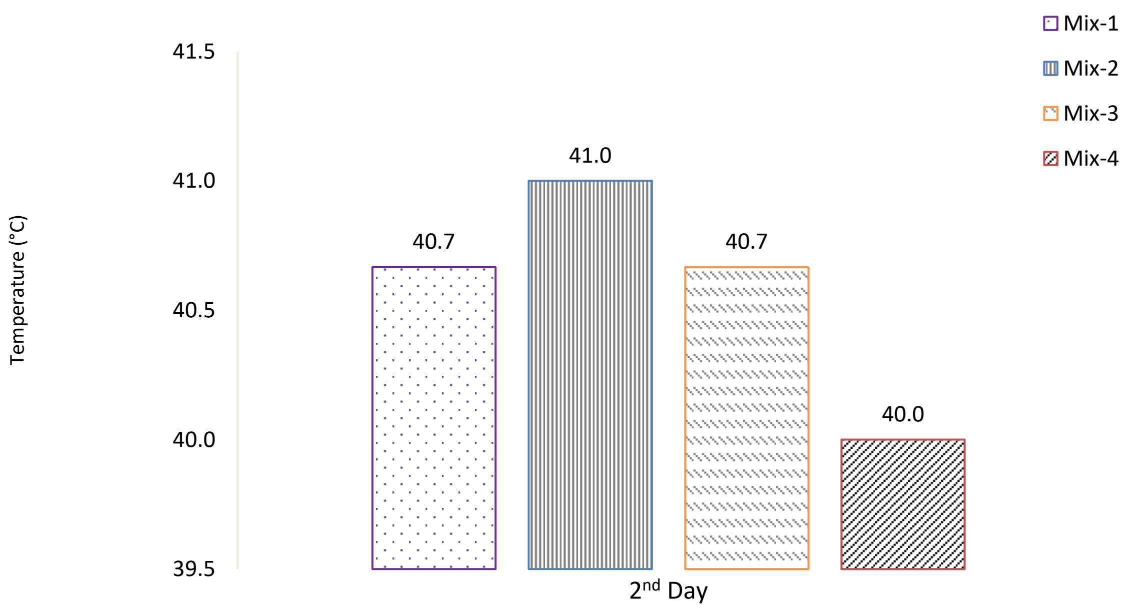
The composting temperature profile is presented in Figure 1 to investigate the effect of chicken manure addition. The temperatures increased quickly in all mixtures and reached their maximum on day 2, except for Mix-2 (on day 3). The temperature began to increase from day 1 and reached a maximum of41ºC 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.

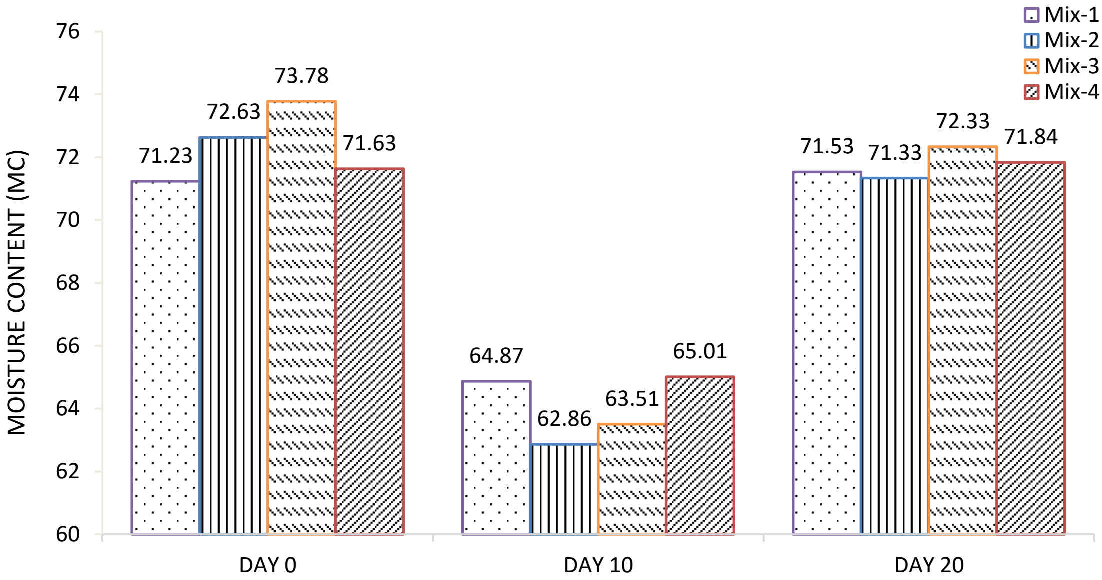


Figure 2: Changes of moisture content (MC) in composting vegetable waste with different chicken manure dosages.

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.

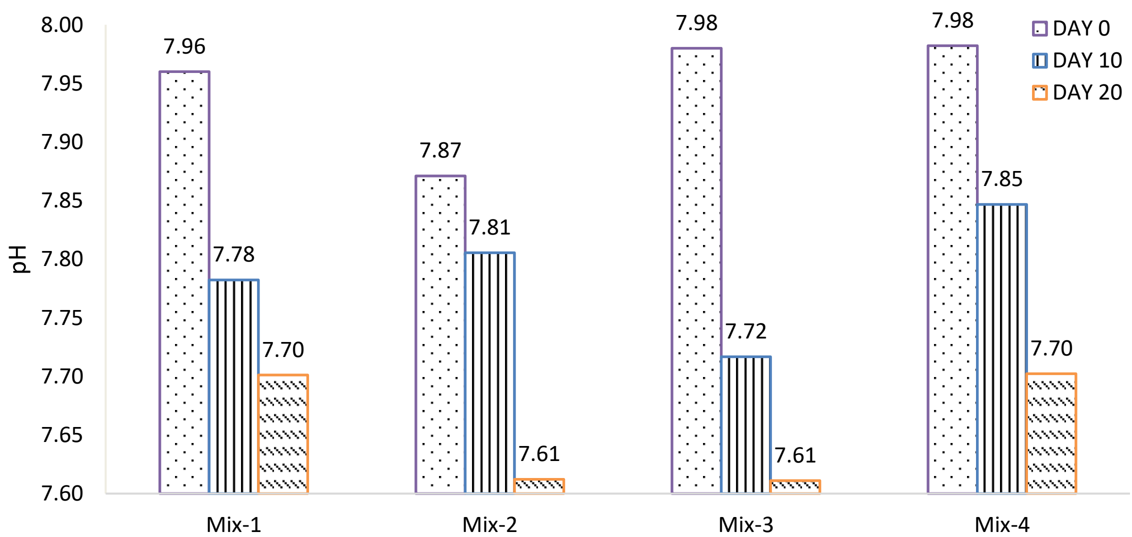


Figure 3: pH value changes during the composting with the addition of chicken manure.

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.

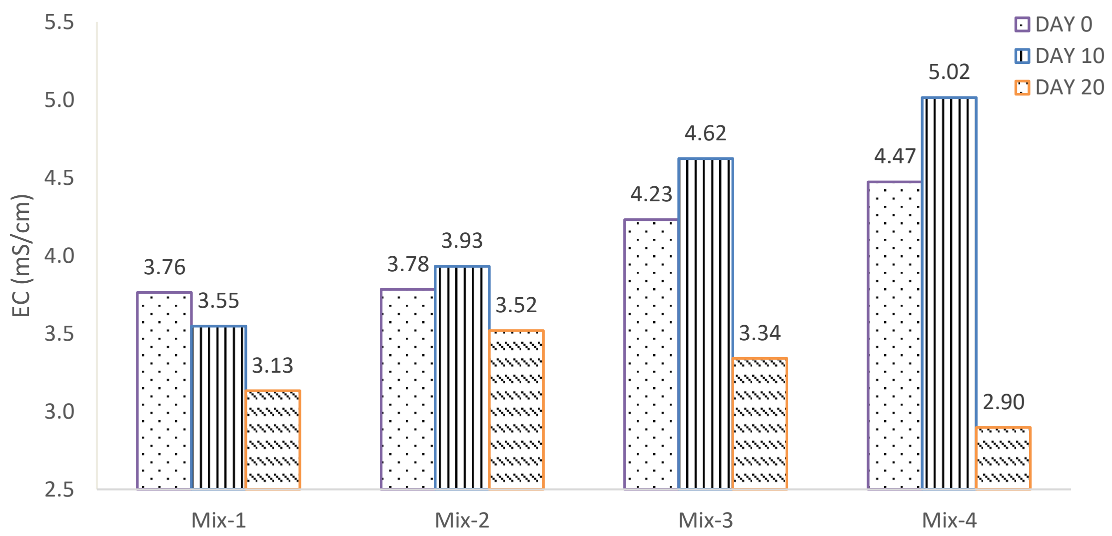


Figure 4: Electrical conductivity (EC) changes during the composting with the addition of chicken manure.

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.

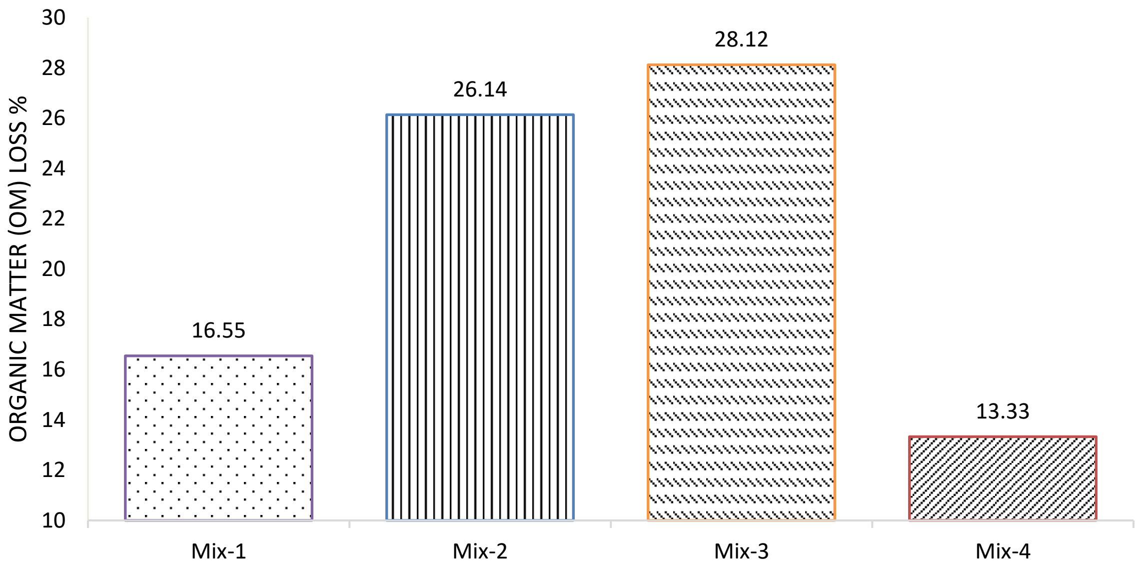


Figure 5: Effects of chicken manure application on organic matter (OM) loss.

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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FOOD WASTE-DRY LEAVES COMPOSTING: MIXTURE FORMULATION, TURNING FREQUENCY AND KINETIC ANALYSIS

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ABSTRACT. *Composting is a controlled biological process that converts organic matter into soil conditioner and kinetic modelling is necessary to design the composting system. The aims of this study are to determine the optimum compost mixture and turning frequency for food waste and dry leaves composting, as well as to evaluate an elemental kinetic model based on volatile solids (VS). The elemental kinetics of the process were determined using pseudo zero-, first-, second- and n-order equations. Three different feedstock mixtures were used, namely 40% FW (Mix A), 60% FW (Mix B) and 80% FW (Mix C). Four sets of experiments (TF for every 0, 1, 3, and 5 days) were conducted to investigate the turning frequency (TF). The composting process was carried out in a compost bottle for 40 days. Based on organic matter loss, Mix B and C had the highest OM loss, indicating an acceptable initial compost mixture. The turning frequency of every three days resulted in the highest organic matter loss. Kinetic analysis was performed using coefficient correlation (R^2), root mean square error (RMSE) and modelling efficiency (EF). Application of the second-order model resulted in good responses for compost mixture Mix B and C. Meanwhile, the n-order model successfully estimated the VS changes for the 3-days TF.*

KEYWORDS. Compost, soil conditioner, modelling, second order, n-order

INTRODUCTION

Proper treatment of food waste is a challenge faced by any developing nation, as unmanaged food waste contributes to adverse environmental impacts (Cerda et al., 2018). Globally, around 1.13 million tons of food waste is discarded daily (Chen et al., 2020; Nguyen et al., 2020), which is expected to increase due to population growth (Nguyen et al., 2020). In Malaysia, an estimated 33,000 tons of solid waste are generated daily, with food waste accounting for approximately 44.5 % of the total (SWCorp, 2020). Moreover, food waste accumulation in landfills or incineration drives negative impacts such as greenhouse gas (GHG) emissions and groundwater contamination (Chen et al., 2020). Composting is an environmentally friendly and cost-effective approach that can replace t organic waste processing (Ajmal et al., 2020).

Composting occurs under biological processes carried out under optimum conditions to produce a high quality and stable compost that is nutrient-enriched soil amendment (Waqas et al., 2018). It has long been recognized that biofertilizers produced from food waste can be used as a soil conditioner to reduce chemical fertilizers, enhance soil quality, and rehabilitate polluted soil (Cerda et al., 2018; Yang et al., 2019). However, suboptimal techniques performed in composting cause a lengthy process and possibly produce immature compost (Fan et al., 2016). Therefore, it is critical to regulate composting efficiency by assessing the substrate's biodegradation rate and enhancing the decomposition rate (Malamis et al., 2016).

Initiative on improving better composting procedures to shorten organic matter degradation has been increasing. However, food waste has certain limitations as a biowaste, such as a low C/N ratio and high moisture content. This will inhibit microbial activity and low degradation effectiveness. It can be fixed through the addition of a bulking agent. Fei-Baffoe et al. (2016) suggested that 3:1 was the best ratio of organic solid waste and sewage sludge. Kamaruddin et al. (2018) also studied the effects of different feedstock ratios on the decomposition of green and brown waste. The authors found that a 3:1 ratio of green waste to brown waste produces better compost compared to 1:1 and 2:1 feedstock ratios. Zhou et al. (2018) used a mixture of food waste, sawdust and Chinese medicinal herbal residue with three different ratios (5:5:1, 2:2:1 and 1:1:1) to evaluate the effect on the composting process. The authors mentioned that a ratio of 1:1:1 had the highest germination index (157.3%), a C/N ratio of 16.0, an electrical conductivity below 4 mS/cm and the highest organic reduction (67.2%).

Aeration also affects the composting process. Aeration can be provided through turning or convection for passive aeration systems and through blowers or air pumps for active aeration systems. Varma et al. (2018) discussed how the agitation and aeration rate in composting will affect the microbial activity. Optimum turning frequency (TF) provides sufficient ventilation, which controls the compost pile's temperature, excess water, and microbial activity (Liu et al., 2020). Low or excessive turning frequencies cause slow biodegradation due to undesired porosity, oxygen availability, and heat loss (Soto-paz et al., 2019; Zhang et al., 2019).

Several successful studies have proposed different TFs for different composting materials. For example, Zhang et al. (2019) evaluated the effect of different TF (every 5, 7, 10 and 15 days) on goat manure combined with Camellia oleifera shell. The results showed that turning every 7 days produced high quality compost in terms of total nutrients and C/N ratio. Another study performed by Manu et al. (2019) investigated the influence of TF (every 5 days) and microbial addition on food waste mixed with garden waste. A similar household-scale study with different TFs (every 1, 2, and 3 days) with a C/N ratio of 20, 25, and 30 using food waste and dry leaves was carried out by Nguyen et al. (2020). They concluded that the optimum conditions for plant growth were a C/N of 30 and a turning frequency of once every 2 days.

The above overview data are in agreement with the statement reported by Nguyen et al. (2020) in which, TF and C/N or mixing ratio are dependent on the input materials and bulking agents. In spite of the broad study of mixing ratio and TF, most of the studies just focused on individual factors, with few studies on the influence of both techniques on the same materials and operational conditions. Furthermore, most modern composting facilities focus on the enhancement of degradation of organic matter in the waste to comply with strict market demands and tight environmental legislation (Hamelers, 2004; Hamoda et al., 1998). Composting process kinetics provide useful information about process progress to improve composting operations (Ebrahimzadeh et al., 2017; Hamoda et al. 1998). Therefore, this study investigates and evaluates the effects of various mixing ratios and different TFs on food waste and dry leaves composting and its kinetic degradation profile.

MATERIALS AND METHODS

Materials

Simulated food waste (FW) and shredded dry leaves are used as feedstocks in the composting process. A mixture of 40% FW (Mix A), 60% FW (Mix B) and 80% FW (Mix C) (by weight) was used for determining the optimum compost mixture. Meanwhile, 72% of simulated food waste mixed with dry leaves was used in determining the optimum turning frequency. Simulated food waste was prepared by mixing vegetables, bread, cooked rice, banana peel and cooking oil with the following ratio: 34%, 29%, 16%, 13%, and 8%, respectively. The ratio for each material was estimated based on the typical wasted food composition in Asia reported by Paritosh et al. (2017). The materials used in simulated food waste were bought from a supermarket while dry leaves were collected within the university landscape area.

Experimental Set-Up and Design

A composting study was conducted at the Environmental Lab, Faculty of Engineering (FKJ), Universiti Malaysia Sabah, located in Sabah, Malaysia. The composting process was carried out using 1.5 L compost bottle. The compost bottle design was inspired by a previous study by Zahrim et al. (2020). The compost bottle has a total of 20 holes (equally spaced) around the bottle for maintaining aerobic condition and one hole at the bottom for leachate. During the composting process, the top opening of the compost bottle was closed and sealed using adhesive tape. The mixture was manually mixed before being put into the compost bottle. Figure 1 shows the design of the compost bottle.

For determining the optimum mixture, three different food waste: dry leaves mixtures were used, namely Mix A, Mix B, and Mix C. Four sets of experiments (TF every 0, 1, 3, and 5) were conducted to investigate turning frequency (TF). Each experiment was carried out in 3 trials simultaneously. The composting process lasted for 40 days. For turning, the sample was rotated to make sure the compost was mixed together and subjected to change, causing the top portion of the compost to move to the central portion.

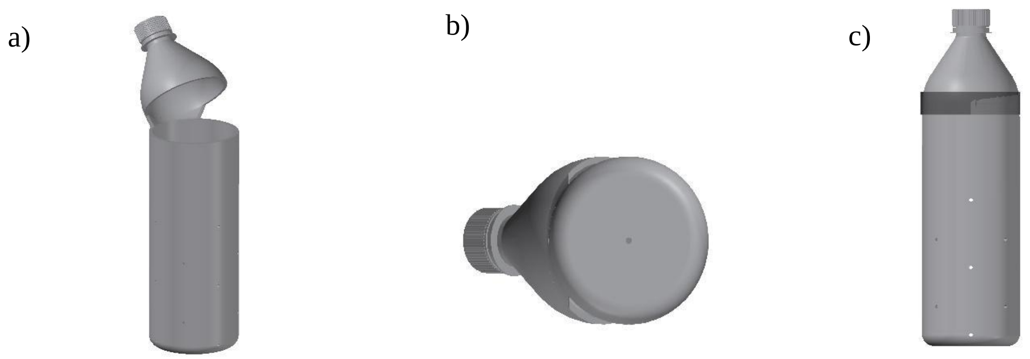

Figure 1. The a) front, b) bottom view of opened compost bottle and, c) front view of closed compost bottle using adhesive tape

Volatile solid (VS) is determined by burning the oven-dry samples using a high-temperature furnace (Thermolyne 46100) at 550 °C for 4 h (APHA, 1985). The ash was calculated using equation (1) (Zahrim et al., 2019), the VS was calculated using equation (2) (Liao et al., 1994) and the organic matter (OM) loss is determined using equation (3) (Paredes et al., 2000);

$$Ash\ (\%) = \frac{W_{crucible + sample\ (after\ burning)} - W_{crucible}}{W_{sample}} \qquad (1)$$

$$TOC\ (\%) = \frac{Organic\ matter\ (\%)}{1.8} = \frac{Volatile\ solid\ (VS)\ (\%)}{1.8} = \frac{100 - ash\ (\%)}{1.8} \qquad (2)$$

Where TOC is total organic carbon.

$$OM\ loss\ (\%) = 100 - 100\left(\frac{A}{B}\right) \qquad (3)$$

where,

$$A = \%\ Initial\ ash\ content\ \times (100 - \%Final\ ash\ content)$$

$$B = \%\ Final\ ash\ content\ \times (100 - \%Initial\ ash\ content)$$

Kinetic Studies

In this study, four different types of kinetic models were used: pseudo-zero order, pseudo-first order, pseudo-second order, and n-order models. The degradation process in terms of volatile solids (VS) content during the composting process was monitored to determine the kinetic models (Baptista et al., 2010). Generally, VS changes are commonly used to determine the level of feedstock degradation (Ebrahimzadeh et al., 2017; Kulcu, 2016). The kinetic model can be derived from Equation (4) (Ebrahimzadeh et al., 2017).

$$\frac{d(VS)}{dt} = -k(VS)^n \qquad (4)$$

Where VS is volatile solids (%), superscript "n" represents the equation's order which can be zero, one, two or any real number and k is the rate constant.

Table 1 shows the mathematical equation, linear equation and graph plot for each kinetic model. The value of k was calculated as the slope of the fitted straight line obtained using a linear equation for each case (Hamoda et al., 1998).

Table 1. Mathematical equation and plots for kinetic models (Ebrahimzadeh et al., 2017)

Kinetic model	Mathematical equation	Linear equation	Plots
Pseudo-zero order	$VS = -kt + VS_o$	$VS = -kt + VS_o$	VS versus t
Pseudo-first order	$VS = (VS_o)exp^{-kt}$	$ln\ ln\ VS = -kt + ln\ ln\ VS_o$	ln VS versus t
Pseudo-second order	$VS = \frac{VS_o}{1 + (VS_o)kt}$	$\frac{1}{VS} = kt + \frac{1}{VS_o}$	1/VS versus t
n-order	$VS = \sqrt[n-1]{\frac{(VS_o)^{n-1}}{1 + (VS_o)^{n-1}(n+1)kt}}$	$\frac{1}{(VS)^{n-1}} = (n-1)kt + \frac{1}{(VS_o)^{n-1}}$	1/[VS]^(n-1) versus t

Evaluation of kinetic model

The quality of the kinetic model fits to the experimental data was evaluated by the coefficient correlation (R^2), root mean square error (RMSE) and modelling efficiency (EF). These parameters were calculated by equations (5), (6), and (7), respectively, as follows (Ebrahimzadeh et al., 2017; Kulcu, 2016; Petric et al., 2012).

$$R^2 = \left(\frac{\sum_{i=1}^{n} \left(X_{obs} - \underline{x}\right).\left(Y_{model} - \underline{y}\right)}{\sum_{i=1}^{n} \left(X_{obs} - \underline{x}\right)^2 . \sum_{i=1}^{n} \left(Y_{model} - \underline{y}\right)^2} \right)^2 \quad (5)$$

$$EF = 1 - \frac{\sum_{i=1}^{n} (X_{obs} - X_{model})^2}{\sum_{i=1}^{n} \left(X_{obs} - \underline{X}_{obs}\right)^2} \quad (6)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs} - X_{model})^2}{n}} \quad (7)$$

where X_{obs} and Y_{model} are values of observed and estimated data, x and y the mean of observed and predicted data, respectively. For model efficiency (EF), X_{model} is the model value, and X_{obs} is the mean value of observed data. For RMSE, X_{model} is modeled value.

RESULTS AND DISCUSSION

Organic Matter (OM)

The different phases of composting and the relative completion of the composting process were characterized using variations in OM content (Manyapu et al., 2018). Organic matter (OM) was decomposed into volatile compounds and lost from the solid compost during composting (Hu et al., 2009); thus, OM will decrease throughout the composting process. Figure 2 shows the final OM loss of the composting process for different mixing ratios. The OM loss for Mix A, Mix B, and Mix C on day 40 were 44.5%, 79.9% and 78.7%, respectively. Higher OM loss was observed in Mix B and Mix C. This finding is in accordance with findings reported by Guidoni et al. (2018). A higher reduction of OM was observed in a mixture rich with food waste than in a mixture rich with bulking agents. Neugebauer and Sołowiej (2017) also suggested that at least 40% of the bulking agent needs to be composted with kitchen waste for the best results. Several studies showed positive results while using a feedstock ratio of between 60% and 80% FW during composting. Kamarudin et al. (2018) recommended the 75% of food waste be composted with yard and garden waste. In another study, the compost produced from food waste and yard waste with 80% FW (by weight) using a passive-aerated static pile has an acceptable pH (6.6), NPK value (2.4%,2.8%,0.2%) and MC (29.5%) but a high EC value (24.9 mS/cm) (Ng et al., 2021).

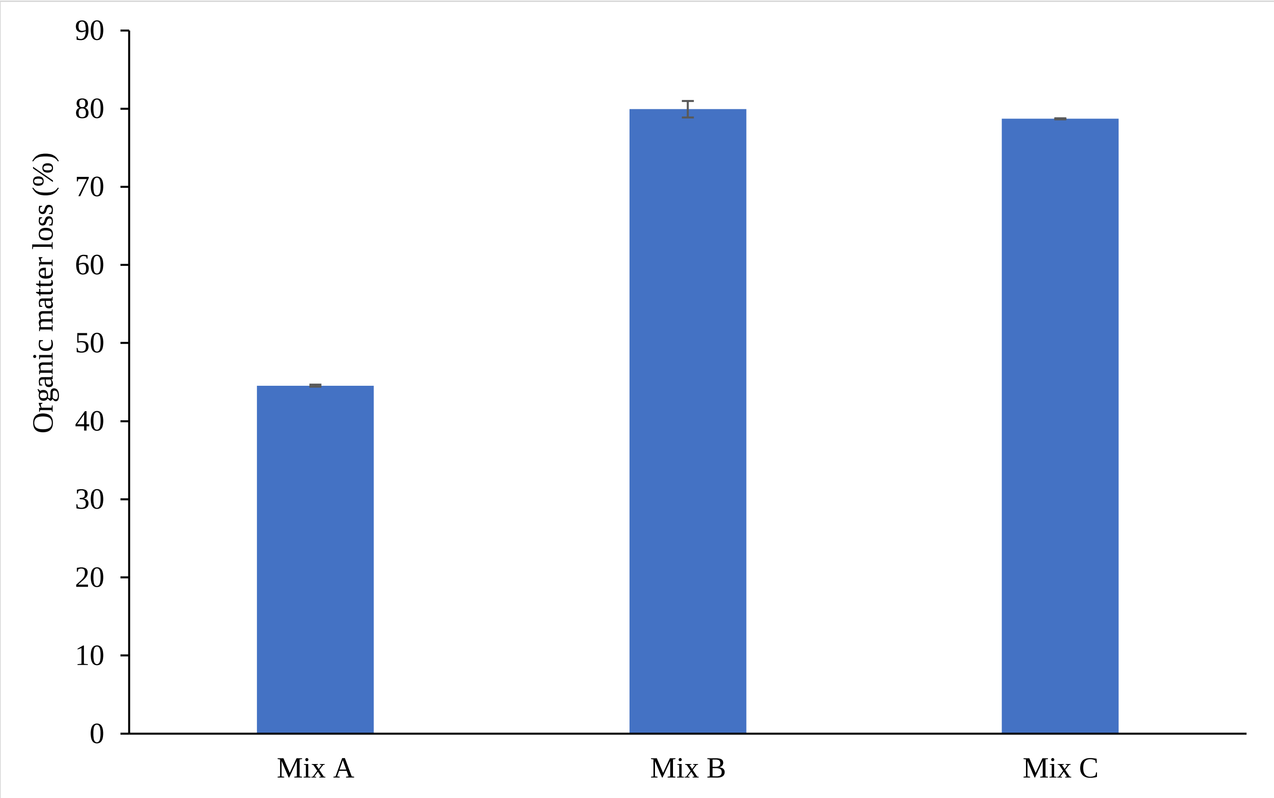

Figure 2. Organic matter loss on day 40 bottle composting under different feedstock proportion (Mix A = 40% FW, Mix B = 60% FW, and Mix C = 80% FW)

The highest OM degradation level was obtained in TF 3, followed by TF 2, TF 4, and TF 1 (Figure 3). Theoretically, increasing turning frequency will result in a higher decrease in organic carbon content (Nguyen et al., 2020). This trend also agrees with the previous study by Soto-Paz et al. (2019). Lack of required oxygen causes a low biochemical degradation reaction rate (Zhao et al., 2012). At the end of the process, organic matter loss of 61.45%, 69.75%, 79.23% and 63.15% were observed for TF 1, TF 2, TF 3, and TF 4, respectively. The result shows that each turning frequency resulted in a significantly different degree of organic decomposition, and TF 3 had higher OM loss than other treatments. The faster organic matter degradation rate was due to enhanced microbial activity for the treatment (Manu et al., 2017). The slow biodegradation in other treatments can be explained by the unfavourable turning frequency. Kalamdhad and Kazmi (2009) reported that excessive or less aeration can significantly influence the degradation of organic matter by reducing the heat and moisture of the material, resulting in nutrient loss and poor final product quality. Therefore, TF should be adequately controlled for an efficient composting process. Several studies also suggested a 3-days TF during composting. However, TF depends on the initial condition of input materials and bulking agents (Nguyen et al., 2020). Nguyen et al. (2020) reported that 3-day TF was suitable during food waste and dry leaves composting with an initial C/N ratio of 25. Trisakti et al. (2017) suggested that the best result was obtained at 3-day TF during composting of empty fruit bunches with activated liquid organic fertilizer. Meanwhile, Jiang-ming (2017) recommended TF once every 2-4 days when composting pig manure and fungus residue to obtain a stable final compost.

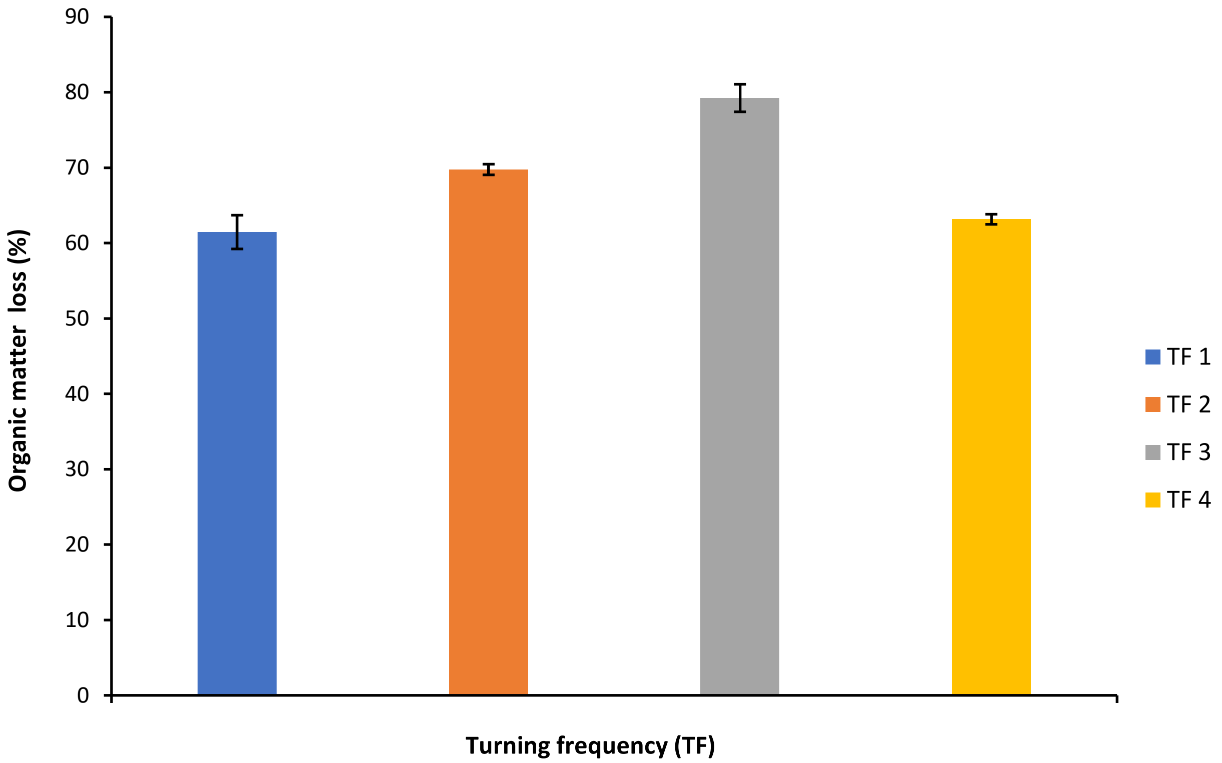

Figure 3. Organic matter loss for TF 1, TF 2, TF 3, and TF 4

Kinetics Modelling of Volatile Solid (VS) Degradation

A composting kinetics study of waste biodegradation is necessary to design the composting system. It is essential to determine waste biodegradability and develop a valuable measure for the loss of organic matter during composting (Hamoda et al., 1998). Proper modeling of substrate degradation progress is essential for predicting the composting process's operating variable (Qdais & Al-Widyan, 2016). Figure 4 shows the plot for VS changes over time with respect to each equation's order in the model for Mix B and Mix C. Based on the graph, the values for the rate of constant, k, and coefficient correlation (R^2) were determined. The values are presented in Table 2.

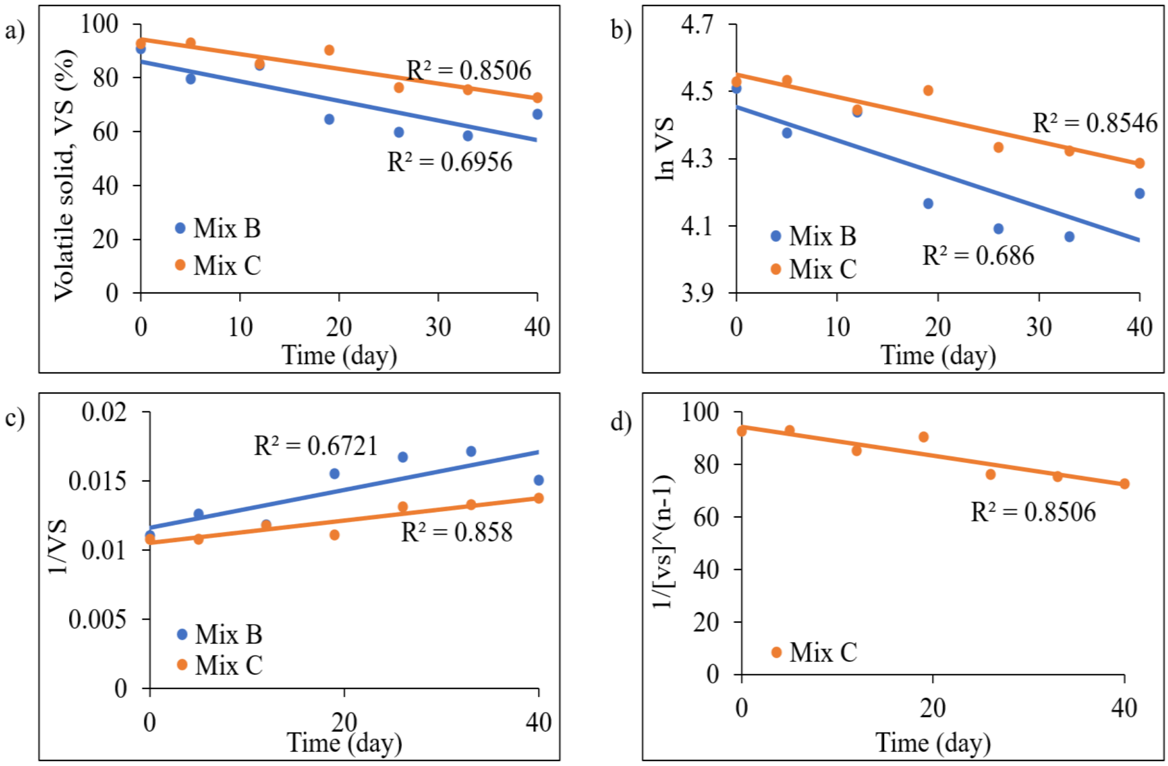

Figure 4. Principles of determining the mixing ratio k for (a) zero-, (b) first-, (c) second-, and (d) n-orders of Mix B and C treatment

The value of k in this study was slightly lower than in the previous study by Manu et al. (2016), where the range of k in first-order is 0.0045–0.0105. The reaction rate in Mix A was lower, possibly due to less microbial metabolism activity as the mixture has the lowest proportion of food waste. Meanwhile, the reaction rates for Mix B and Mix C were comparable with the previous study, which might be due to a similar proportion of feedstock mixture where Manu et al. (2016) used ~70% of food waste for the compost mixture. Overall, Mix B and Mix C showed a higher reaction rate, which means high degradation of organic matter. This is due to an optimum condition during composting compared to Mix A. This also supports the high OM loss observed in Mix B and Mix C, as shown previously.

A high value of EF and a low value of RMSE are chosen as the criteria for goodness of fit (Sangamithirai et al., 2015). At all kinetic models, Mix A did not adequately fit the experimental data because the R2 values obtained were very low (0.00002 – 0.0021). This might be due to the ratio in Mix A being unfavourable for composting. Similarly, Kabbashi et al. (2014) stated that poor performance was observed in closed systems with low R^2 compared to open systems. Meanwhile, for Mix B and C, the highest R^2 was obtained in zero-order (0.6956) and second-order (0.8580), respectively. A previous study by Jolanun et al. (2005) mentioned that an R^2 value of 0.67 is acceptable. The highest EF with the lower RMSE was found in second-order. For all of the derived models, second order models better predict the volatile solid dynamics of the composting process based on the R^2, EF, and RMSE. Similar observations have been reported by Ebrahimzadeh et al. (2017) where the second-order is the best kinetic model to predict the degradation of VS over time for all the reactors. The best model and mathematical equation of Mix B and C are shown in Table 4.

Table 2. The rate constant, coefficient correlation, modelling efficiency and root mean square error of Mix A, Mix B and Mix C by using zero-, first- and second-order equations

		Model number	k	R^2	EF	RMSE
Zero-order	Mix A	1	0.0277	0.0021	0.0021	8.1703
	Mix B	2	0.7290	0.6956	0.6956	6.5510
	Mix C	3	0.5477	0.8506	0.8506	3.1181
First-order	Mix A	4	0.0002	0.0006	0.0006	0.1089
	Mix B	5	0.0099	0.6860	0.6860	0.0911
	Mix C	6	0.0066	0.8546	0.8546	0.0371
Second-order	Mix A	7	0.0000005	0.00002	-0.0003	0.0015
	Mix B	8	0.0001	0.6721	0.5187	0.0016
	Mix C	9	0.00008	0.8580	0.8574	0.0004
n-order	Mix A	10	0.0141	0.0019	0.0018	4.4130
	Mix B	11	0.00000003	0.6285	0.6183	0.0000004
	Mix C	12	0.5477	0.8506	0.8506	3.118

Figure 5 shows the plot for VS changes over time with respect to each equation's order for TF 3. According to the results of a mathematical models discussed earlier, the values of the coefficients k, n, and statistical values R^2, RMSE, and EF are summarized in Table 3. It is observed that the correlation coefficient (R^2) for all experiments is higher than 0.67, showing a good linear regression fit for all models. Table 3 shows the correlation coefficients of four models. It was found that n-order models were better at predicting the VS profile for TF 3.

Table 3. The rate constant, coefficient correlation, modelling efficiency and root mean square error of TF 1, TF 2, TF 3 and TF 4 by using zero-, first- and second-order equations

		Model number	k	N	R^2	EF	RMSE
Zero-order	TF 1	1	0.209	0	0.9858	0.9857	0.35514
	TF 2	2	0.3535	0	0.8768	0.8767	1.87396
	TF 3	3	0.5257	0	0.9849	0.9842	1.050129
	TF 4	4	0.3131	0	0.9856	0.9856	0.593947
First-order	TF 1	5	0.0024	1	0.9883	0.9857	0.359728
	TF 2	6	0.0044	1	0.8903	0.8767	2.058163
	TF 3	7	0.0066	1	0.9925	0.9842	0.734076
	TF 4	8	0.0037	1	0.9891	0.9856	0.487071

Second-order	TF 1	9	0.00003	2	0.9903	0.9787	0.433917
	TF 2	10	0.00005	2	0.9013	0.8782	1.862446
	TF 3	11	0.00008	2	0.9973	0.9945	0.553396
	TF 4	12	0.00004	2	0.9918	0.9551	0.937975
n-order	TF 1	13	3.13E-05	1.9593	0.9902	0.9891	0.309581
	TF 2	14	6.87E-09	3.9095	0.9159	0.892447	1.750826
	TF 3	15	1.54E-08	2.9492	0.9988	0.998473	0.292891
	TF 4	16	2.38E-06	2.6818	0.9932	0.993123	0.367454

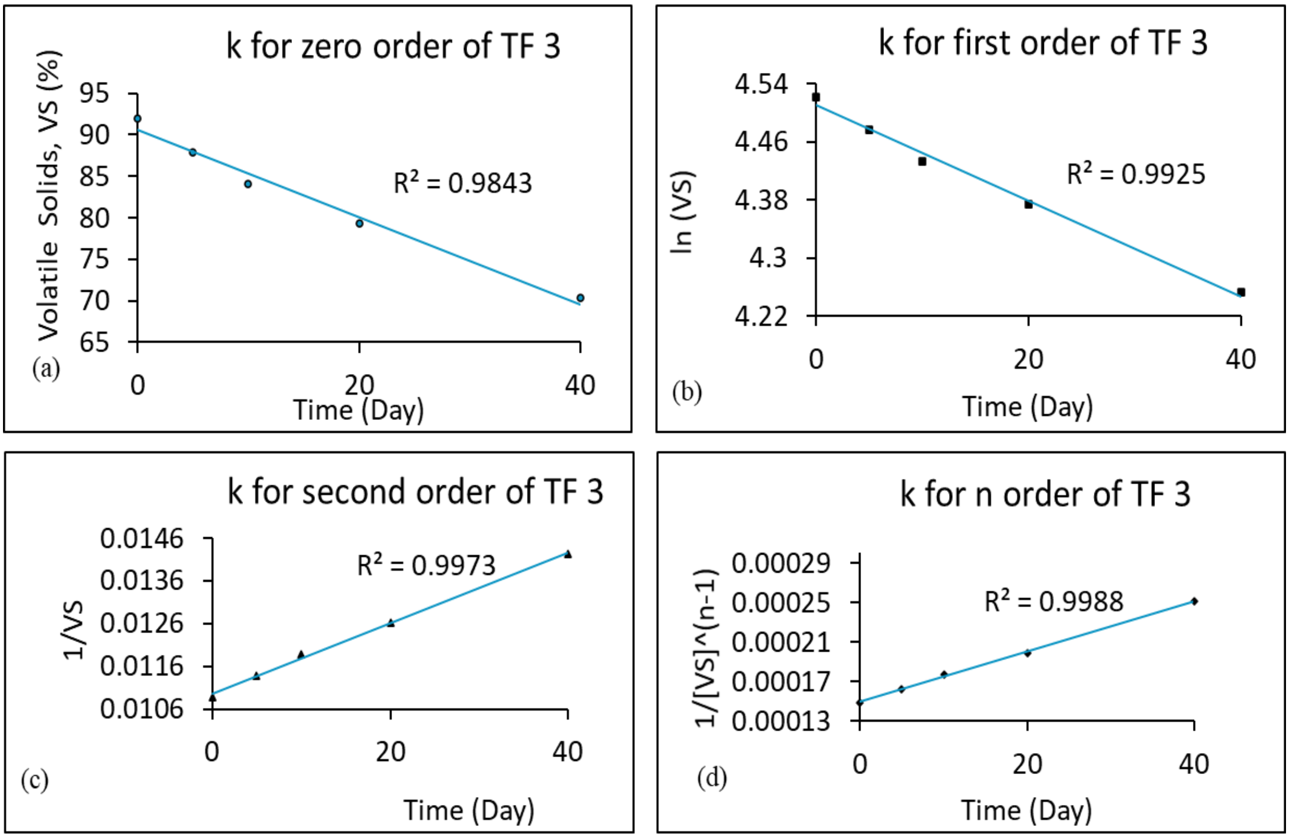

Figure 5. Principles of determining the rate constant k for (a) zero-, (b) first-, (c) second-, and (d) n-orders of TF 3 treatment.

After determining the VS rate constant k, mathematical equations were obtained to predict the degradation of compost VS over time. It should be noted that the kinetic study only focuses on the best mixture formulation and turning frequency, as shown in Figure 2 and Figure 3. Summarizing the data from Tables 2 and 3, the best model and mathematical equation for Mix B, Mix C, and 3-day TF (TF 3) are shown in **Table 4**. The specific equation was found by substituting the coefficient from the kinetic modelling with the one from the Table 1.

Table 4. The best model to predict changes in volatile solid over time for Mix B, Mix C, and TF 3

Treatment	Model number	Order	Specific equation
Mix B	8	2	$VS = \frac{88.6}{1 + 0.009t}$
Mix C	9	2	$VS = \frac{92.6}{1 + 0.007t}$
TF3	16	2.9492	$VS = \left(\frac{6692.08}{1 + 0.0169t}\right)^{0.5130}$

CONCLUSION

In this study, food waste: dry leaves mixture of 60:40 (Mix B) to 80:20 (Mix C) and TF every 3 days are recommended for achieving higher organic matter degradation. Application of the second-order model resulted in good responses for compost mixture Mix B and C. Meanwhile, the n-order model successfully estimated the VS changes for a 3-day TF.

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THE ROLE OF GOVERNMENT INSTITUTIONS IN MANAGING THE ENVIRONMENT IN NIGERIA: POLICY AND GOVERNANCE REVIEW

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ABSTRACT. *Environmental protection starts with individuals, groups, and communities at large. The government at its level formulates, regulates, and enforces laws and policies governing environmental protection as well as the punishment of violators through designated legal institutions. The aim of this review is to examine the role of environmental institutions in protecting the environment in Nigeria. The findings revealed that national policies for the protection of the environment came into existence only in 1991. This study employed literature review and combed through articles published from 2000 to 2022 in the contexts of Nigeria. The objective of this study is to highlight the role that environmental institutions play in managing the environment in Nigeria. There are numerous environmental challenges in Nigeria, including air pollution, water pollution, lead poisoning, poor waste management, deforestation, desertification, wind erosion, and flooding, all of which have harmed the environment and the population. National policies for the sustainable use of the environment include the National Environmental Policy, National Policy on Climate Change, Environmental Impact Assessment Act, Endangered Species (Control of International Trade and Traffic) Act, and the National Drought Plan. The national regulatory bodies include the National Environmental Standards and Regulations Enforcement Agency; the National Oil Spill Detection and Response Agency; the Federal Ministry of Environment; the Directorate of Petroleum Resources; the Nigerian Nuclear Regulatory Authority; the Federal Ministry of Water Resources; and the National Oil Spill Detection and Response Agency, among others. The study recommends that the government strengthens the national policies, laws, and regulations on the environment to meet the challenges of the 21st century, strengthens the capacity of environmental law enforcement personnel, and provides necessary logistics to aid in executing their functions. Governments should inject more funds into environmental protection and stakeholder engagement.*

KEYWORDS: Environment, Law, Policy, Governance, Nigeria

INTRODUCTION

The first global environmental conference, held in Stockholm in 1972, set in motion three decades of debate, negotiation, and ratification of a slew of international environmental treaties (Najam et al., 2006). This has given rise to environmental concern globally and the emergence of policies related to the environment and governance institutions at international, national and local levels. According to Elenwo and Akankali (2014), environmental policy is a commitment to environmental laws, regulations, and other policy mechanisms. The environment has undergone numerous changes and modifications over the years because of economic, political, and environmental forces, to the point where the pattern of its epigenetic trend can no longer be used with high precision in predicting the near future (Oruonye and Ahmed, 2020). The effects of pollution on water, air, and land are just a few examples of a broader range of environmental issues (Elenwo and Akankali, 2014). Environmental governance is the ongoing process of making interactive decisions on international and national environmental matters. It encompasses institutions and organisations and legally binding agreements, policy instruments, and procedures that govern environmental protection (United Nations Environment Programme, 2017). Environmental and economic policies are crucial in designing a sustainable environment (Young, 2003). This can be achieved with more general improvement of institutions to ensure that policies are implemented and monitored effectively (Dasgupta et al., 2016). Institutions, specifically environmental management institutions, are prominently placed in an effort to understand the causes of environmental problems and devise solutions that have a reasonable chance of success (Young, 2003).

Efficient governance, as well as enabling legal and regulatory frameworks, are the foundations of good governance for environmental management, allowing governments at all levels to initiate and enforce critical environmental protection measures. It is now widely acknowledged that both economic development and environmental protection are critical for achieving environmental management goals. The emphasis has shifted to institutional mechanisms aimed at promoting a balance between the environment and development (Okafor-Yarwood, 2018; Roos et al., 2020).

Nigeria has a rich natural resource heritage spread across its various climatic belts. This includes mangrove swamps and wetlands in the coastal region and the Niger Delta, the lowland tropical rain forests of the south, the middle belt savannah grasslands, and the northern Sahel and semidesert vegetation zone. These belts are interspersed with scenic and wildlife resources, and they have much potential for tourism development. Furthermore, Nigeria has abundant reserves of the following mineral resources: crude oil and gas, coal, tin, gold, iron ore, and various other earth minerals and vast land for agriculture (Oluwaseyi, 2017; Omotehinse & Ako, 2019).

Human activities and natural disasters pose an increasing threat to Nigeria's environment. There are already some concerning environmental issues, as well as visible scars associated with the destruction of the natural resource base (land, water, and air) on which all life depends. The country's large population of approximately 200 million people, as well as its rapid growth rate of 2.8%, contribute to environmental degradation (FME, 2016). Nigeria established its first national environmental policy in 1991. It was revised in 1999 and in 2016 to reflect emerging environmental issues and concerns. Thus, these national policies and programs on the environment aim to establish a new holistic framework to guide the country's management of the environment and natural resources (FME, 2016; Akamabe and Kpae., 2017). In addition to the existing draft policy documents, there were a lot of policies and regulations guiding the use of the environment in Nigeria. The fundamental obligation to protect the environment is stated in Section 20 of the Constitution of the Federal Republic of Nigeria 1999, which states that the "State shall protect and improve the environment and safeguard the water, air, and land, forest and wild life of Nigeria" Furthermore, Nigeria is a signatory to a number of international treaties and conventions governing environmental issues (Kankara, 2013; FME, 2016; Ifesinachi, 2018). Therefore, the objective of this paper is to examine the role of environmental institutions in achieving a sustainable environment in Nigeria. Therefore, this study attempts to highlight the latest trends in environmental policy and governance and the role they play in ensuring a sustainable environment in Nigeria. The objective of this study is to highlight the role of environmental institutions in environmental management in Nigeria. Policy strategies and strengthening institutions for sustainable development based on the identified gaps in the current policies and governance to manage the environment were part of the recommendation.

METHODOLOGY

The study focuses on the linkages between environmental institutions, policy and governance and explore their functions in environmental management in Nigeria. To achieve these, a substantial literature review was carried out for up to date information on environmental laws and policies in Nigeria.

The bulk of literatures were obtained from sophisticated databases: science direct from Elsevier, Web of science, google scholar, and research gate. The study use keywords such as “environmental law”, “environmental policies”, “environmental regulations”, “environmental ethic” in combination with search strings, Nigeria, etc.

Based on the objective of the research, titles and abstracts of the retrieved literature were screened and evaluated and selected the best that fits the objective of the review. Therefore, out of 100 literature retrieved, 23 were retained after exclusion of duplicate and articles that are not relevant. The selection criteria indicate that articles must be written in English and between 2000-2022 to obtain recent information. The review considered both qualitative and quantitative studies and prioritize on the role of environmental institutions in environmental management in Nigeria.

Table 1. Criteria for Document Inclusion and Exclusion

Inclusion	**Exclusion**
Phase 1: keyword search	
English articles	Non-English articles
2000-2022 peer review articles	Pre 2000 and after 2022
Review and articles	Non-peer review articles (meetings, editorial, abstract)
Phase 2: title and abstract review and full-text review where necessary	
Environmental policy	Environmental planning
Environmental law	Environmental vulnerability
Environmental regulations	Environmental disaster

Berrang-Ford et al. (2011)

Synopsis of Policies, Laws and Regulations on the Environment in Nigeria

National policies, laws and regulations on the environment emerged in 1991, a few years after the Koko pollution incident. In 1988, Italian businesspeople illegally dumped over 2000 hazardous waste drums, sacks, and containers in a small fishing village in southern Nigeria. The dealer claimed that the waste was fertiliser that would benefit poor farmers, but it turned out to be a nightmare. A few months later, the containers began to leak, causing stomach upset, headaches, failing vision, and death in the surrounding community. The area around the dumpsite became inhabitable, and over 500 people were evacuated. People in the Koko village still remember this accident as the 'drums of death' (United Nations, 2018).

The policies/laws for the sustainable use of the environment at the national level include; the National Policy on Environment; Environmental Impact Assessment Act (Cap E12 LFN 2004); National Drought Plan; National Water Policy; Harmful Waste (Special Criminal Provisions Act (Cap H1 LFN 2004); Endangered Species (Control of International Trade and Traffic) Act (Cap E9 LFN 2004); National Oil Spill, Detection and Response Agency Act 2006 (NOSDRA); National Park Services Act (Cap N65 LFN 2004); Nigerian Minerals and Mining Act 2007; Water Resources Act (Cap W2 LFN 2004); Hydrocarbon Oil Refineries Act; Associated Gas re-injection Act; Nuclear Safety and Radiation Protection Act; Oil In Navigable Waters Act, National Erosion and Flood Control Policy; National Renewable Energy Efficiency (NREE) 2015, Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) 2002; National Policy on Climate Change; Sea Fisheries Act; Exclusive Economic Zone Act; Oil Pipelines Act; Petroleum Act; Petroleum Products and Distribution (Management Board) Act; Territorial Waters Act; Nuclear Safety and Radiation Protection Act; Nigerian Mining Corporation Act; Quarantine Act; River Basins Development Authority Act; Pest Control of Production (special powers) Act; Agricultural (Control of Importation) Act; Animal Diseases (control) Act; Bees (Impact Control and Management) Act; Civil Aviation Act; Factories Act; Water Resources Act; Hides and Skins Act; Federal National Park Act; Niger-Delta Development Commission (NDDC) Act e.t.c. (Akinwumi et al., 2001; Nicholas et al., 2016; Wonah, 2017; Efobi et al., 2018; Aye & Wingate, 2019). In addition, each of the 36 states in the federation of Nigeria has its own environmental protection agencies (Ejide et al., 2017). These policies act as important checks and balances in environmental management, planning and decision-making and works to protect Nigeria's land, air, water, and soil. These policies also prevent, reduce, remedy, and punish actions that endanger or harm the environment and its inhabitants. In addition, the policies ensure sustainable use of the environment to meet the need of present and future generations.

Table 1: Summary of some policies/laws/regulations related to environment in Nigeria.

Policies/law/ regulations	Objective	Expected outcome
National Environmental Policy	To ensure environmental protection and the conservation of natural resources for sustainable development.	Promote coordination of environmental protection, natural resources conservation, and securing a quality environment for good health and economic prosperity.

National Policy on Climate change	Strengthen national capacity to adapt to climate change	Strengthen resilience and adptation to climate change.
Environmental Impact Assessment Act (Cap E12 LFN 2004)	To set out the general principles, procedures, and methods of environmental impact assessment in various sectors.	Ensure in-depth assessment of the potential impacts, whether positive or negative, of a proposed project on the natural environment.
Endangered Species (Control of International Trade and Traffic) Act (Cap E9 LFN 2004)	To provide for the conservation and management of Nigeria's wild life and the protection of some of its endangered species in danger of extinction.	Ensure regulation of hunting, trading of wild animals, export and import of specified species, penalties and forfeitures for violators.
National Oil Spill, Detection and Response Agency Act 2006	To protect human life and the environment, minimize losses due to flooding and erosion and their effects on vulnerable areas by regulating land-disturbing activities and controlling accelerated soil erosion and flooding.	Ensure restrict or prohibit land disturbing activities/uses which are dangerous to health, safety, and property due to water induced erosion caused by increased flow velocity and volume/depth of surface run-off.
Nigeria Minerals & Mining Act 2007	To guide the exploration of mineral resources and and protection environment.	The law is expected to deal with possession of mining materials, small-scale mining and the protection of the interests of host communities, provide incentives for mining operations and define offences.
Water Resources Act (Cap W2 LFN 2004)	To protect, conserve, and control water resources for equitable and sustainable social and economic development and to maintain environmental integrity.	Promote the optimum development, use and protection of water resources and ensuring authorized licenses for water users.

Nigeria Flare Gas (Prevention of Waste & Pollution) Regulations 2018.	To reduce the social and environmental impact of gas flares.	Ensure to deal with gas flaring activities by oil and gas companies through regulation and legal permit.
National Drought Plan	To provide an effective and systematic means of monitoring and assessing drought conditions	Enhance capacities of risk communities, reduce vulnerability and exposure to recurrent droughts, as well as monitoring of droughts.

The Role of Institutions and Legislations for Environmental Protection in Nigeria

The environmental governance in Nigeria is based on federal, state and local government laws. The legislature and executive arms of government work together in formulating laws and policies governing the use and management of the environment in Nigeria. Environmental non-governmental organisations (NGOs) play a critical role in bridging gaps by conducting research to aid policy development, building institutional capacity, and facilitating independent dialogue with civil society to help manage and protect the environment and people live in more sustainable ways.

The Environmental Bodies

There are two types of environmental bodies in Nigeria. These include government and non-government environmental organisations. In Nigeria, both government and non-governmental organisations collaborate to ensure environmental protection.

The National regulatory bodies include: National Environmental Standards and Regulations Enforcement Agency (NESREA); National Oil Spill Detection and Response Agency; Federal Ministry of Environment; Directorate of Petroleum Resources (DPR); Nigerian Nuclear Regulatory Authority; Federal Ministry of Water Resources; National Oil Spill Detection and Response Agency (NOSDRA); National Biosafety Management Agency; Department of Climate Change; Energy Commission of Nigeria; Erosion, Floods and Coastal Zone Management; Department of Planning, Research and Statistics; drought and desertification agency. Others include environmental non-governmental organizations; civil society organisations (CSOs); state planning authorities; community-based organisations (CBOs); faith-based organisations (FBOs); non-governmental organizations (NGOs); international community and donor agencies. (Ejide et al., 2017). However, in the 36 states of the Federation and Federal Capital Territory have designated ministries and agencies responsible for environmental protection and management; for example, the Jigawa State Environmental Protection Agency (JISEPA) and the Lagos State Environmental Protection Agency (LASEPA), among others. The officers are authorised by law to search for and seize illegal items and arrest violators. Some of the offences include; discharge of untreated raw human waste into any public drain, gorge, or piece of land; and discharge of any type of oil, grease, spent oil, or manufacturing waste into any public drain, watercourse, gorge, or road verge (Ejidae et al., 2017). Some state governments, for example, have recently reinstated the monthly environmental sanitation exercise. Lagos, Oyo, Ebonyi, Kano, and Kebbi are among them. The reintroduction was made possible by passing environmental sanitation laws in various state legislatures.

Table 2: Summary of government agencies related to environment their objectives and expected outcome in Nigeria

Ministry/Agency	Objective	Expected outcome
Federal Ministry of Environment	To ensure protection of land, air, vegetation and water for sustainable development	Ensure a quality environment, promote sustainable use of natural resources, preserve biodiversity, ecosystem management, raise public awareness and promote understanding of the linkages between the environment.
Federal Ministry of Water Resources	To develop and implement policies, projects and programmes that will enable sustainable access to safe and sufficient water supply to meet the social, cultural, environmental and economic development needs of all Nigerians.	Ensure the nation's integrated water resources management contributes optimally to the socio-economic activities of the nation through comprehensive planning; facilitating and creating an enabling environment for integrated conservation.
National Oil Spill, Detection and Response Agency (NOSDRA).	To monitor and regulate oil spills as well as coordinate, implement and review the National Oil Spill Contingency Plan for Nigeria	Ensure the co-ordination and implementation of the Plan within Nigeria, including within 200 nautical miles of the baseline for which the breath of the territorial waters of Nigeria is measured; undertake surveillance, reporting, alerting, and other response activities as they relate to oil spillages.
National Environmental Standards and Regulation Enforcement Agency (NESREA) Act 2007	To ensure the protection and the development of the environment, biodiversity conservation and sustainable development of natural resources.	Ensure compliance with laws, guidelines, policies, and standards on environmental matters. It also promotes coordination and liaises with stakeholders within and outside Nigeria on matters of environmental standards, regulations, and enforcement.

Department of Climate Change	To provide a sustainable policy framework and enabling environment for climate change action (mitigation, adaptation and resilience) in Nigeria	Promote a sustainable policy framework and an enabling environment for climate change action in Nigeria and to regularly update information regarding national greenhouse gas emissions, mitigation options, vulnerability assessment and adaptation measures to the impacts of climate change.
Energy Commission Nigeria (ECN)	To ensure adequate, reliable, cost-effective and sustainable energy supply for the nation's economic and sociopolitical development.	Promote energy sector planning and policy implementation, promote the diversification of energy resources through the development and optimal utilization of all, including the introduction of new and alternative energy resources like solar, wind, biomass, and nuclear energy.
National Biosafety Management Agency, 2015	To establish and strengthen the institutional arrangement on biosafety matters in Nigeria	Develop a risk management plan and strategy for protecting human health, biological diversity, and the environment from potential risks and ensure compliance with the legal obligations of the act.

The Federal Ministry of the Environment monitors other ministries, implements government initiatives, monitors compliance with regulations, and provides secretariat services to higher bodies, acting as a link between the ministry and the overall policymaking body. The Ministries (Federal and State) also coordinate state and provincial activities in their respective domains. According to Osawe and Magnus (2016), environmental factors for governance include soil deterioration, climate change, biodiversity, water, wildlife, agriculture e.t.c. Institutions and agencies take preventive measures to ensure compliance with all applicable relevant legislation and licencing provisions, but the institutions/agencies will use their enforcement powers if voluntary compliance is not satisfactory. The enforcement strategies include; inspection, compliance monitoring, negotiation, legal action and prosecution, whereas some of the methods of enforcement include; permits and licences are issued, prohibition and enforcement notices are issued, changing the terms of a licence, in accordance with the "polluter pay" principle, permits and licences may be suspended or revoked, injunction and completion of corrective actions (Ejidae et al., 2017).

Oruonye and Ahmed (2020) observed that the government is oftentimes the primary violator of environmental policies and provisions. The authors further pointed out that the advantages of enforcing environmental regulations include creating new job opportunities, environmental protection, and environmental sustainability. Some of the challenges to effective environmental regulation compliance include outdated laws, high cost of environmental regulations, weak institutional capacity, poor governance, understaffing, insufficient funding and special interests, a plethora of legislation/conflicting laws, ignorance, and lack of the rule of law, to name a few.

In Nigeria, several environmental agencies have been established to protect the environment at all levels of government. These environmental agencies are established by the federal, state, or local governments to coordinate programmes geared at limiting pollution and safeguarding the environment. Despite that, Nigeria signed different international environmental treaties in safeguarding the environment in its effort to protect the environment. Therefore, the objectives of signing international environmental treaties are "to analyse or monitor the environment for misuse or degradation, conserve natural resources and the existing environment, and, where possible, repair damage and reverse the trend e.t.c" (Public Health Nigeria, 2022). Table 3 summarises some of the international environmental treaties and conventions to which Nigeria is a signatory.

Table 3: Summary of the international treaty/convention ratified by Nigeria

Title of treaty or convention	Year of signing	Year of enforcement
African Convention on the conservation of nature and natural resources	1968	1974
Convention concerning the protection of the world cultural and natural heritage	1972	1975
Convention on international trade in endangered species of wild fauna and flora (CITES)	1973	1987
Vienna convention for the protection of Ozone layer and Montreal protocol on substances that deplete the ozone layer	1985	1988
Basel convention on the control of trans-boundary movement of hazardous wastes and their disposal	1990	1992
Convention on the conservation of migratory species of wild animals	1979	1983
United nations Framework convention on climate change	1992	1994
Convention on Biological diversity (Rio conference)	1992	1993
International convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa	1994	1996
Convention on wetlands of international importance especially as waterfowl habitat	1971	1975
The Kyoto Protocol to the UN convention on climate change	1997	1997

Source: Urhobo Historical Society (2006) and Cunningham *et al*., (2003).

CONCLUSION

The environment is subject to changes as individuals and society progress. These changes might be positive or negative for the environment. Protection of the environment entails the formulation of laws and policies to guide the use of the environment. The study concludes that numerous policies govern the use of the environment in Nigeria, but they require amelioration. Therefore, the study recommends that emphasis should be given to national policies and laws related to environment to overcome the challenges of the rapidly changing environment and ensure law enforcement personnel are provided with necessary logistics to aid in the execution of their functions, governments should invest more funds in environmental protection, and the need to integrate all stakeholders is apparent.

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PRESERVATION COATING EFFECT OF ACID-SOLUBLE CHITOSAN ON THE SHELF LIFE OF BANANA IN SABAH

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ABSTRACT. *Chitosan, a biopolymer that consist of various properties, has multiple applications throughout industries where one of the promising applicarion of chitosan is its preservative effect. Chitosan, a bioactive natural edible coat can be considered a promising alternative to overcome the freshness of bananas during storage. Throughout this study, observations were made on weight loss, peel colour changes and titratable acidity for the effect of chitosan coating. In terms of weight loss, among four different concentration of chitosan coating solution, the 2.0% chitosan coating solution showed the lowest weight loss percentage which is 22.6% compare to others which were 1.0% (26.00%), 0.5% (26.20%) and 1.5% (34.24%) significantly. The result marked variations between the uncoated banana and coated banana at different concentrations of chitosan coating solution (ASC) which are 0.50, 1.00, 1.50 and 2.00%. The peel color changes were significantly different during the first and final day of observation for each concentration. A significant variation was observed for the titratable acidity of the banana fruit where the lowest value obtained was 0.812% during coating with 2.0% chitosan coating solution while the highest titratable acidity was observed during the coating with 1.5% chitosan solution which is 2.11%. To summarize, banana coating with chitosan can decreased the weight loss of the banana fruit as well as improve the peel color changes during 12 days of storage. Besides that, banana coating with chitosan can also lower the value of titratable acidity of the banana fruit compared to uncoated bananas.*

KEYWORDS: chitosan, shelf life, coating, titratable acidity.

INTRODUCTION

Throughout the past decades, the modern food industry is facing challenges associated with food packaging with short shelf life period. The recent packaging materials or storage forms were unsophisticated and there is a need to a betterment and innovations. Ideally, food packaging materials that can protect food quality over time, portability, convenient to use, inexpensive, renewable, biodegradable, and produce no municipal solid waste accumulation should be what consumers need. By far, the most utilized and best choice for food packaging applications are plastics and polymers.

However, on the other hand, they are non-biodegradable and increase municipal solid waste accumulation. Thus, the issue has grown in importance to the initiation of research on biopolymers which is not only biodegradable, but exhibits antimicrobial and antifungal properties (Priyadarshi and Rhim, 2020).

Recently, researchers have been showing an increasing interest in the improvement and use of bio-based active films based on antimicrobial and antifungal properties to improve the food preservations without using chemical preservations. Chitosan which can be obtained from the exoskeletons of crustaceans, insect and cell walls of fungi is a natural polysaccharide consisting of glucosamine copolymers *N*-acetylglucosamine. It has been widely used in various industrial and biomedical fields such as pharmaceutical and biotechnology, making it a suitable candidates for this matter (Priyadarshi & Rhim., 2020). Additionally, chitosan is enclosed with reactive amino group, reactive hydroxyl group, linear polyamine, and can chelates many transitional metal ions whereas the biological properties of chitosan comprise biocompatible, binds to mammalian and microbial cells, hemostatic, fungistatic, antimicrobial, spermicidal, antitumor, anticholesteremic, accelerates bond formation, immunoadjuvant, and depressant for the central nervous system (Dutta *et al*., 2004).

The potential of chitosan to act as fruit preservative of natural origin has been widely reported an excellent film forming material and coating (Duan *et al*., 2019). Some researchers also reported that the results indicated that chitosan has more advantages because of its antibacterial activity and bivalent minerals chelating ability where it can affect several physical characteristics of the fruits and these can be used to evaluate the quality of the fruit directly. Several characteristic of fruits that can be affected are weight loss, peel colour changes and titratable acidity (Duan *et al*., 2019).

In Sabah fruit industry, banana was considered one of quite popular tropical fruit that contain a lot of nutrients and minerals that are very beneficial for health. Therefore, the need for tropical fruits coating can be considered an essential procedure. The short shelf life of banana is common because the quick ripening process leads to browning incidence thus lower the quality of banana during harvest or shelf life storage. These major postharvest problems significantly affect the quality of banana thus result in a decline of its market value. Therefore, a postharvest technique is necessary to develop or keep banana fruit quality stable during marketing. Thus the study was undertaken to investigate the effect of acids soluble chitosan on the shelf life of banana in term of weight loss, peel color changes and titratable acidity.

MATERIALS AND METHODS

Production of Chitosan

Deproteination (DP)

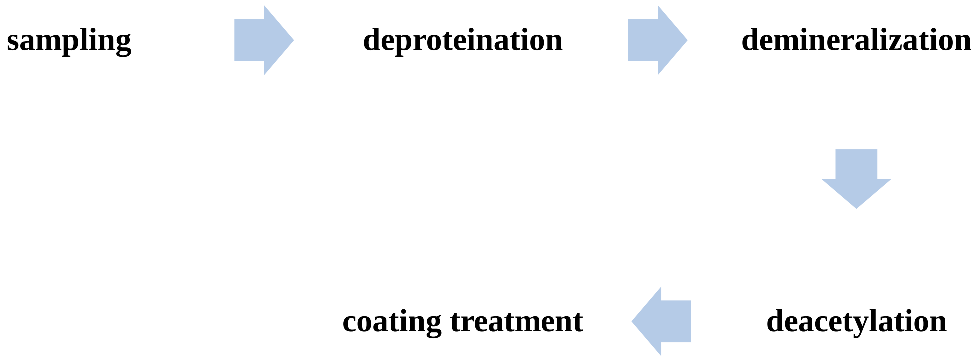
A total of 20 g sample of flakes shrimp shell were placed in a 1000 mL beakers and soaked in 2.0 M NaOH in the ratio of 1:16 (w/v) for one hour at room temperature (~25^{o}C) according to Patria (2013). Then the solution was filtered and the residue was washed with tap water until neutral pH was achieved. The residue was re-dried under the sun for 4 hour or more for samples decolouration (Youn *et al*., 2007).

Demineralization (DM)

The dried saample from the deproteination process was added with 1.0 M HCl in the ratio 1:16 (w/v) to remove minerals such as calcium carbonate, ($CaCO_3$) to produce carbon dioxide, (CO_2). The process was allowed to stand for one hours at room temperature (~25^{o}C). After that, the sample was separated from the solution by vacuum filtered and washed with distilled water until neutral pH was achieved. The sample obtained known as chitin was re-dried using the same drying method.

Deacetylation (DA)

A total of 10 g of dried chitin flakes will be further undergone deacetylation process where the chitin sample was immersed in 48 % NaOH with ratio 1:16 (w/v) and the treatment was carried out at 70^{o}C for 48 hours.



Preparation of Acid Soluble Chitosan (ASC) Solution

The chitosan solution was prepared by dissolving 0.0, 0.5, 1.0, 1.5, 2.0 g of chitosan in 1000 mL distilled water and added 10 mL of glacial acetic acid to dilute the chitosan to produce different concentrations of chitosan solution which is 0(control), 0.5, 1.0, 1.5, 2.0% (Batista Silva *et al*., 2018).

Coating Treatment

Banana samples were selected with about the same size and weight as well as free of visual defects. A complete randomized with three replicates will be establish. The treatment was carried out by dipping samples into each concentration for 1 minute following by air drying for about 1 hour. All samples were weighted and stored in a perforated cardboard carton for 12 days. Observation was made for 2, 4, 6, 8, 10 and 12 days of experiment for peel color changes while weight loss and titratable acidity were obtained during the final day of investigation.

Quality of Sabah Banana fruit

The quality of the banana fruit will be determine in terms of weight loss, peel colour changes, and titratable acidity.

a) Weight Loss

The total fruit weight loss was calculated on initial weight basis and expressed in percentage.

$$\text{Weight loss} = \frac{initial\ weight\ (g) - final\ weight (g)}{initial\ weight\ (g)}\ x\ 100\%$$

b) Peel Colour Changes

Peel colour changes score were according to Al-Qurashi *et al*. (2017) method with modification. The peel colour changes were recorded with the help of a chart (1-10 scale; 1-green, 2- green with trace of yellow, 3- more green than yellow, 4- more yellow than green, 5- yellow with trace green, 6- full yellow, 7- yellow with brown spots, 8- more yellow than brown, 9- more brown than yellow, and 10- full brown).

c) Titratable Acidity (TA)

A total of 10g of banana fruit pulp samples were crushed and homogenized for 1 hour with 100 mL of boiled distilled water. The mixture was titrated with 0.10 M NaOH with phenolphthalein used as an indicator. The end point of the reaction was identified as transformation of the colorless into a pale red. The TA was expressed as the percentage of malic acid (Li *et al*., 2019).

$$TA(\%) = \frac{0.067\ C1xV1xV2}{V3xW} x\ 100\% \quad (1)$$

Where C1 (mol/L) is the concentration of NaOH, V1 (mL) is the volume of NaOH, V2 (mL) is the total volume of apple juice, V3 (mL) is the titration volume of banana juice mixture, W (g) is the total weight of the banana.

RESULTS AND DISCUSSION

The study was conducted to investigate the effect of acid soluble chitosan on the shelf life of banana in term of weight loss, peel colour changes and titratable acidity. The findings are discussed as follow.

Weight Loss

During the 12 days of storage observations, a statistically significant variation of weight loss was found on the final day of investigation where the overall of all uncoated banana for each batch of treatment showed significant higher percentage of weight loss compared to coated banana with ASC solution. The results of weight loss percentage are shown in Figure 1.

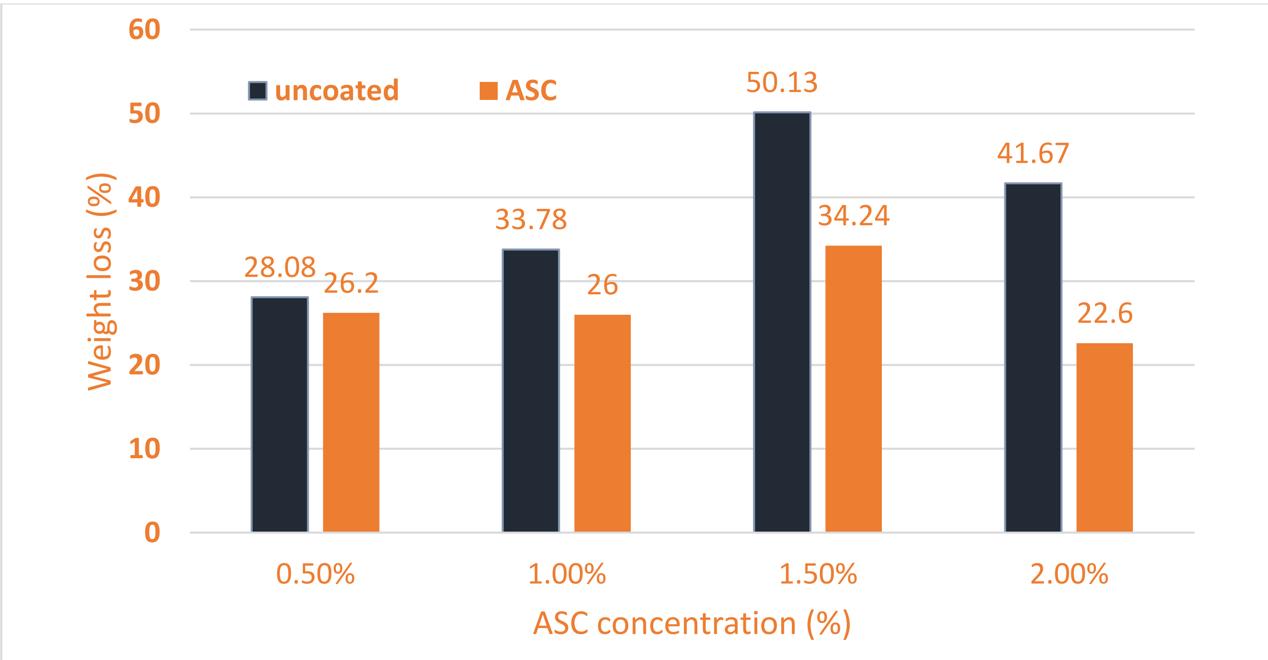


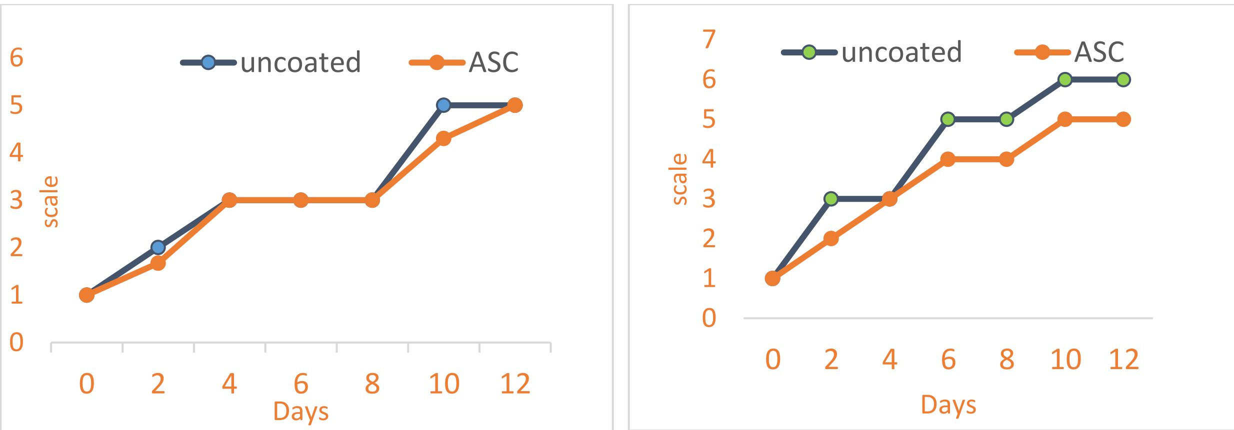
Figure 1: Weight loss of banana after 12 days at different concentration of ASC solution.

From the results show in Figure 1, the percentage weight loss for uncoated banana for all concentration was significantly higher than coated banana with ASC, ranging from 28.08 to 50.13%. While for the coated banana with ASC, the percentage weight loss ranged from 22.6 to 34.24%. The lowest percentage weight loss was recorded for 2.0% ASC solution and the highest was 1.5% ASC solution which were 22.6 and 34.24% respectively. The physiological weight loss between coated and uncoated banana was also reported by Suseno *et al*., (2014).

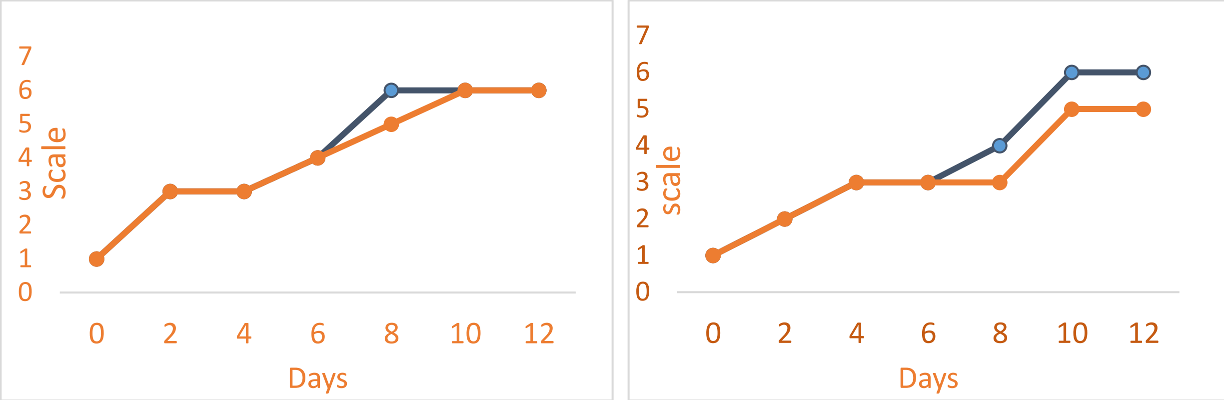
The primary reason for weight loss from banana was due to vapour-phase diffusion which was driven by a gradient of water vapour pressure between inside and outside of the banana which leads to a higher in transpiration process (Suseno *et al*., 2014). By coating banana with ASC solution, it can improved several aspects of the banana such as increased in barrier properties of the cell wall, prevention of water transfer, as well as sealing small wounds which can result in protecting the fruit skin and delaying dehydration. Between all four types of concentration, 2.0% ASC solution results showed the lowest weight loss percentage due to the higher chitosan concentration. A higher chitosan concentration will results in greater thickness of coating on the peel surface, thus increase firmness and reducing moisture loss (Suseno *et al*., 2014).

Peel Colour Changes

The occurrence of peel browning on banana is one of the main symptoms of postharvest problem for farmers and seller, which can significantly affect the quality of banana thus shorten the shelf life of banana. The peel colour changes were recorded with the help of a chart (1-10 scale; 1- green, 2- green with trace of yellow, 3- more green than yellow, 4- more yellow than green, 5- yellow with trace green, 6- full yellow, 7- yellow with brown spots, 8- more yellow than brown, 9- more brown than yellow, and 10- full brown). Figure 2 showed the results of peel colour changes for banana for 12 days storage.



(a) (b)



(c) (d)

Figure 2: The peel color changes at (a) 0.50%, (b) 1.00%, (c) 1.50% and (d) 2.00% ASC solution.

From the results obtained after several days, it showed that the browning can be seen starting day 4 for every treatment for uncoated banana as well as coated banana with ASC solution. However, the uncoated banana reached fully brown, which is scale 6 starting day 10 for all concentrations except 1.50% ASC solution. For coated banana with ASC solution, the peel browning reached fully brown starting day 10 for 1.50% ASC while for 0.50, 1.00 and 2.00% ASC, the peel colour has yet to be fully brown during day 12. This showed that these concentration of ASC can delay peel colour browning up to 12 days. The coated banana with ASC showed a slight change in colour due to the higher protection against moisture cause by the barrier formed by the coating and this will decline the respiration rate of the banana. This also can alter the amount of chlorophyll which indicates the reduction in the aging of the banana (Soradech *et al*., 2017).

Titratable Acidity (TA)

The effect of different coatings on the TA of bananas after 12 days of storage are shown in Figure 3.

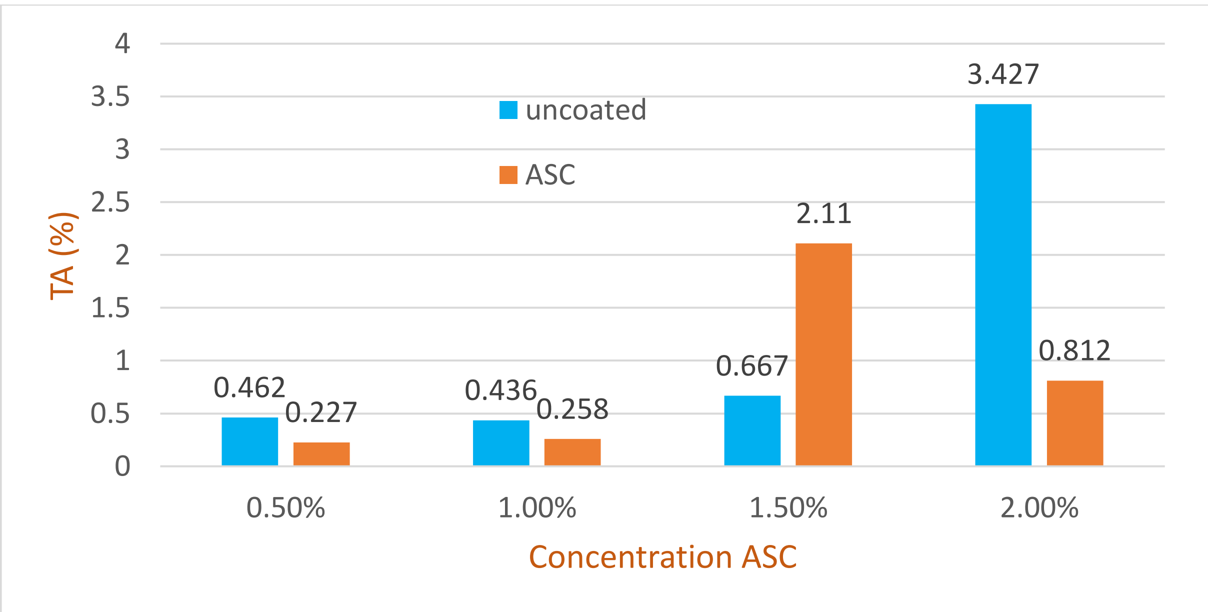


Figure 3: Titratable acidity of banana after 12 days of storage after coating with different concentration of ASC solution.

The result shows that the TA value for uncoated banana during treatment 0.5, 1.0 and 2.0% ASC was higher than the coated banana with ASC, while on the other hand 1.5% ASC TA value was lower during treatment. These results obtained also showed that lower TA value was recorded at lower concentration of ASC solution which was 0.227 and 0.258 % for 0.5 and 1.0% respectively. This indicate that lower concentration of ASC solution can reduced the amount of TA better than a higher concentration of ASC solution. The same results also has been reported by Soradech *et al*., (2017) where samples with coated film can reduce the amount of TA. This is because due to the change in the prevalent organic acids in the banana fruit such as malic acid and citric acid, where they can act as a substrates for the enzymatic reaction of respirations. Besides that, other study also reported that TA value decreased when coating fruit with chitosan where Jiang *et al*., (2005) reported that chitosan can reduced the amount of TA for litchi fruit.

CONCLUSION

In conclusion, chitosan coating could be considered as one of the commercial application to improve the shelf life of banana fruit and also maintain the quality of banana during storage. *In terms of weight loss, among four different concentration of chitosan coating solution, the 2.0% chitosan coating solution showed the lowest weight loss percentage which is 22.6% compare to others significantly. The result also revealed that between the uncoated banana and coated banana at different concentration of ASC solution where the peel colour changes were significantly different during the first day and the final day of observation for each concentration. A significant variation was observed for the titratable acidity of the banana fruit where the lowest value obtained was 0.812% during coating with 2.0% chitosan coating solution while the highest titratable acidity was observed during the coating with 1.5% chitosan solution which is 2.11%*. Some previous study have shown that chitosan can successfully inhibits postharvest diseases of fruits where chitosan can control the respiration process of the banana. Our study suggest that chitosan can effectively prolongs the quality of banana during storage as chitosan can decrease the weight loss, delay peel browning process as well as lower the titratable acidity.

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NATURAL RESOURCE-BASED RECREATIONAL ACTIVITIES DURING COVID-19 PANDEMIC: A LOCAL COMMUNITIES PERSPECTIVE IN SABAH, MALAYSIA

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ABSTRACT: *The COVID-19 pandemic has disrupted many activities, including tourism and recreational activities. This study determines the local communities' perceptions of local recreational activities or staycation based on the natural resources in Sabah during the pandemic. Using the convenience sampling method, the questionnaire survey was distributed to respondents through social media and email. Respondents including students, government, and private sectors were from different socio-demographics. Most of them preferred recreational activities based on nature-panorama activities, followed by those who chose extreme activities such as hiking, cultural base recreation, river-based activities, leisure vacation and jungle trekking. The respondents opined that recreational activities could generate income for the state's economy. They perceived that the assistance provided by the government could help recover the present state to its original condition. Among the elements that needed special attention and improvement were related to the safety of visitors, the cleanliness of the surrounding recreation sites, the landscape beautification and basic infrastructure facilities. Among the roles that the government could contribute to stimulating and uplifting the tourism and recreation sectors include funding and finance allocation to help the industry players, promotion and publicity, upgrading and maintenance of facilities such as infrastructures and enforcement of related laws and policies. Reviving the local tourism is promising as long as the public observe the state's Standard Operating Procedure (SOP).*

KEYWORDS: COVID-19 Pandemic, Natural Resources-Based Recreation, Local Communities, Staycation, Tourism

INTRODUCTION

Natural resource-based recreational activities are referred to as vacations involving people connecting with the surroundings (Valentine P., 1992). The natural resources, also referred to as Alfresco or outdoor recreations, are the pull factors that draw visitors for recreational activities (Hall C.M., & Boyd S., 2005). In a broader term, tourism or ecotourism denotes the people's recreational activities. When it comes to the local level, the recreational activities are staycations in which the local community travels to local destinations for recreation. The additional themes that are used locally to imply the natural resources for recreations and tourism in Sabah are biophysical (Pei Sung *et al*., 2012), culture and heritage (Md Zain *et al*., 2015; Latip, N.A. *et al.*, 2018), community-based tourism and indigenous tourism (Latip, N.A. *et al*., 2018), rural tourism, agro-tourism (Jaafar M. *et al*., 2013), Astro or star tourism (Fong, 2021), adventure (Nik Hashim *et al.*, 2020), as well as the idea of 'dark tourism,' which is less popular among the locals. (Masanti M., 2016).

Outdoor recreations and nature-based tourism provide ample benefits to individuals, communities, and society. Several studies have proved that visiting natural settings and outdoor activities could enhance human health, improve social connection, and connect people to nature and their natural heritage. Wolsko et al. (2019), for instance, reported that people who frequently engage in active nature-based activities such as fishing, camping, hunting and other physical recreations would experience self-restoration, stress reduction, well-being improvement and positive feelings. People also begin to be aware of the environmental problems and their commitments to protect the recreation sites. Kuo (2015) also suggested that exposure to a greener natural surrounding could reduce the risk of morbidity and mortality as natural environments carry chemical and biological agents which have health implications in the long run. Tourism in protected areas also benefits in terms of the financial sustainability of the nation, promoting the sharing of benefits amongst stakeholders, and increasing the possibility to achieve conservation and biodiversity goals (Synman & Bricker, 2019). Recreational and tourism activities have been significantly disrupted due to the government's movement control order, announced after the Covid-19 breakout in 2020. The literature section of the study will focus on the background of nature-based recreational activities and the overall impact of Covid-19. There have been few studies on the impacts of the COVID-19 pandemic on natural resource-based recreational activities locally. Therefore, this study aims to address the issues on the current and post-Covid prospects of nature-based recreations and tourism, particularly the preference of activities, destinations, and the general perceptions and considerations of improving the nature-based recreational activities from the perspectives of the local communities.

LITERATURE REVIEW

Sabah is known as the 'land below the wind', blessed with natural beauty as it is covered with extensive rainforests, captivating ancient caves, beaches, and islands. Sabah encapsulates the third largest island in the world (Amazing Borneo, 2021), with a vast diversity of landscapes, mountains, and environments. The biodiversity of flora and fauna, islands, cultures, and ethnic diversities, would satisfy most adventure seekers who enjoy nature-based recreational activities (Bedford, 2018). Among the most known and prominent natural resources-based destinations of interest in Sabah is Sabah Park, which consists of four terrestrial parks featuring the famous Mount Kinabalu and five marine parks. The Sabah Tourism Board has recorded 4,195,903 total visitors in 2019; about 1,469,475 were international tourists from China, South Korea, Brunei, Taiwan, Singapore, United Kingdom, Ireland, Japan, the Philippines, Australia, and the USA (Usop, 2020). The astronomical number of visitors shows that nature-based tourism is the fastest-growing sector. It appears that the protected areas have become the prominent destinations of interest (Winter et al., 2019). However, the number of tourists plunged drastically in 2020 after the movement control orders (MCO) were introduced and enforced when the pandemic covid hit the country (Sabah Board Tourism, 2021).

The Coronavirus disease (Covid-19) has exponentially affected public health. The ongoing transmission of the pandemic has severely impacted most operations around the globe. Meanwhile, every state in Malaysia is recently under different phases of the National Recovery Plans (NRP). All activities have strictly adhered to Standard Operating Procedures (SOP) (Flanders Trade, 2021). The prolonged enforcement of the MCO, which was first imposed in March 2020, has been seen to severely impact most businesses and disrupt their economic revenues, especially those sectors which were not listed as essential services. These include tourism sectors such as airline and hotel businesses (Lee-Peng Foo et al., 2020). Dzulkifly (2020) reported that during the first two months of 2020, Malaysia had lost RM 3.37 billion in the tourism sector as most tour were cancelled, thus affecting those who worked with airlines, hotels, and transport industries. Malaysia's Gross Domestic Product (GDP) growth for the year deteriorated from 0.8 to 1.2 points, with an expected total loss of up to RM17.3 billion.

In January 2020, Sabah was the first state to ban the entry of tourists from China to halt the local spread of Covid-19 (Bernama, 2020a). Chinese tourists were perceived as the largest contributors to tourism economies in Sabah. There was a sudden decrease in tourist arrivals with a total of 567,108, which was about an 86.5% decline of tourists compared to tourist arrivals in 2019 (Goh, 2021). The restricted operation of these non-essential activities had caused many related companies, travel agents, communities, and individuals to lose their incomes due to the imposition of physical and social isolation to slow down the spread of the virus. According to Nga et al. (2021), the data retrieved from the Social Security Organization (SOCSO) showed that the loss of employment in Sabah were those with maximum wages less than RM2000 (about 74.6%). This makes Sabah the most severe state impacted by job loss in Malaysia. It was perceived that most businesses in Sabah are related to tourism, thus contributing to the unemployment issues.

The closure of the international border has hindered the entry of international tourists to Sabah. This has affected the livelihood of the local communities. This situation can be seen among low wage earners who depend solely on a single job. For example, a local tour guide in Kinabatangan, Sabah admitted that he had lost his source of income showing tourists Bornean pygmy elephants and proboscis monkeys because there were no tourists. He now lives on the government assistance (Wong, 2020). The United Nations World Tourism Organisation also reported that the continuing crisis might affect women involved in the tourism workforce. Since most of them are in the low-skilled or informal work categories which do not have access to social protection (UNWTO, 2021a). In Sabah, women are mostly engaged in community-based tourism. They generate their income by producing traditional handicrafts, sharing cultural festivals, introducing local delicacies, offering fish spas, providing homestays and many more (Tibok, 2018). Hence, their businesses are hit hard by the pandemic.

The natural-based recreational activities in Sabah are mostly associated with its natural biodiversity and wide-protected areas. During the Covid-19, none of these activities is allowed to operate, causing Sabah to lose its state revenue as tourism is the third-largest contributor to Sabah's GDP, which supports more than 80,000 jobs (The Borneo Post, 2020 & Sabah Tourism Board, 2021). The tourism loss of revenue may disrupt the source of conservation funding. The fund from tourism activities is used to maintain the protected areas, including law enforcement, poaching control and other illegal activities. The local communities rely on natural resources as they have already lost their income (BIMP-EAGA, 2020). As reported by various local news, there were few cases in Sabah on illegal poaching and hunting of wildlife amid Covid-19 transmission. For instance, the enforcement operation against forest crime and wildlife poaching and trafficking led by the Sabah Forestry Department in 2020 had successfully made 68 arrests and confiscated RM3.1 million worth of forest produce from various illegal activities (Free Malaysia Today, 2021).

A similar event happened in early 2021, a male Bornean Pygmy elephant in Tongod, Sabah, was found dismembered and its body parts had several gunshot wounds (Geraldine, 2021). Due to the limited resources, monitoring in every forest reserved and protected area in the whole state has been somewhat impossible during the pandemic. Yet, the government authority managed to secure more than 200 enforcement operations to put pressure on poachers and illegal loggers (The Borneo Post, 2021). In addition, the Sabah Parks had also deployed their enforcement teams around the protected areas in Kinabalu Park to look out for intruders who intended to illegally collect valuable plants such as *Caladium* and *Alocasia* as many communities have shifted to gardening and this has fuelled the demand for wild plants (Daily Express, 2021).

It is suggested that the impacts caused by the pandemic is not completely obstructive. Some studies have pointed out that the transmission of pandemics gives opportunities for 'nature recovery'. Throughout the pandemic, it has shown that the mobility restriction improved the air quality (Monteiro *et al*., 2021), reduced the emission of greenhouse gases due to reducing travel (Varzaru *et al*., 2021) as well as reduced over-tourism (Higgins-Desbiolles, 2020). Fewer tourists' visitation in a protected area could give ample time for nature to recuperate and attract inhabitants back to their habitats, as reported in Kinabalu Parks protected area (Bernama, 2020b). It is also predicted that the rebound in international tourism, a return to pre-pandemic 2019 levels, will not occur before 2023 (UNWTO, 2021b). Thus, domestic demand would recover faster than international demand (Goh, 2021). The pandemic should not be viewed as a crisis but an opportunity to rethink sustainable tourism models without excluding the rights of the community and nation interests (Varzaru *et al*., 2021). Sabah has a huge ecotourism attraction for tourists, which is an advantage for tourism recovery. It is expected that the travellers may have some behavioural patterns changing preference (Lai, 2021). Hence the pre-existing issues on tourism need to be reviewed, so that new approaches can be adopted to achieve more sustainable tourism (Goh, 2021).

MATERIALS AND METHODS

Using convenience sampling, the questionnaire survey through the online survey monkey was developed and emailed to the respondents. The data collection was conducted from November to December 2020. The questionnaire was divided into three main sections, namely (i) socio-demographic of respondents, (ii) preference and participation in natural resource-based recreation activities, and (ii) general perception and consideration of improvement needed for nature-based recreation activity in Sabah during the COVID-19 pandemic. The survey consisted of both open and closed-ended questions, statements were rated on 5 points Likert scale with 1- indicate Highly Not Agree, 2-Not Agree, 3-Moderate, 4- Agree, 5–Highly Agree. Data were analysed based on descriptive statistics that involved frequency, percentage, score ranking and weighted average.

RESULTS AND DISCUSSION

Results

215 respondents who participated in the study were in the 18-25 age group (55.61%), followed by 26-30 age group (11.66%) and 41-45 age group (8.88%). A total of 110 (51.40%) of the respondents were students, 33 (15.42%) were government employees, and 53 (24.76%) were private and self-employed employees. Most of the respondents, or 85.26% (131), were enthusiasts of natural resources-based recreational activities, while 13.07% (20) of them participated actively in the recreational activities. 11.76% (18) of the respondents were involved in recreational and tourism employments, while only 1.31% (2) were operators or the owners of the tourism businesses. The respondents' scores based on the preference for nature-based recreational activities were related to the nature panoramic or picturesque (Table 1). It is followed by extreme based activities such as mountain or hill climbing, cultural-based recreation, river-based activities (e.g., kayaking, swimming), leisure and jungle tracking.

Table 1: Ranking of Preference for Natural Resource-Based Recreational Activities

RANKING	Number of respondents (Percentage, %)						SCORE ± SD	n
	1	2	3	4	5	6		
Nature Panoramic	69 8.16%	27 18.37%	16 10.88%	20 13.61%	3 2.04%	12 8.16%	4.70 ± 1.59	147
Extreme based (mount climbing etc.)	19 12.67%	37 24.67%	35 23.33%	26 17.33%	16 10.67%	17 11.13%	3.77 ± 1.69	150
Cultural	12 8.39%	38 26.57%	24 16.78%	17 11.89%	21 14.69%	31 21.68%	3.37 ± 1.52	143
River-based (e.g., Kayaking, white water rafting)	15 10.14%	16 10.81%	34 22.97%	28 18.92%	34 22.97%	21 14.19%	3.24 ± 1.52	148
Leisure	25 16.78%	14 9.40%	16 10.74%	20 13.42%	33 22.15%	41 27.52%	3.03 ± 1.82	149
Exploration / Jungle Trekking	5 3.38%	13 8.78%	23 15.54%	37 25.00%	43 29.05%	27 18.24%	2.78 ± 1.33	148

Some keywords mentioned in the preferred destinations were specific towns, mountains or hills, forests and rivers, islands, villages, public parks, hot springs, beaches, waterfall, wildlife, resort, and cultural village (Figure 1). The most mentioned destinations were Ranau, Kundasang, mount Kinabalu and Kinabalu Park, Semporna, Kota Belud, Kiulu and Kinabatangan River, waterfalls, island, and beach. The respondents also mentioned other places of interest, which they have not visited yet but are looking forward to visiting these areas in the future, such as Mount Kinabalu, Maliau Basin, Kundasang, Ranau, Lembah Danum, Semporna and Sandakan. The places of interest are related to various natural resources-based destinations, including islands, forests, and geographical characteristics like mountainous areas in Mt. Kinabalu in Kundasang and Ranau.

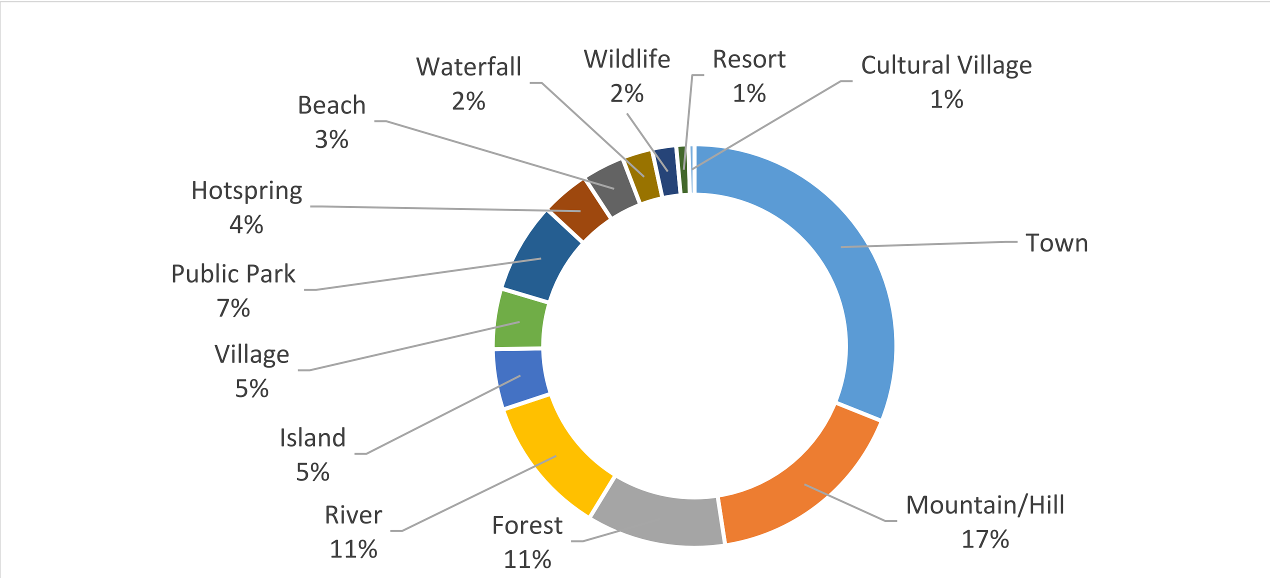

Figure 1: Preferred destinations for Recreational Activities (N=215).

The respondents' agreed that nature-based tourism has a great potential in generating income and creating many economic opportunities for the state with a weighted average of (4.59), based on the Likert Scale (1-Highly Not Agree, 2-Not Agree, 3-Moderate, 4- Agree, 5–Highly Agree). They also agreed that natural resource-based tourism was severely affected by the pandemic Covid-19 with a weighted average of (4.25). Those who perceived that they required dire assistance from the government to bring back the industry to its previous state was 4.34. On the special attention and improvement needed by the nature-based recreation and tourism, the highest agreement is on ensuring the safety of visitors, followed by the surrounding cleanliness of the recreation site and the beautification of the surrounding landscape (Table 2). The respondents also agreed on improving and maintaining or developing basic infrastructure and facilities such as roads, water, toilets, etc. They presumed that study is needed to determine the reasonable rates of charges and service fees, the visitor's carrying capacity, and the customer's satisfaction level.

Table 2: Consideration and improvement needed for nature-based recreation, N=156

	Number of respondents (Percentage, %)						
	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree	Weighted Average ± SD	n
Basic infrastructure and facilities	2 1.28%	0 0.00%	9 5.77%	42 26.92%	103 66.03%	4.56 ± 0.72	156
Surrounding cleanliness	2 1.29%	1 0.65%	3 1.94%	24 15.48%	12 80.65%	4.74 ± 0.65	156

Landscape beautification	2 1.28%	0 0.00%	11 7.05%	33 21.15%	110 70.51%	4.60 ± 0.73	156
Safety of visitors	2 1.28%	0 0.00%	8 5.13%	14 8.97%	132 84.62%	4.76 ± 0.66	156
Reasonable rates of charges and fees	2 1.28%	1 0.64%	9 5.77%	44 28.21%	100 64.10%	4.53 ± 0.75	156
Visitors carrying capacity studies	2 1.92%	1 0.64%	8 5.13%	49 31.41	95 60.90%	4.49 ± 0.79	156
Customer's satisfaction level	2 1.28%	0 0.00	15 9.62%	42 26.92%	97 62.18%	4.49 ± 0.77	156

To restore tourism and recreation, the respondents agree that the education and awareness programs for all levels of society is integral. The restoration and opening of recreation and tourism destinations can be done in phases with strict SOP. The reintroduction of the recreation and tourism package should come with reasonable fees. Besides, cooperation from all parties in the industry was essential. Other measures and considerations suggested were the promotions and campaigns for local tourism or staycation, and rehabilitation of the existing recreation sites. Providing incentives for local recreational and tourism activities and promoting programs through media were also recommended. The respondents also concurred that the industry needs assistance from the government, such as special funding, incentive, and a platform for promoting recreation and tourism activities.

Discussion

Based on the study, there are many prominent natural resources-based programs and activities in the state that could be integrated under nature-based recreation and tourism. Many recreations and tourist destinations can be incorporated in a package under nature-based tourism. Surely, the diversity and richness of the recreational programs and activities can help promote the state as an attractive destination for tourism (Zain et al., 2016). Since COVID-19 has influenced the ecotourism of the state, all related aspects of the tourism industry, the development or improvement of the recreational and tourism industry, and the nature-based recreation and tourism destinations should be integrated. All parties play vital roles to manage or develop the prospects of tourism and recreational activities. Collaboration with those directly involved with tourism and those from the local community is important. The government has a more prominent role in determining how to improve the recreation and tourism (UNEP and WTO, 2005).

It is time to upgrade the marketing or benefit-sharing by conducting research, promotion, enhancement, and rebranding. The recreation and tourism industry should be restored and upgraded (Abbas et al., 2021). The visitor's safety hygiene is the main focus. The promotional efforts in reviving the tourism industry in the 12th Malaysian Plan 2021-2025 are underway (Bernama, 2021). To revitalise the tourism sectors, several strategies have been adopted such as campaigns to restore the tourists' confidence, increase the incentives and promotion of domestic ecotourism products and services. Establishing monitoring mechanisms, reforming the governance, upgrading and marketing the products, and promoting the local communities' engagement with the private sectors are some of the strategies (Bernama, 2021).

After the post-pandemic, to attract international tourists, local recreations and tourism could be the starting point. The current progress and observation show how the government handles the pandemic COVID-19 situation is remarkable. It includes the enforcement of strict SOPs and MCO approaches to restrain the pandemic COVID-19 and by striving for the prospect of the industry. Funding and finance allocation to assist industry players, promotion and publicity, upgrading and maintenance of facilities such as infrastructures, and enforcement of related laws and policies are just a few of the roles that the government could play in stimulating and uplifting the tourism and recreation sectors.

CONCLUSION

Information and reflection from the local community on the local natural resource-based recreational programme and activity can contribute to the future progress of the industry. The diverse range of natural resource-based recreational programmes and activities has made Sabah a popular tourism destination for local and international visitors. The COVID-19 pandemic has affected the recreation and tourism industry. Consequently, restoring recreation and tourism at the local level is a way forward. Therefore, it is essential to rejuvenate the local tourism so that this industry is ready for the next phase vis-à-vis attracting international tourists to our state. Some of the considerations to refresh the nature-based recreational activities from the local communities include visitors' safety, and hygiene. Also, the beautification of the surrounding landscape is of paramount importance. When all of these are in place, recreation and tourism industry in Sabah is set to sustain its growth. With the current scenario of the COVID-19 that is still occurring, further study is recommended to be conducted from time to time to monitor the progress of the sector based on the latest development of the pandemic.

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