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Decomposing Process of Food Waste using Black Soldier Fly Larvae (BSFL): Case Study in Taman Pura Kencana, Johor

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Abstract: Food waste is one of the critical issues which has been discussed in many countries including Malaysia. Apart from that, about 50% of food waste usually being dumped at landfill sites and incinerators which root to more problems towards the environment, economic and society. In this research, Taman Pura Kencana, Johor was chosen to identify the average total of food waste generation from selected households in 3 months from April 2021 to June 2021 and to determine decomposing days of food waste using BSFL. Raosoft Sample Size Calculator was used to calculate sample respondents bringing 48 households in this research. Hence, the average total of food waste generation from households per month was 1056.82 kg The collection of food waste from selected households in Taman Pura Kencana during the normal month of June was the highest compared to the fasting month in April and Eid month in May. 25 samples of food waste were examined to identify duration of decomposing days using BSFL based on pH, temperature and moisture content. The results showed that, the food waste successfully decompose after 10 days compare to control sample which was taking the longest time to fully decompose at about 90 days. The range of average temperature of the food waste using BSFL were 27℃ to 34℃. The initial range of average pH value for the food waste samples were 3.22 to 4.00 while on the last decomposing days of the food waste samples were 7.06 to 7.12. Moisture content for food waste samples is 51% except for control sample. Inconclusion, BSFL were the ideal insects to decrease amount of food waste in landfills and incinerators as they could accelerate the time of composting food waste and could reduce the negative impacts towards the environment, economic and society.This research's findings will help create awareness and a better understanding of how much food waste could be generated from residential area, as this contributes to many negative issues when discarding them through landfills and incinerators.

Keywords: Food waste generation, households, incinerators, landfills

1. Introduction

Food waste was a worldwide issue which obtaining additional concern due to food security problems and associated environmental impacts. According to Muth *et. al.*, (2019) upstream production and post-harvesting process contribute

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nearly 54 % of food waste in the global food supply chain. In contrast, the remaining 46 % of food waste is generated during manufacturing, consumption and transportation. Notably, the global value of annual food waste is appraised at $1 trillion which indicating a large amount of money needed to spend specifically on food waste production (Septianto *et. al*., 2020).

Food waste usually consist of 90% organic matter such as leftover rice, vegetables and fruits whose moisture level could reach up to 80% (Charkhestani *et. al*., 2022). Among all types of organic waste, 40% to 50% was from food waste contributing to the percentage of municipal solid waste in Malaysia (Zamli *et. al*., 2021). This statement is also supported by (Woon *et. al*., 2021) which mentioned about 45% from 70% of the total municipal solid waste in Malaysia was food waste. Additionally, food waste is usually produced in three places namely residential, commercial and institutional but the highest amount of food waste was found in households (Maroušek *et. al*., 2020).

Notably, about 38.32% of food waste in Malaysia generated from households making it the primary contributor to food waste productions (Wong *et. al*., 2021). At the same time, Mohd Yatim *et. al*., (2019) 50% out of 70% of daily generated municipal solid waste in Malaysia was food waste which usually disposed of at landfill sites. Based on previous researches, food waste generation kept increasing yearly contributing to many negative issues in many countries. Significantly, large food waste production was due to population growth, consumer behaviours, food processing stages and food waste policies.

One of the biggest challenges to dispose of food waste was non-adequate landfill sites as there was too much waste to fill up the sites in a short time. Moreover, human population was getting increased annually, leading to high cost of land and lack of land available (Mohd Yatim *et al*., 2019). Other than that, assorted environmental problems could occur from landfill sites such as groundwater contamination, leachate, toxic gases and odour diffusion which mostly came from food waste. These problems are also related to the condition of weather in Malaysia which are experiencing hot and rainy days suited for microbes to degrade solid waste and food waste. At the same time, waste degradation could diffuse leachate together with bad odour. Regarding to these issues, food waste must be managed sustainably in order to prevent environmental problems and subsequently provide convenient infrastructure for future generations.

Correspondingly, (Foday *et al*., 2017) mentioned that food waste was also being the main problem in Johor as it was the second highest percentage of waste composition after plastic waste. Specifically, in Taman Pura Kencana, Johor, the highest ranking of generated waste was from food waste (Abdul Kadir *et al*., 2017). According to Abdul Kadir *et al*., (2017) food waste production in Taman Pura Kencana became a main contributor of waste composition generating about 47.87% of food waste per week. The food waste in this mixed area of residential and commercial sources mostly came from households. Most of the food waste consisted of leftover, expired food, rotten fruits and vegetables.

Subsequently, SWM Environment Sdn. Bhd. was the concession company that managed the waste collection in Taman Pura Kencana, Johor. The food waste was disposed of by using landfill sites at Kulai, Johor. However, these methods were not practically sustainable as they brought a lot of disadvantages to the environment, economics and society. This could be seen through a statement from Rasool *et al*., (2021) which mentioned that discarding food waste on landfill sites would cause many negative issues namely greenhouse gases productions, toxic leachate and bad odours. In other cases, incinerators produced excessive carbon dioxide, toxic chemicals and high maintenance cost which proved this method unsuitable for use (Sridhar *et al*., 2021).

Particularly, 8% of total greenhouse gases was produced from global food waste generation, equivalent to 4.4 billion tonnes of carbon dioxide (Jeswani et al., 2021). According to Usmani *et. al*., (2021) one tonne of food waste on landfills sites could generate about 580 tonnes of carbon dioxide. Currently, Malaysia produced 29 million tonnes of carbon dioxide per year and 10 million from it was produced by 16,687 tonnes of food waste in 2019 (Sinha *et al*., 2021), (Mohamed Zain & Abdul Rahman, 2021) At the same time, one tonne of food waste incinerated could produce 700 kg of carbon dioxide which also pollutes the air (Christensen & Bisinella, 2021).

Other than that, the excessive water content in food waste could generate high leachate production and toxic gases in landfills and also during incineration. This could harm peoples' health as this could affect natural resources, namely air and groundwater when there were no protective measures were taken during discarding the waste (Silva *et al*., 2020). Some options to minimize environmental issues such as using sanitary landfills which providing better treatments during discarding the waste and installed gas trap technology while using incinerators. However, they created another issue when the capital cost for sanitary landfills and incinerations in Malaysia were extremely high which took about RM 114 million and RM 68 million respectively (Ooi & Woon, 2021).

Thus, to reduce the amount of food waste at landfill sites and incinerators, some initiatives published by the government of Malaysia in its main policy include waste reduction, reuse of materials and recycling projects *(Yong et al*., 2019). This could be seen by 3R's concept namely reduce, reuse and recycle. However, this concept was ineffective due to lack of awareness of the concept and the unbothered attitude of people, which made this concept only contributed about 5% (Wong & Roslan, 2019).

2. Background of Study

Subsequently, food waste from households in Taman Pura Kencana was disposed of through landfills and incinerators in Johor. Based on previous studies, landfills in Malaysia are not adequate to handle the capacity of various types of waste, including food waste as the amount of waste keeps increasing. Other than that, (Al-Obadi *et al*., 2022) mentioned that disposing of food waste at landfills could pollute ground water and cause the appearance of leachate. At the same time, the production of greenhouse gases could take place along with methane gases once the landfills operate and even after they shut down. In the meantime, using incinerators still contributed to environmental issues regarding the presence of flue gases and the high production of nitrous oxide (Simanjuntak *et al*., 2022). Flue gases from incinerators consist of gases and particles which genuinely risky and toxic to the environment.

Particularly, Ali *et al.*, (2019) discussed that the investment cost and operational cost for a landfill were overall RM 26 million to RM 42 million and RM 31 million to RM 77 million tonnes of municipal solid waste which contained 50% of food waste per year respectively. This could be worse when using incinerators as the cost was genuinely high. This could be seen when the operational cost for incinerators in Malaysia was RM 93 million to RM 232 million per ton of food waste. At the same time, the capital cost of an incinerator facility with a capacity 800 to 1000 tonnes of food waste is approximately RM 500 million until RM 800 million (Bashir *et al*., 2019).

In the meantime, discarding food waste through landfills could bring high leachate contamination to groundwater, allowing inorganic pollutants to pass through the water (Kurwadkar *et al*., 2020). This could be harmful to humans' health as groundwater was one of the primary sources of drinking water. Other than that, the rising level of greenhouse gases caused by landfills was due to the enormous amount of carbon dioxide, methane and nitrous oxide released into the air and trapping heat which also caused global warming. Meanwhile, toxic organic pollutants released from incinerated food waste could irritate human's skin and human carcinogens that root to cancer (Rovira & Domingo, 2019).

On the other hand, flue gases usually emitted from incinerators could impact the society's health by having birth defects and tumors which could even lead to mortality (Di Maria *et al*., 2021). As a result, the public need to face these kinds of illnesses namely heat stroke, hypotension, and loss of consciousness which in several cases could lead to death (Ahima, 2020). (Gholami *et al*., 2020) mentioned that eye irritation, chest tightness, nausea and headache could occur if a lot of nitrous oxide is released into the air.

3. Black Soldier Fly Larvae (BSFL)

There were 5 genes belong to sub family Hermetiinae namely *Chaetosargus*, *Patagiomyia*, *Chaetohermetia*, *Notohermetia* and *Hermetia illucens*. Particularly, the most popular gene which being used in animal feeding was *Hermetia illucens* which also known as black soldier fly (BSF). This species was highly distributed in warm temperature zone of America and currently spread in warmer regions throughout the world (Salomone et al., 2017).

Lifecycle of BSF involved 5 phases namely eggs, larvae, prepupae, pupae and adults. Among all of these phases, hatching eggs and adults BSF were having minimal time in this lifecycle compared to larvae and pupae phase. The lifespan of adults BSF was 5-8 days and depend to environmental condition where BSF would live longer if it was in favourable conditions (Muhamadi Saifulizan, 2021).

Kim *et al*., (2021) and Al-Obadi *et. al*., (2022) stated that one of the practical method for sustainable waste management in Malaysia was using Black Soldier Fly Larvae (BSFL) which provided environmentally friendly treatment in food waste. This method could be used for composting organic waste which consequently generated high nutrients of natural fertilizer (Muhamadi Saifulizan, 2021). BSFL also helped in decreasing the food waste at landfill sites and protecting the environment since there were no harmful chemicals involved in this method. In addition, BSFL method have been used in Malaysia to compost food waste and also being used in animal feeding which mentioned by Ahmad et al., (2022); Jalil *et al*., (2021); and Ng et al., (2021). Additionally, application of BSFL method could least the negative impacts to the environment, economic and society.

4. Materials and Methods

4.1 Materials

Food waste from selected households in Taman Pura Kencana was used in this research. A food waste bin was allocated to every selected households to put the food waste. In the meantime, a kilogram weighing machine was used to measure the weight of food waste.

The experiments for decomposing process was using six bioponds where each five bioponds was having five replicated samples of food waste except for control sample which using only one biopond without having any replications. The control sample was labelled as TC (Test Control) with 2 kg of food waste without having any BSFL to decompose. Meanwhile, the other 5 samples were labelled as T1 (Test 1), T2 (Test 2), T3 (Test 3), T4 (Test 4) and T5 (Test 5) with different amount of food waste starting from 2 kg until 4 kg of food waste by having 12g of 4-day-old BSFL in each sample.

The temperature of the surrounding area was measured by using temperature meter while temperature for food waste was taken by food thermometer. At the same time, pH value of the food waste was recorded by using digital pH meter. The accuracy of digital pH meter was done by performing callibration test by using distilled water and buffer solutions. The pH for residue of the food waste samples were measured using digital soil pH meter while temperature for residue was measured using soil thermometer. The digital soil pH meter was used due to final condition of the food waste after decomposing process which called as residue was in a state of soil. Moisture content of the food waste and residue were measured by using gravimetric method where they needed to be heated in oven at laboratory for 24 hours at 105 degree celcius.

4.2 Methods

A few methods that could be used to determine sample sizes in research such as Taro Yamane Formula and Krejcie & Morgan. However, these methods were suitable for survey research but unsuitable for experiment research (Uakarn, 2021). Thus, the number of sample respondents was measured by using Raosoft Sample Size Calculator where this method was suitable for experimental research and was also used by previous researchers namely (Ahmat et al., 2018),(Almeslet, 2019) and (Al-Balas et al., 2020).

Number of sample respondents was calculated by taking into account the significant parts of the sample size elements namely margin of error, percentage confidence level and population size. In the meantime, margin of error was defined as accuracy related to evaluating population data. The margin of error (%) also needed to be small to make the data more reliable (Kosar et al., 2018). Based on (Chiarini et al., 2021) and (Conroy, 2021), the acceptable margin of error for experiment research was not more than 10%. At the same time, the preferred percentage confidence level was more than 80% for experiment research as used by previous researchers namely (Xu et al., 2022) and (Jamshidi et al., 2020). Minimum recommended sample size with 10% margin of error and 80% confidence level was 39 respondents according to Raosoft Sample size Calculator.

However, this research managed to achieve 48 sample respondents in Taman Pura Kencana in alternate scenarios. Subsequently, 48 sample respondents in this research could decreased the margin of error from 10% into 8.92% and increased percentage of confidence level from 80% into 84.5% which suitable for experiment research. According to Sekaran 2000, the ideal sample size of a research was more than 30 and less than 500 which also depend with budgets and time constraints (Asiimwe et al., 2021) and (Halim & Ishak, 2014). In this research, it proved that 48 sample respondents from Taman Pura Kencana was accepted for this research. Furthermore, (Khodier et al., 2020) mentioned that the minimum weight of waste to analyse in sample research was at least 200 kg to make it accurate which was also applied in this research. Hence, this could prove an 8.92% margin of error and 84.5% confidence interval of this research could be accepted and accurate to estimate data in population.

Through sample size calculation, data on food waste generation were collected from 48 households as selected respondents in Taman Pura Kencana. Particularly, food waste generation from households were taken from 48 respondents out of the 671 population in Taman Pura Kencana. Food waste was collected 3 times a week but during the fasting month, the food waste was collected 2 times per week from the allocated bin for each household. At the same time, this research has a collaboration with SWM Environment Sdn. Bhd. They were assisting in collecting food waste from Taman Pura Kencana to Solid Waste Research Centre (SWRC). Food waste collection was conducted for 3 months, from April 2021 to June 2021. All food waste was weighted by using the weighing machine in kilograms to get the total amount of food waste generated by households in Taman Pura Kencana. The data collection process for food waste generation from households in Taman Pura Kencana could be seen clearly through the flowchart in Figure 1.

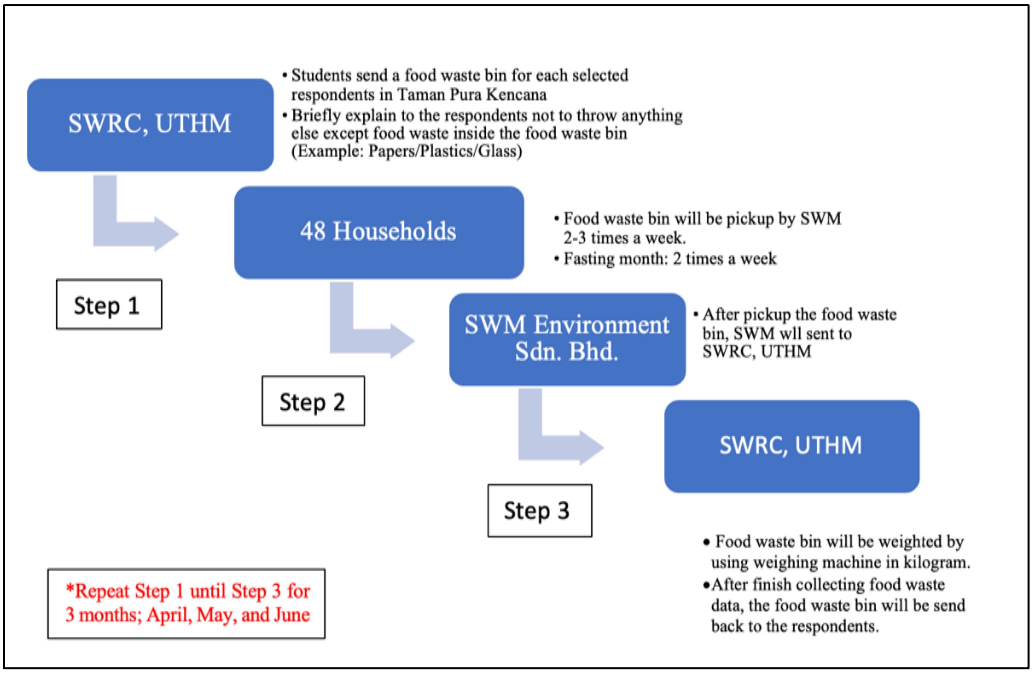

Fig. 1 - Flowchart of food waste collection from households

The temperature for surrounding area was recorded at the site before starting the experiments. After the food waste samples have been placed in the bioponds according to their weight, the temperature and pH value of the food waste were rapidly recorded. After done measuring all the temperature and pH value, 12 g of BSFL was poured on top of each food waste samples except for control sample. Physicochemical parameters such as moisture content, temperature and pH were recorded within 2 days interval and on the last decomposing day of the food waste samples.

5. Results and Discussions

5.1 Food Waste Generation

Table 1 showed food waste generation from selected households in Taman Pura Kencana respectively.

Table 1 - Food waste generation in Taman Pura Kencana (48 selected households)

Households	Months		
	April	May	June
48 Households	776.27 kg	1057.88 kg	1336.32 kg
Total	776.27 + 1057.88 + 1336.32 = 3170.47 kg		
Average per month	3170.47/3 = 1056.82 kg		

Based on Table 1 data food waste generation for households were analysed in column graph based on three months collection showed in Figure 2. Food waste generation from households showed inclination data from April to June 2021. The least amount of food waste could be seen in April which was 776.27 kg for households as the fasting month for Muslims was started on 12th April 2021. Most residents in Taman Pura Kencana are Muslims and usually they would only have their early meal in the morning before fasting and break fasting after sunset.

In the meantime, the amount of food waste in May drastically increased for households, namely 1057.88 kg. This might regard the end of the fasting month which ended on 12th May 2021. Muslims were celebrating Eid and some of them were celebrating holidays in their hometown which might reduce the amount of food waste produced inside the house. On the other hand, the highest food waste production was in June when 48 households generated about 1336.32 kg of food waste. Food waste production during this month could be seen as a guideline for the normal month of food waste generation in Taman Pura Kencana. The total of food waste generation was about 3170.47 kg with average per month 1056.82 kg which showed more than 1 tonne of food had been wasted every month.

5.2 Decomposing Process of Food Waste

Data for decomposing process of food waste samples through physicochemical parameters would be used to justify decomposing days of food waste samples using BSFL as showed in Table 2.

Table 2 - Decomposing days of food waste samples

EXP	T1=2.0kg	T2=2.5kg	T3=3.0kg	T4=3.5kg	T5=4.0kg	TC=2.0kg
1	10	10	12	12	12	90
2	10	12	10	12	12	-
3	10	12	12	12	12	-
4	10	10	12	12	12	-
5	10	10	10	12	12	-

Table 2 shows ten food waste samples decomposed on the 10th day of experiments namely T1,T2,T3,T4,T5 from experiment 1, T1,T4,T5 from experiment 2, and T2,T5 from experiment 3. The other fifteen food waste samples decomposed on the 12th day of experiments which were T2,T3 from experiment 2, T1,T3,T4 from experiment 3, T1,T2,T3,T4,T5 from experiment 4, and T1,T2,T3,T4,T5 from experiment 5. In the meantime, TC was taking the longest time to fully decompose which about 90 days. From this result, it could be conclude that without using BSFL, the decomposing days of the food waste would be numerous and needed to wait for several months compared to food waste samples decomposed using BSFL.

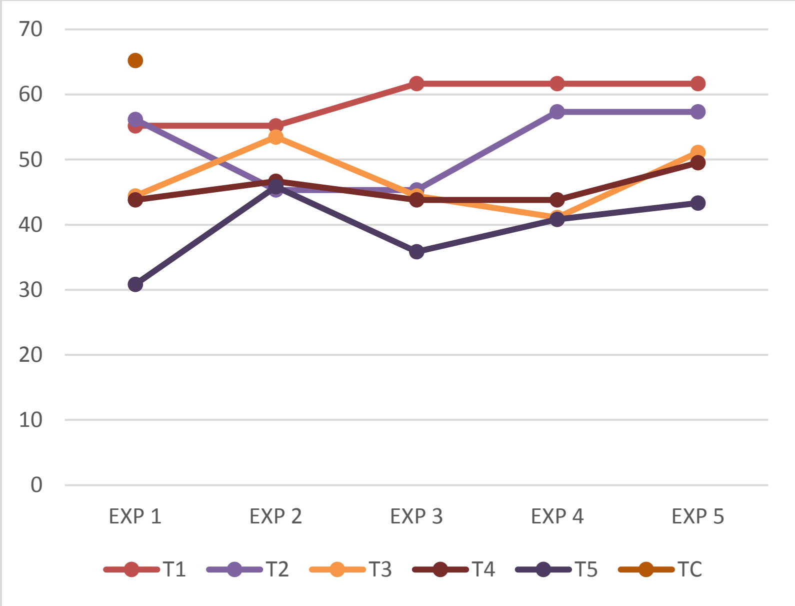

Fig. 3 - Moisture content of food waste samples % based on experiments

Figure 3 shows moisture content of food waste samples in percentage. Moisture content for food waste samples which decomposed during day 10 were in a range of 51% to 62% compared to moisture content for food waste samples which decomposed during day 12 except for TC. Sample TC took longer time to decompose due to no BSFL along the decomposing process even though moisture content of the food waste was 65.2%. Particularly, when the range of moisture contents were between 30% to 50%, the food waste samples decomposed more slower than other samples.

Conversely, even though moisture contents were below 50%, BSFL could still able to grow and decomposed the food waste samples in this condition. From the results, it can be concluded that the best condition of food waste samples for BSFL to decompose was with more than 50% of moisture content. According to Fadhilah *et. al*., (2020), excessive moisture content more than 85% could decreased the decomposition rate of the food waste samples. Thus, the best range of moisture content for food waste samples were between 50% to 85%.

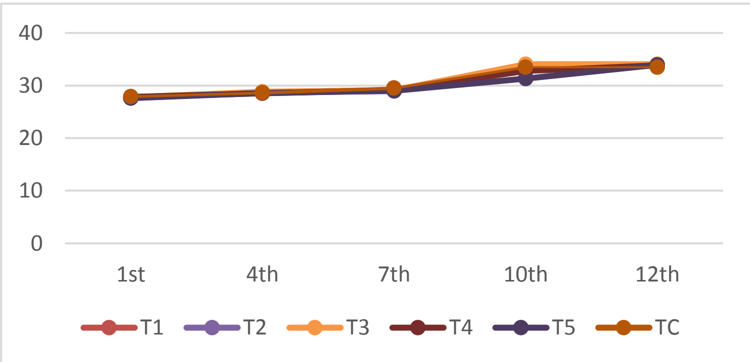

Fig. 4 - Average temperature of food waste samples in days

Figure 4 illustrates average temperature of food waste samples in days. Line pattern for average temperature of the food waste samples were increasing with the lowest temperature of 27℃. On 12th day of the experiment, mostly average temperature of the food waste samples were in the range of 33℃ to 34℃. This may be happened due to heat produced by BSFL while decomposing food waste samples. However, temperature of TC was also rising due to the activity of natural microorganisms which could also decompose the food waste. Thus, from this result, the range of average temperature of the food waste using BSFL were 27℃ to 34℃.

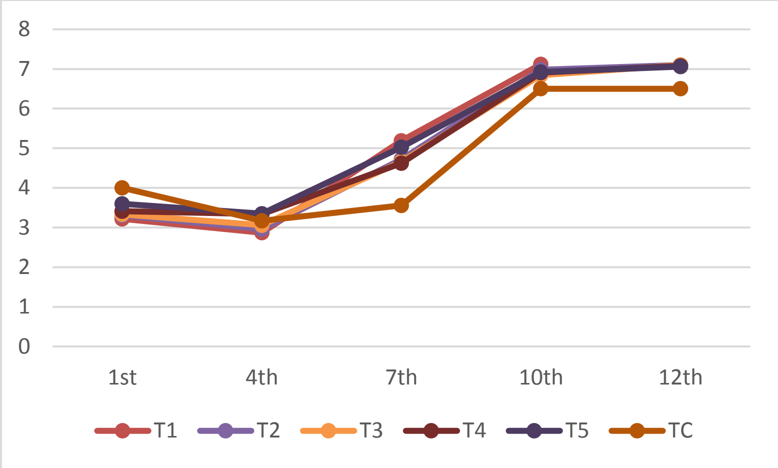

Fig. 5 - Average pH of food waste samples in days

Figure 5 illustrates average pH of food waste samples in days. Line graph for average pH of the food waste samples indicated two variations of pattern. The first pattern shows decreasing value of pH from day 1 to day 4. The second pattern shows increasing value of pH from day 4 to day 10 while on day 12, the pH value was slightly increased. The initial range of average pH value for the food waste samples were 3.22 to 4.00 while on the last decomposing days of the food waste samples were 7.06 to 7.12. However, pH value for TC on 12th day of the experiment was 6.50 which showed this sample was still in acidic condition while others were alkaline. This showed the use of BSFL in food waste was able to fasten the decomposing process of food waste compared to TC.

Notably, according to Fadhilah *et. al*., (2020), the declination of the pH value occurred due to the decomposing process of food waste becoming into organic acids. On the contrary, the inclination of the pH value also happened regarding to the formation of ammonia during decomposing process of food waste samples. From these statements, the decomposing process of food waste using BSFL in this research were showing accurate results as the previous research. Overall, these proved BSFL were having good endurance in pH value where they could live in acidic and alkaline condition which concurrently suitable to be used for decomposing food waste.

6. Conclusions

Inconclusion, the least amount of food waste generated by 48 households could be seen in April which was 776.27 kg while the highest food waste production was in June which about 1336.32 kg of food waste. This brought a total of food waste generation in Taman Pura Kencana was about 3170.47 kg with average per month 1056.82 kg which showed more than 1 tonne of food had been wasted every month. At the same time, average decomposing days of food waste samples using BSFL were only took about 10 to 12 days compared to control sample which fully decomposed in 90 days. Additionally, the range of average temperature of food waste samples using BSFL were 27℃ to 34℃. The initial range of average pH value for the food waste samples were 3.22 to 4.00 while on the last decomposing days of the food waste samples were 7.06 to 7.12. Moisture content for food waste samples which decomposed during day 10 were in a range of 51% to 62% compared to moisture content for food waste samples which decomposed during day 12 except for TC. This showed BSFL could survived in various condition of food waste which is effective to dispose food waste without using landfills and incinerators. Hence, this study could be apply in reducing food waste at the source and decrease negative impacts to the environment, economic and society.

7. Research Contribution in UNSDG

United Nations of Sustainable Development Goals was focussing on zero hunger by achieving food security among people and performing sustainable methods to solve problems. Production of food waste based on three months data collection from selected households in Taman Pura Kencana was more than one tonne per month which might decline the level of food security in this area. Other than that, application of landfills and incinerators as the dispose methods of food waste in Taman Pura Kencana were not sustainable to the environment, economic and society. Throughout this research, level of awareness among users could be increased to decrease food waste and finding sustainable applications to discard food waste.

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References

Abdul Kadir, A., Sarani, N. A., Onthong, S. F., & Haqeem Hassan, M. I. (2017). Study on Waste Composition at Taman Pura Kencana, Batu Pahat. *MATEC Web of Conferences*, *103*. https://doi.org/10.1051/matecconf/201710303006

Ahima, R. S. (2020). Global warming threatens human thermoregulation and survival. *Journal of Clinical Investigation*, *130*(2), 559–561. https://doi.org/10.1172/JCI135006

Ahmad, I. K., Basri, N. E. A., Jalil, N. 'Ain A., & Amrul, N. F. (2022). The efficiency of effective microorganism (EM) as catalyst in food waste composting using black soldier fly larvae. *E3S Web of Conferences*, *347*, 04016. https://doi.org/10.1051/e3sconf/202234704016

Ahmat, S. N., Muda, M. R., & Neoh, C. F. (2018). Self-esteem level and its relationship to academic performance among undergraduate pharmacy students in a Malaysian public university. *Indian Journal of Pharmaceutical Education and Research*, *52*(2), 197–201. https://doi.org/10.5530/ijper.52.2.21

Al-Balas, M., Al-Balas, H. I., Jaber, H. M., Obeidat, K., Al-Balas, H., Aborajooh, E. A., Al-Taher, R., & Al-Balas, B. (2020). Correction to: Distance learning in clinical medical education amid COVID-19 pandemic in Jordan: current situation, challenges, and perspectives (BMC Medical Education, (2020), 20, 1, (341), 10.1186/s12909-020-02257-4). In *BMC Medical Education* (Vol. 20, Issue 1, pp. 1–7). BMC Medical Education. https://doi.org/10.1186/s12909-020-02428-3

Al-Obadi, M., Ayad, H., Pokharel, S., & Ayari, M. A. (2022). Perspectives on food waste management: Prevention and social innovations. *Sustainable Production and Consumption*, *31*, 190–208. https://doi.org/10.1016/j.spc.2022.02.012

Ali, R. A., Nik Ibrahim, N. N. L., & Lam, H. L. (2019). Conversion Technologies: Evaluation of Economic Performance and Environmental Impact Analysis for Municipal Solid Waste in Malaysia. *Processes*, *7*(10), 752. https://doi.org/10.3390/pr7100752

Almeslet, A. S. (2019). Knowledge and Awareness of Oral Precancerous Lesions Among Dentists and Dental Students in Riyadh City, Kingdom of Saudi Arabia. *Microbiology & Infectious Diseases*, *3*(4), 1–5. https://doi.org/10.33425/2639-9458.1071

Asiimwe, C., David, N., & Geoffrey, N. (2021). Internal control practices and health service delivery in local governments of Uganda. *African Journal of Business Management*, *15*(6), 165–172. https://doi.org/10.5897/ajbm2021.9205

Bashir, M. J. K., Ng, C. A., Sethupathi, S., & Lim, J. W. (2019). Assessment of the Environmental, Technical and Economic Issues Associated with Energy Recovery from Municipal Solid Waste in Malaysia. *IOP Conference Series: Earth and Environmental Science*, *268*(1), 012044. https://doi.org/10.1088/1755-1315/268/1/012044

Charkhestani, A., & Kebria, D. Y. (2022). Laboratory Analysis To Determine The Accurate Characteristics Of Urban Food Waste. *Global Journal of Environmental Science and Management*, *8*(2), 225–236. https://doi.org/10.22034/GJESM.2022.02.06

Chiarini, A., Castellani, P., Rossato, C., & Cobelli, N. (2021). Quality management internal auditing in small and medium-sized companies: an exploratory study on factors for significantly improving quality performance. *Total Quality Management and Business Excellence*, *32*(15–16), 1829–1849. https://doi.org/10.1080/14783363.2020.1776101

Christensen, T. H., & Bisinella, V. (2021). Climate change impacts of introducing carbon capture and utilisation (CCU) in waste incineration. *Waste Management (New York, N.Y.)*, *126*, 754–770. https://doi.org/10.1016/j.wasman.2021.03.046

Conroy, R. M. (2021). The RCSI Sample Size Handbook. *Royal College of Surgeons in Ireland*, *May*, 1–57. http://www.rcsi.ie/files/research/docs/20160811111051_Sample size 2016.pdf

Di Maria, F., Mastrantonio, M., & Uccelli, R. (2021). The life cycle approach for assessing the impact of municipal solid waste incineration on the environment and on human health. *Science of The Total Environment*, *776*, 145785. https://doi.org/10.1016/j.scitotenv.2021.145785

Foday, H., As'shikin Ramli, N., Nabilah Ismail, H., Malik, N. A., Fikri Basri, H., Syahirah, F., Aziz, A., Sakinah, N., Nor, M., & Jumhat, F. (2017). Municipal solid waste characteristics in Taman Universiti, Skudai, Johore, Malaysia. *Journal of Advanced Research Design Journal Homepage*, *38*(1), 13–20. www.akademiabaru.com/ard.html

Gholami, F., Tomas, M., Gholami, Z., & Vakili, M. (2020). Technologies for the nitrogen oxides reduction from flue gas: A review. *Science of The Total Environment*, *714*, 136712. https://doi.org/10.1016/j.scitotenv.2020.136712

Halim, & Ishak. (2014). Post Election Behavior ? Is it Possible ? A Framework Based on Hirschman (1970) Model. *Australian Journal of Basic and Applied Sciences*, *8*(12), 67–75.

Jalil, N. A. A., Abdullah, S. H., Ahmad, I. K., Basri, N. E. A., & Mohamed, Z. S. (2021). Decomposition of food waste from protein and carbohydrate sources by black soldier fly larvae, Hermetia illucens L. *Journal of Environmental Biology*, *42*(May), 756–761.

Jamshidi, B., Rezaei, M., Najafi, F., & Sheikhi, A. (2020). The Prediction of COVID-19 Spread in Iran From 15 March to 15 April 2020. *Iranian Red Crescent Medical Journal*, *22*(5), 4–8. https://doi.org/10.5812/ircmj.102822

Jeswani, H. K., Figueroa-Torres, G., & Azapagic, A. (2021). The extent of food waste generation in the UK and its environmental impacts. *Sustainable Production and Consumption*, *26*, 532–547. https://doi.org/10.1016/j.spc.2020.12.021

Khodier, K., Viczek, S. A., Curtis, A., Aldrian, A., O'Leary, P., Lehner, M., & Sarc, R. (2020). Sampling and analysis of coarsely shredded mixed commercial waste. Part I: procedure, particle size and sorting analysis. *International Journal of Environmental Science and Technology*, *17*(2), 959–972. https://doi.org/10.1007/s13762-019-02526-w

Kosar, T., Bohra, S., & Mernik, M. (2018). A Systematic Mapping Study driven by the margin of error. *Journal of Systems and Software*, *144*(January 2017), 439–449. https://doi.org/10.1016/j.jss.2018.06.078

Kurwadkar, S., Kanel, S. R., & Nakarmi, A. (2020). Groundwater pollution: Occurrence, detection, and remediation of organic and inorganic pollutants. *Water Environment Research*, *92*(10), 1659–1668. https://doi.org/10.1002/wer.1415

Maroušek, J., Strunecký, O., Kolář, L., Vochozka, M., Kopecký, M., Maroušková, A., Batt, J., Poliak, M., Šoch, M., Bartoš, P., Klieštik, T., Filip, M., Konvalina, P., Moudrý, J., Peterka, J., Suchý, K., Zoubek, T., & Cera, E. (2020). Advances in nutrient management make it possible to accelerate biogas production and thus improve the economy of food waste processing. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *00*(00), 1–10. https://doi.org/10.1080/15567036.2020.1776796

Mohamed Zain, I. N., & Abdul Rahman, H. (2021). Food Waste Management and Green Purchasing Behaviour Among Youths in Malaysia. *International Journal of Academic Research in Business and Social Sciences*, *11*(15). https://doi.org/10.6007/ijarbss/v11-i15/10635

Mohd Yatim, S. R., Ku Hamid, K. H., Noor Ismail, K., Rashid, Z. A., Zainuddin, N. A., Shafie, F. A., & Azmi, A. (2019). STUDY ON WASTE GENERATION AND COMPOSITION IN RAPID RESIDENTIAL DEVELOPMENT OF SUB URBAN AREA IN KUALA SELANGOR DISTRICT, SELANGOR. *Journal of Wastes and Biomass Management*, *1*(1), 01–05. https://doi.org/10.26480/jwbm.01.2019.01.05

Muth, M. K., Birney, C., Cuéllar, A., Finn, S. M., Freeman, M., Galloway, J. N., Gee, I., Gephart, J., Jones, K., Low, L., Meyer, E., Read, Q., Smith, T., Weitz, K., & Zoubek, S. (2019). A systems approach to assessing environmental and economic effects of food loss and waste interventions in the United States. In *Science of the Total Environment* (Vol. 685, pp. 1240–1254). The Authors. https://doi.org/10.1016/j.scitotenv.2019.06.230

Ng, C. A., Chan, C. W., Andiappan, V., Ng, L. Y., & Ng, D. K. S. (2021). Development of optimisation model for black soldier fly-based aquaculture feed supply chains in Malaysia. *IOP Conference Series: Materials Science and Engineering*, *1195*(1), 012049. https://doi.org/10.1088/1757-899X/1195/1/012049

Ooi, J. K., & Woon, K. S. (2021). Simultaneous greenhouse gas reduction and cost optimisation of municipal solid waste management system in Malaysia. *Chemical Engineering Transactions*, *83*, 487–492. https://doi.org/10.3303/CET2183082

Rasool, S., Cerchione, R., Salo, J., Ferraris, A., & Abbate, S. (2021). Measurement of consumer awareness of food waste: construct development with a confirmatory factor analysis. *British Food Journal*, *123*(13), 337–361. https://doi.org/10.1108/BFJ-02-2021-0160

Rovira, J., & Domingo, J. L. (2019). Human health risks due to exposure to inorganic and organic chemicals from textiles: A review. *Environmental Research*, *168*(September 2018), 62–69. https://doi.org/10.1016/j.envres.2018.09.027

Salomone, R., Saija, G., Mondello, G., Giannetto, A., Fasulo, S., & Savastano, D. (2017). Environmental impact of food waste bioconversion by insects: Application of Life Cycle Assessment to process using Hermetia illucens. *Journal of Cleaner Production*, *140*, 890–905. https://doi.org/10.1016/j.jclepro.2016.06.154

Septianto, F., Kemper, J. A., & Northey, G. (2020). Thanks, but no thanks: The influence of gratitude on consumer awareness of food waste. *Journal of Cleaner Production*, *258*, 120591. https://doi.org/10.1016/j.jclepro.2020.120591

Silva, L. J. de V. B. da, Santos, I. F. S. dos, Mensah, J. H. R., Gonçalves, A. T. T., & Barros, R. M. (2020). Incineration of municipal solid waste in Brazil: An analysis of the economically viable energy potential. *Renewable Energy*, *149*, 1386–1394. https://doi.org/10.1016/j.renene.2019.10.134

Simanjuntak, J. P., Daryanto, E., Tambunan, B. H., & Eswanto. (2022). An operating parameter study of the biomass solid feedstock incinerator of fixed-bed type with two stage air supply. *Journal of Physics: Conference Series*, *2193*(1). https://doi.org/10.1088/1742-6596/2193/1/012077

Sinha, S., & Tripathi, P. (2021). Trends and challenges in valorisation of food waste in developing economies: A case study of India. *Case Studies in Chemical and Environmental Engineering*, *4*(November), 100162. https://doi.org/10.1016/j.cscee.2021.100162

Sridhar, A., Kapoor, A., Senthil Kumar, P., Ponnuchamy, M., Balasubramanian, S., & Prabhakar, S. (2021). Conversion of food waste to energy: A focus on sustainability and life cycle assessment. *Fuel*, *302*(March), 121069. https://doi.org/10.1016/j.fuel.2021.121069

Uakarn, C. (2021). Sample Size Estimation using Yamane and Cochran and Krejcie and Morgan and Green Formulas and Cohen Statistical Power Analysis by G*Power and Comparisons. *APHEIT INTERNATIONAL JOURNAL*, 76–88.

Usmani, Z., Sharma, M., Awasthi, A. K., Sharma, G. D., Cysneiros, D., Nayak, S. C., Thakur, V. K., Naidu, R., Pandey, A., & Gupta, V. K. (2021). Minimizing hazardous impact of food waste in a circular economy – Advances in resource recovery through green strategies. *Journal of Hazardous Materials*, *416*(March), 126154. https://doi.org/10.1016/j.jhazmat.2021.126154

Wong, K. K. S., Sharifuddin, J., Nik Masdek, N. R., Wong, W. L., & Lai, K. S. (2021). Determinants of household's intention of practicing sustainable food waste management in Malaysia. *IOP Conference Series: Earth and Environmental Science*, *756*(1), 012036. https://doi.org/10.1088/1755-1315/756/1/012036

Wong, P. ., & Roslan, S. N. A. (2019). Construction and Demolition Waste Management in Malaysia Construction Industry- Concrete Waste Management. *Infrastructure Universiti Kuala Lumpur Research Journal*, *7*(1), 26–42.

Woon, K. S., Phuang, Z. X., Lin, Z., & Lee, C. T. (2021). A novel food waste management framework combining optical sorting system and anaerobic digestion: A case study in Malaysia. *Energy*, *232*, 121094. https://doi.org/10.1016/j.energy.2021.121094

Xu, X., Qian, Z. D., Huang, Q., Ren, Y., & Liu, B. (2022). Probabilistic anomaly trend detection for cable-supported bridges using confidence interval estimation. *Advances in Structural Engineering*, *25*(5), 966–978. https://doi.org/10.1177/13694332211056108

Yong, Bashir, Ng, Sethupathi, Lim, & Show. (2019). Sustainable Waste-to-Energy Development in Malaysia: Appraisal of Environmental, Financial, and Public Issues Related with Energy Recovery from Municipal Solid Waste. *Processes*, *7*(10), 676. https://doi.org/10.3390/pr7100676

Zamli, A. F., Mahmood, W. M. F. W., Ghopa, W. A. W., & Lim, M. T. (2021). *The Research on Food Waste Pre-Treatment Technology for Incineration in Malaysia*. *9*(1), 139–147.