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GREEN TECHNOLOGY FOR SUSTAINABLE AGRICULTURE: BIO-FERTILIZER PRODUCTION FROM MUNICIPAL WASTE TO PRESERVE THE ENVIRONMENT

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Abstract

This study addresses the pressing issue of municipal waste (MW) management by proposing an innovative approach to transform residential solid waste into a valuable resource using green technology. MW, sourced from diverse sectors, undergoes various disposal methods, including incineration, recycling, and landfilling. In Malaysia, the composition of MW aligns with global trends, with food waste and plastic being the predominant categories. This research focuses on producing fertilizer from residential solid waste through a green technology process, utilizing a sequential procedure involving high pressure, high temperature, and energized water to de-polymerize hemicellulose and lignin, followed by microbial enzymatic fermentation. The developed green technology introduces a novel apparatus designed for treating MW in a high-temperature, low-pressure rotating vessel using indirect heating with thermal fluid. The experimental protocol involves four batches of MW samples, evaluating the mass differential before and after the treatment process. Furthermore, a 7-week observation period assesses chili plant growth as an indicator of fertilizer effectiveness. Results indicate a significant 71% mass reduction of MW, amounting to 201.26 kg, emphasizing the efficacy of the developed process. The investigation extends to plant height, comparing MW-derived fertilizer with commercial fertilizer over a 5-week period. Remarkably, chili plants fertilized with MW-derived fertilizer exhibit a greater height of 8.6 cm, surpassing the 7.3 cm observed with commercial fertilizer. This study concludes that MW-derived fertilizer is highly recommended for enhancing plant growth and health in Malaysia, suggesting a sustainable production system. The research not only contributes to waste management but also aligns with broader goals of promoting environmentally conscious and sustainable agricultural practices, emphasizing the potential of green technology in addressing the challenges of municipal waste.

Keywords: Municipal Waste, Biodegradable, Bio-Fertilizer, Green Technology, Plant Growth

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1. Introduction

The meaning of municipal waste is normally assumed to include all of the waste generated in a community without generating waste for municipal services, agricultural processes, and treatment plants. This refers to all waste collected and controlled by the municipality and comprises the most diverse categories of wastes. It comprises waste from several different sources, such as domestic, commercial, and institutional. On average, the composition of household solid waste in Malaysia is 45% of food waste, 24% of plastics, 7% paper, 6% metal, 3% glass, and 15% of other materials. Part of this waste can be managed and used to help balance the environment [1].

This research aims to solve the urban waste disposal problem, which the government does not fully handle. Therefore, universities need to collaborate with the fertilizer industry to produce organic fertilizer from municipal waste. This fertilizing process uses the steam system to shrink and soften solid waste to produce fine material with low moisture content. The novelty of this research is in the production process steam system that has the potential to produce organic fertilizer with low moisture content to decrease the possibility of fungal growth after fertilizer production.

Solid waste is one of several types of environmental pollution in the country. Nowadays, most landfills are covered with solid waste, and to overcome this problem, biotechnology has been

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Table 1. The Composition of Waste (Percentage of Weight) in Malaysia Between 1975-2005 [4]

Waste Composition	1975	1980	1985	1990	1995	2000	2005
Organic	63.7	54.4	48.3	48.4	45.7	43.2	44.8
Paper	7.0	8.0	23.6	8.9	9.0	23.7	16.0
Plastic	2.5	0.4	9.4	3.0	3.9	11.2	15.0
Glass	2.5	0.4	4.0	3.0	3.9	3.2	3.0
Metal	6.4	2.2	5.9	4.6	5.1	4.2	3.3
Textiles	1.3	2.2	NA	NA	2.1	1.5	2.8
Wood	6.5	1.8	NA	NA	NA	0.7	6.7
Others	0.9	0.3	8.8	32.1	4.3	12.3	8.4
Total	**90.8**	**69.7**	**100**	**100**	**74**	**100**	**100**

created to convert MW to compost. MW can be managed by incineration, composting, gasification, and refuse-derived fuel (RDF). Incineration of waste treatment is the combustion of organic substances contained in waste to produce gas and heat. It is also one of the waste technologies that converts to energy through anaerobic digestion and gasification. Composting occurred by an aerobic biological process that uses naturally occurring microorganisms to convert biodegradable organic matter into a humus-like product [2].

1.1 Materials Municipal Waste Management in Malaysia

In an economic downturn and increasing population, insufficient expertise and scarcity of land for managing municipal solid waste is one of the environmental issues. In Malaysia, the scale generation rate is generally around 0.5-0.8 kg/person/day, where domestic waste is a major source. The major components of Malaysia MW are food, plastic, and paper, which comprise over 80% of the weight [3]. Organic and paper compositions show changes and the addition of a significant amount from 1975 to 2005. Table 1 shows the composition of waste (percentage of weight) in Malaysia between 1975 and 2005.

1.2 Composition of Municipal Solid Waste

The composition of municipal waste is the factor to be considered before proposing any management option. It was also reported that in all the Asian countries except Japan, the waste was dominated by organic material, comprising approximately 75% of the total waste stream [5]. Therefore, Malaysia has a lack of data on solid waste compositions. This resulted in most researchers and government officials using or presenting old ones or otherwise estimates [6]. Fig. 1 presents the municipal solid waste contributions by the various sources. It shows that the residential source dominated the portion of the solid waste produced in Malaysia with 48%, followed by the commercial sector with 24%. The domestic, commercial, and municipal (street sweepings, etc.) were largely called the MW [7].

1.3 Aerobic

Aerobic processes include the decomposition of organic wastes in the presence of oxygen (air). Besides, products from this process include CO_2, NH_3, water, and heat. This can be used to treat various types of organic waste. Generally, sewage sludge and food waste provide nitrogen, while wood and paper are significant carbon sources. Ventilation of the waste, either forced or passive, is essential to ensure an adequate supply of oxygen throughout [8].

1.4 Anerobic

The anaerobic process conducts the decomposition of organic wastes in the absence of O_2, with the products being methane (CH_4), CO_2, NH_3, and trace amounts of other gases and organic acids. Anaerobic composting was traditionally used to compost animal manure and human sewage sludge, but recently, it has recently become more common for treating municipal waste (MW) and green waste [8].

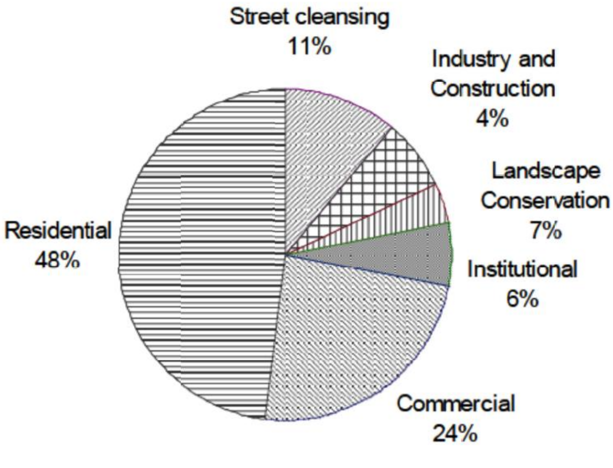

Fig. 1. Composition of municipal solid wastes by sector in Malaysia. Source: (Saeed, 2009)

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Table 2. Weight of waste product before and after process

	Before (raw waste) kg	After (fine waste) kg	Wastage Difference kg	Diesel Oil (liter)	Water (liter)
Batch 1	185.16	75.00	110.16	15.12	222.72
Batch 2	160.42	139.66	20.76	4.50	109.81
Batch 3	152.20	117.12	35.08	6.34	86.61
Batch 4	185.24	149.98	35.26	8.02	50.26
Total	683.02	481.76	201.26	33.98	469.40

Fig. 2. The prototype of steam hyperbaric hydrothermal chamber

1.5 Organic Fertilizer

Organic fertilizer is a natural thing that can be composted, such as manure, food waste, and animal feces. The interesting thing about compost is that it is not a burned plant or chemical material. It also has positive effects on soil without groundwater damage. For organics, the beneficial organisms will break down the contents of the fertilizer material and let moisture for the plants to get to the nutrients inside. Ammonia (NH_3) and nitrous oxide (N_2O) gases are categorized as greenhouse gasses, which can produce nitrogen fertilizers. Besides supplying nitrogen, ammonia can also increase soil acidity. Excessive nitrogen fertilizer applications lead to pest problems by increasing the birth rate, longevity, and overall fitness of certain pests [9].

2. Experimental and Procedures

The flowchart of MW fertilizer production is started by collecting MW and steamed, dried, and separated, as well as by characteristic analysis, including pH value, crushed and sieved, and packaging process.

2.1 Steam Hyperbaric Hydrothermal Chamber

The steam hyperbaric hydrothermal chamber machine is used to produce fine MW with high steam and pressure. The input of solid waste can be driven into the chamber by rotating the chamber, whereby the inner auger-like fins push waste material deeper into the chamber corner to maximize capacity. Once loaded, the chamber will be pressurized with air before high-pressure steam is introduced into the chamber with a rotatable connector to hit a target pressure of 10-24 bars. The chamber will rotate at about 10-20 rpm for 20-80 minutes to tumble the waste material, during which pressure will be continuously injected to maintain the target pressure within the chamber.

2.2 Bioreactor Specification

Capacity	:	220 Tons
Holding time	:	25 days of 8.75 tons/day
Type	:	continuous rotating digester with internal attached to body screw type fin
Power	:	506.81 Watts
70% motor efficiency	:	724 Watts
Gear ratio	:	1:100,000
Multiple gear ratio	:	1:10, 1:100, 1:100

3. Results and Discussion

In these tests, the fertilizers are tested on chili seeds. The result shows the different growth of chili seeds in 7 weeks.

Operational data for fertilizer process

1. Starting boiler – 35 minutes
2. Pressure before – 160psi
3. Temperature before – 160°c
4. Pressure after – 170psi
5. Temperature after – 170°c
6. pH value – 6.01

Table 2 shows the weight of the waste products before and after the process. It can be seen that the weight before processing is higher than after processing. The decrease in water content is up to 79% from batch 1 to batch 4, where the total water difference is 201.26 kg. It means that the high-water content of MW is up to 469.40 kg from an initial

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Fig. 3. Sieving equipment

Fig. 4. Material that cannot be resolved

Fig. 5. Crushing machine

Fig. 6. Sieved machine

weight of 683.02 kg. High water content in organic fertilizer will produce unwanted bacteria and fungi, affecting the fertilizers' nutrient content [10-12].

Fig. 3 shows the sieving equipment used to separate unwanted materials. The inappropriate materials separated from organic material are shown in Fig. 4.

Fig. 4 presents the materials that cannot be resolved, such as plastic, glass, and aluminum clumped together and shrunk. After heated under high steam and pressure, an organic material will be separated in a machine. Therefore, it will be a purely organic fertilizer that is crushed and sieved to divide fine and rough organic fertilizer, as shown in Fig. 5 and Fig. 6. Table 3 compares MW fertilizer with commercial fertilizer for growing chili plants. The MW fertilizer is faster in growing chili plants, up to 15% faster than commercial fertilizer. The differences in the height of plants every week between MW fertilizer and commercial fertilizer are shown in Fig. 8.

Table 4. shows an appropriate pH of MW fertilizer of 6.04 with a relatively high moisture content of 76.6%. pH range of commercial fertilizer is 4.5 to 6.5, which fulfills the requirement of Australia standard AS 4454, whose pH range is 5.0 to 7.5. MW fertilizer produces appropriate chemical content and micronutrients as the source of MW fertilizer is pure organic fertilizer. The Focus of organic fertilizer in the market is on Nitrogen (N), Potassium (P), and Sodium (K) content on fertilizer [13-15]. The NPK content of MW fertilizer are 1.17, 6.68, and 7.6, respectively.

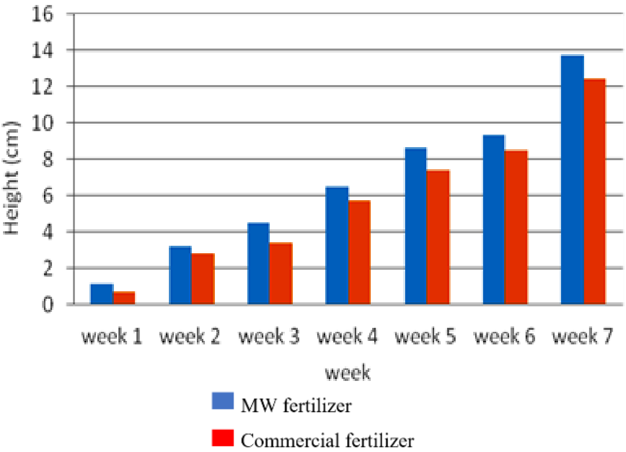

Fig. 7. The comparison of the height of chili for 7 weeks between MW fertilizer and commercial fertilizer

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Table 3. The comparison of the height of chili seed between municipal waste fertilizer and commercial fertilizer

Week	Municipal waste fertilizer	Height (cm)	Commercial fertilizer	Height (cm)
1		1.1		0.7
3		4.5		3.4
5		8.6		7.3

Table. 4. Material that cannot be resolved

Test Parameters	Unit	Method	Results (Average)	European Compost Std Heavy Metal
pH @ 28.3 C		pH Meter	6.04	
Total Nitrogen	%	MS 954: PART 11:1986	1.17	-
Moisture	%	MS 954: PART 1:2000	76.6	-
Phosphorus as P_2O_5	%	COLORIMETRIC	6.92	
Water Soluble P_2O_5	%	COLORIMETRIC	0.38	
Potassium Oxide, K_2O	%	AAS	0.58	
Water Soluble MgO	%	AAS	0.041	
Selenium, Se	%	AAS	0.084	
Molybdenum, Mo	%	AAS	0.004	
Mercury, Hg	%	AAS	<0.001	1
Organic Matter	%	FURNACE ASHING	79.4	
Lead (Pb)	ppm	ICP:OES	3.905	150
Cadmium	ppm	ICP:OES	ND (<0.01)	1.5
Zinc	ppm	ICP:OES	25.815	300
Iron	ppm	ICP:OES	800.145	
Arsenic	ppm	ICP:OES	ND (<0.01)	0
Nickel	ppm	ICP:OES	ND (<0.01)	50
Sodium	ppm	ICP:OES	760.325	
Potassium	ppm	ICP:OES	684.6	
Calcium	ppm	ICP:OES	3072.76	
Magnesium	ppm	ICP:OES	201.035	
Manganese	ppm	ICP:OES	12.93	
Tin	ppm	ICP:OES	ND (<0.1)	
Chromium	ppm	ICP:OES	0.265	10
Copper	ppm	ICP:OES	2.655	100

A comparison of the effectiveness between municipal waste fertilizer and commercial fertilizer is shown in Table 3. The observation was conducted in weeks 1, 3, and 5 for the chili growth. The indicator of the effectiveness of the fertilizer is according to the height of the plant. It is observed that municipal waste fertilizer is more effective for growing the plant compared with commercial fertilizer, with 1.1 cm in the first week, 4.5 cm in the third week, and 8.6 cm in the fifth week.

The data of MW organic fertilizer is compared with commercial fertilizer regarding the chili plant's height, shown in Figure 7. In the first week, it is shown that MW fertilizer recorded a fast growth of the chili plant at the height of 1.1 cm compared to commercial fertilizer at only 0.7 cm; third week, the height reached 4.5 cm and 3.4 cm, while in the fifth week, the height was at 8.6 cm and 7.3 cm for MW fertilizer and commercial fertilizer, respectively. The performance of MW fertilizer was also observed to be more effective in increasing chili plant growth in the seventh week compared with commercial fertilizer. It means that MW fertilizer is more effective and faster in helping the growth of a chili plant, and it is available for all types of plant.

4. Conclusions

The successful production of Municipal Waste (MW) fertilizer has been achieved through a comprehensive process involving steam treatment, drying, separation, and characteristic analysis, including assessing waste material weight before and after crushing, along with examining plant growth. The findings unequivocally demonstrate the superior effectiveness of MW fertilizer compared to commercial fertilizer, resulting in a remarkable 15% improvement in plant growth. Importantly, the efficacy of MW fertilizer is applicable across a

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spectrum of plant types, signifying its versatility and potential impact on agricultural practices.

This breakthrough in MW fertilizer production holds significant promise for farmers, offering a sustainable and efficient alternative to commercial fertilizers. The enhanced plant growth observed with MW fertilizer has the potential to accelerate fruit production, providing a valuable resource for agricultural communities. The success of this research underscores the viability and applicability of MW fertilizer across various plant species, highlighting its potential as a transformative agent in agricultural practices.

The research suggests further avenues for exploration, emphasizing the need for an in-depth analysis of the environmental effects of both MW and commercial fertilizers. Understanding the broader environmental implications of these fertilizers will contribute valuable insights to sustainable agricultural practices, ensuring that the benefits extend beyond enhanced plant growth to encompass a holistic and environmentally conscious approach to farming. This research lays the foundation for ongoing investigations that can delve into the environmental aspects of fertilizer use, fostering a comprehensive understanding of its impact on ecosystems and agricultural sustainability.

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