Journal of Engineering Science and Technology
Vol. 15, No. 2 (2020) 882 - 893

EXPERIMENTAL INVESTIGATION INTO HOME BASED BIODEGRADABLE MATERIAL AS A FERTILIZER SOURCE

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Abstract

This project aims to investigate the functional group of hand-made Blackstrap Molasses Fertilizer using Blackstrap Molasses, Epsom Salt, and food wastes. The product was modified to enhance existing fertilizers in terms of environment, time, and cost. Several procedures were carried out started with a collection of food wastes, boiling food wastes with water until the food wastes were fully composted, cooling the food wastes and mixing with additives ingredients (Blackstrap Molasses and Epsom Salt). One type of test was used to test the fertilizer, which was the Fourier Transform Infrared Spectroscopy. The Fourier Transform Infrared Spectroscopy produced graph data that should be interpreted by referring to the spectroscopy chart. The results demonstrated that the wavenumber at peak 1, 2 and 3, which were 3238.9 cm-1, 2363 cm-1 and 1645 cm-1, in Blackstrap Molasses Fertilizer Infrared Spectrum Chart contained amines, phosphorus, and urea in the fertilizer. Amines, phosphorus, and urea are components that are important for plant growth development as these components are based on nitrogen and carbon elements. This study helps to reduce environmental pollution caused by food wastes and provide a more cost-effective way of producing fertilizer using food wastes.

Keywords: Biodegradable fertilizer, Blackstrap molasses, Epsom salt, Food wastes.

1. Introduction

Fertilizer is a natural substance that is used to enhance plant growth and fertility. Fertilizers could also enhance water retention and filter any excess liquid to enhance soil effectiveness. Fertilizers offer three significant macronutrients, which ear potassium, phosphorus and nitrogen, which are needed by plants in abundance. Plants need nitrogen, phosphorus, and calium (potassium), or collectively known as NPK, in the right ratio to ensure a good balance of carbohydrates, protein, and fats. Fertilizers may also provide secondary nutrients such as sulphur, magnesium, and calcium to the soil or growing media [1]. In this regard, a high percentage of calcium may help prevent rot and boost the plant's growth. Aged manure and compost are by far the most popular fertilizers used with just about any type of plant. In this light, it often depends on the plant itself.

As the country and the world become more environmentally conscious, considerable efforts have been made to recycling food waste and recovery. The sustainable use of food wastes have generated an interest to address nationwide regarding wastes and recycling. According to Thomson [2], in theory, composting is an excellent practice to reuse food wastes, however, the reality is that it can be kind of tedious, dirty, and smelly process. The traditional composting process can take up to six months to a year to produce ready-to-use compost. In order to address this issue, it is recommended that instead of making composts in a bin, composting could be done by creating a trench to make composts directly in the yard. Furthermore, a company called Zera Food Recycler has improved the traditional method by creating a machine that can process food waste to fertilizer in 24 hours when there are oxygen, moisture, heat, and agitation.

Fruits and vegetables are food wastes that are suitable composting materials as they could add nutrients and moisture to the soil. However, wastes such as bread products, oils, meat, dairy, sawdust, human waste, and rice are materials that cannot be included in the composting material because such wastes will only attract pests and harm the plants. Other recommended wastes for the compost include crushed eggshells, seed and nutshells, paper towel rolls, citrus peels, banana peels, coffee grounds, and hot pepper seeds. Each type of waste brings a different type of benefits; for instance, kitchen scraps add nutrients, moisture, and more to garden soil without the need for a compost bin.

Apart from composting, studies have reported several methods that can be used to convert food wastes into fertilizers. One method is known as the Compost Free Technology (CFT). CFT uses heat and enzymes to turn chopped food waste and other green wastes into organic fertilizer. Yes-Sun Environmental Biotech introduced this process in 2005. In May 2006, the patent for CFT was granted and registered in the United States. The patent started to be used widely in 2012. The CFT method can be applied to crops wet upon cooling or dried for storage. However, Rekha et al. [3] mentioned in his study that the fertilizer made by CFT method is not suitable for abundant crops as CFT is a slow process, especially after spring planting.

Kawamura-Aoyama et al. [4] introduced hydroponic nutrients derived from food wastes. Organic hydroponic is a natural hydroponic nutrient produced without using any animal wastes or synthetic ingredients and can be used to fertilize both flowering and vegetable plants. It may improve plants growth and bloom by providing more micronutrients, humic and fulvic acid. The study also mentioned that the organic hydroponic system using solid food wastes shows sound nitrate ion generation and lettuce cultivation performance. Nonetheless, generating nitrate ions takes about two months, longer than liquid organic fertilizer. Kawamura-Aoyama et al. [4] also found the hydroponic system using rectangular containers could decrease the efficiency of inorganic nitrogen ions recovery.

Another study by Khalid et al. [5] has proved that the Berkeley and Bokashi method can successfully be used to produce fertilizer from food wastes in Malaysia. This study found that peanut crops treated with Berkeley and Bokashi fertilizer have a higher growth rate, nodulation increment, and higher yields than crops treated with inorganic fertilizer.

The Fourier Transform Infrared Spectroscopy, known as FTIR, analysis of Berkeley and Bokashi fertilizer proved that this homemade product has the same potential as a manufactured product for plant growth.

The Berkeley and Bokashi method consider many variables, such as cost, time, and weight. For both methods, the weight of food wastes collected is fixed at 1 kg. The time taken for both methods to finish their product is approximately one month or less. The cost involved is also reasonable; in all RM12.00 is spent for the mesh wire, RM8.00 for the water dispenser and RM60.00 for three packs of Bokashi powder.

Thus, the use of the Berkeley and Bokashi fertilizer by hot composting and fermentation method has proved to be more cost-effective and practical to increase nutrient and the ability to absorb more light than inorganic fertilizer. The findings of the current study could assist policymakers as well as entrepreneurs to boost their return of investment and better quality of life method [5].

Other than incinerating food wastes, recycling food residues is one of the technologies to transform food wastes into liquid fertilizer. The technology forms a cycle where agricultural products are harvested by using this fertilizer and the product is delivered to those who supply the food residue. This process uses microorganism to decompose food residues and produce liquid fertilizer by relying on microorganisms. Consequently, this has eliminated the need for heat adjustment in the production processes.

Food recycling plant does not generate by-products, wastewater, or waste gas. Compared to the incineration process, this recycling plant requires much less fuel and water. In addition, the recycling plant can recycle most food residues as fertilizer from edible, including liquids. Food residues are collected from supermarkets and recycled to produce liquid fertilizer.

The use of liquid fertilizer will affect agriculture production rate. The agriculture products, such as vegetables, are then delivered to the supermarkets. In 24-hours, it can produce up to 12 tons of fertilizer, and the amount of liquid fertilizer produced monthly is at average 135 tons monthly.

There is still no specific investigation on the interaction between Blackstrap Molasses, Epsom salt, and food waste to produce fertilizer in Malaysia. Therefore, this work aims to determine the suitability and effectiveness of Blackstrap Molasses and Epsom salt as additional items in fertilizer made from food wastes and apply to soil in Malaysia. The finding of this study will help to reduce environmental pollution caused by food wastes and provide a more cost-effective way of producing fertilizer using food wastes.

2. Preparation of Food Wastes Based Fertilizer

Food waste-based liquid fertilizer was prepared with Blackstrap Molasses and Epsom salt in this study. Blackstrap Molasses and Epsom salt composition are shown in Tables 1 and 2. Blackstrap Molasses, Epsom salt, and 4 gallons of water were used to produce fertilizer. In this light, the fertilizer needs to mix with other types of fertilizer; however, instead of mixing it with another fertilizer, it was replaced with food wastes. In order to transform the food wastes into organic compounds, the food wastes had to go through a composting process. In this light, it takes a long time to compose food wastes into organic fertilizer.

In order to save time, the boiling process was done where 4 gallons of water was used to make the fertilizer. According to numerous studies, the boiling process allows extracting nutrients from food wastes in a shorter amount of time. After a few minutes of boiling, the food wastes were fully composted in the boiling water. The boiled water was then filtered from the composted food waste and cooled down to room temperature, which is 25℃.

As the boiled water was cooled to the room temperature, a cup of blackstrap molasses, a thick and dark syrup, was added to the boiled water along with a cup of Epsom salt. The mixture of boiled water, Epsom salt, and blackstrap molasses were stirred gently until the mixture synthesized well. Then, the mixture was ready to be tested as Blackstrap Molasses Fertilizer (BMF) as the simplified process, as shown in Fig. 1, and the detailed process was illustrated in Fig. A-1, *Appendix A*.

Table 1. Blackstrap molasses composition [6].

Minerals	Unit	Average	Min	Max
Calcium	g/kg DM	9.2	6.8	12.6
Phosphorus	g/kg DM	0.7	0.1	1.2
Potassium	g/kg DM	51.0	27.7	77.3
Sodium	g/kg DM	2.4	1.0	5.4
Magnesium	g/kg DM	4.0	2.4	6.0
Manganese	g/kg DM	74	22	121
Zinc	g/kg DM	18	4	77
Copper	g/kg DM	6	2	22
Iron	g/kg DM	173	123	277

Table 2. Epsom salt composition [7].

Minerals	Unit	Average
Magnesium sulphate ($MgSO_4$)	% min	48.3
Magnesium sulphate ($MgSO_4$, $7H_2O$)	% min	99.0
Magnesium equivalent	% min	9.7
Magnesium oxide (MgO)	%	16.4
Chloride (Cl)	ppm max	600
Water content (weight loss @ 450 °C)	%	51.0
Sulphur (S)	% min	12.7
Lead	mg/kg max	10
Iron	mg/kg max	20

Fig. 1. Process of making fertilizer from the food wastes.

3. Experimental Test

In the study, there was one test used to verify the objectives, which are functional group testing using Fourier Transform Infrared Spectroscopy (FTIR).

Fourier transform infrared spectroscopy (FTIR)

The Fourier Transform Infrared Spectroscopy, or as known as FTIR, is an analysis that helps people understand materials and products. FTIR helps to identify chemical compounds in products, paints, polymers, coatings, pharmaceuticals, foods, and other products. In the study, FTIR- Attenuated Total Reflectance (ATR) was used to run the samples.

The samples of both fertilizers were prepared according to the same procedure used by Khalid et al. [5]. In order to analyse the samples, the FTIR apparatus was prepared by lifted its mirror cover, and there was an interferometer installed inside it.

The interferometer's lid was opened, and it should be cleaned off from any dust or particles on its surface. Then, the lid and mirror cover was closed for a background test, which was taken to eliminate external factor such as environment changes.

Later, as the FTIR had been analysing the actual samples, its chart was filtered and cleared with the chart that yielded from the background test. Right after the background test was done, FTIR mirror cover and interferometer's lid were lifted to place a small drop of samples on the centre of the interferometer.

The interferometer's lid and The FTIR's mirror cover, then, were closed for data intake. The data was taken then through a signal connection from the FTIR to a computer desktop. There was a specific software, EZ Omnic, used to capture and interpret the signal into the significant spectrum chart. Then, the process was repeated for other samples. The detailed steps can be referred to as Fig. 2.

FTIR method was used to make a comparison between two types of fertilizers, Conventional Fertilizer (CF), and BMF. Both fertilizers are in a liquid form, and the test was done in order to identify the efficiency of each fertilizer for various plants.

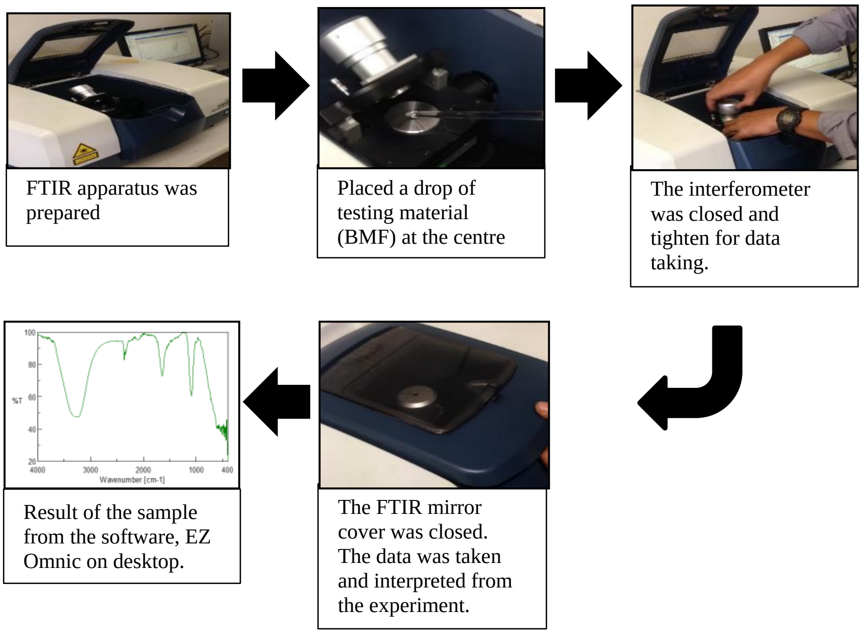


Fig. 2. Process of using Fourier transform infrared spectroscopy (FTIR).

4. Results and Discussion

The study is aimed to conduct one process of testing, which is the FTIR test. FTIR test is a test that compares functional groups of two types of fertilizers, CF and BMF.

4.1. Effects of functional group in fertilizer

In Fig. 3, the CF illustrates that the characteristic absorption was at the range of 2500 – 3100 cm^{-1} at peak 1. Within this range, the lowest transmittance and highest wavenumbers were 64% and 2914.4 cm^{-1}, at which, only the functional group of C-H (alkanes) stretch, C_3OOH (carboxylic acid) and SO_2OH (sulphur) were exhibited.

The characteristic absorption of BMF in Fig. 4, on the other hand, did not show any existence of C-H (alkanes) stretch. However, the characteristic absorption of BMF, otherwise, showed that the lowest transmittance and highest wavenumbers were 45% and 3238.9 cm^{-1}, where the functional group of O-H (phenol) stretch, CH_4N_2O (urea) stretch and N-H (imide) had come up. At peak 2, the characteristic absorption of CF in Fig. 4 was at the range of 1710-1780 cm^{-1} where the lowest transmittance and highest wavenumbers were 87% and 1743.9 cm^{-1}. Functional groups of C = O (ketones) stretch, C = O-O (esters) stretch and C = O (imides) stretch had appeared within this range.

In Fig. 4, characteristic absorption of BMF at peak 2 illustrated that only two functional groups, which were P-H (phosphorus) stretch and sulphur (SOOH) stretch, emerged in BMF IR-chart. The chart also presented different value from CF IR-chart in term of wavenumber and transmittance parameter, which were 2363.3 cm^{-1} and 84%.

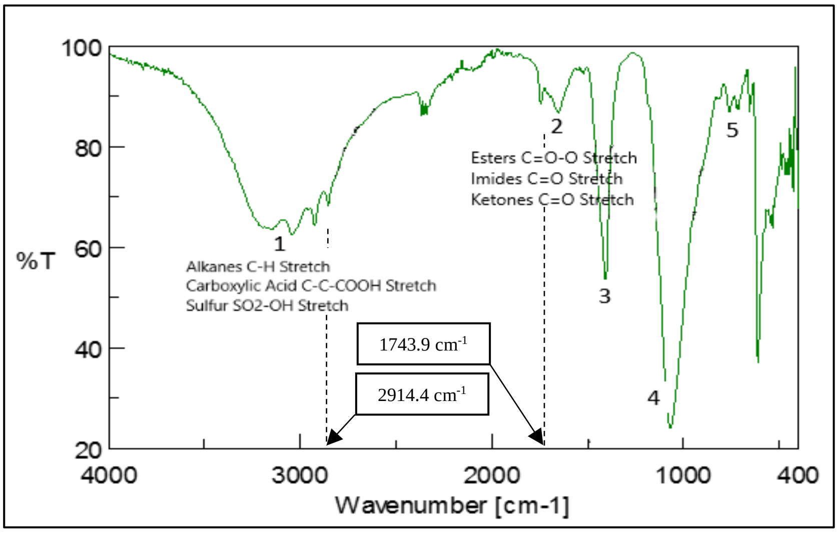


Fig. 3. CF FTIR testing result.

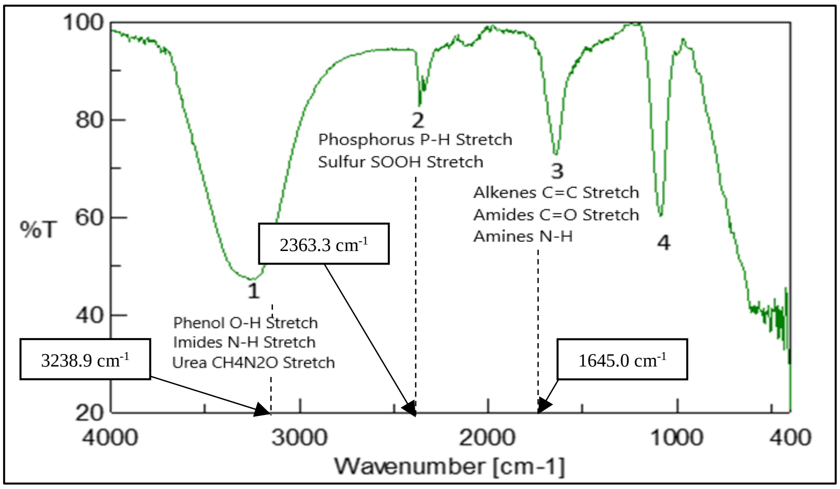


Fig. 4. BMF FTIR testing result.

At peak 3, the characteristic absorption of CF in Fig. 3 was within the fingerprint region. In this region, any single bond or functional group is challenging to be recognized and identified. On the contrary, the highest wavenumber and lowest transmittance of BMF in Fig. 4, at peak 3, were 1645.0 cm^{-1} and 74%. The values were within the range of 1620-1700 cm^{-1}, at which, the range was not in fingerprint region and any functional group could still be singled out individually. Functional groups of BMF at peak three recognized C = C (alkenyl) stretch, medium C = C (aromatic) bending and C = O (amide) stretch within the range.

At peak 4, 5, 6 and 7, the functional groups cannot be identified as an individual group because massive bending bonds emerge, and each group is arduous to be recognized within the wavenumber range of 1500-400 cm^{-1}. The range mentioned is called as fingerprint region. No bonds can be singled out as an individual bond in this region; however, the fingerprint region can be compared between compounds since every compound has its unique fingerprint region.

The comparison chart between CF and BMF can be referred to as Fig. 5. The fingerprint region of both CF and BMF clearly showed the different characteristic of the chart. Figure 5 illustrated the fingerprint region of CF had several peaks of transmittance. On the other hand, the fingerprint region of BMF only illustrated one peak, and its transmittance started to decline drastically as the BMF absorbed lots of energy at low wavenumber.

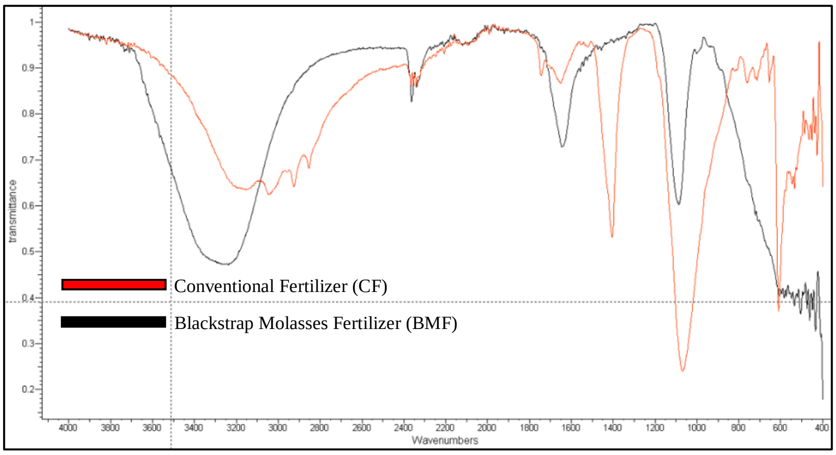


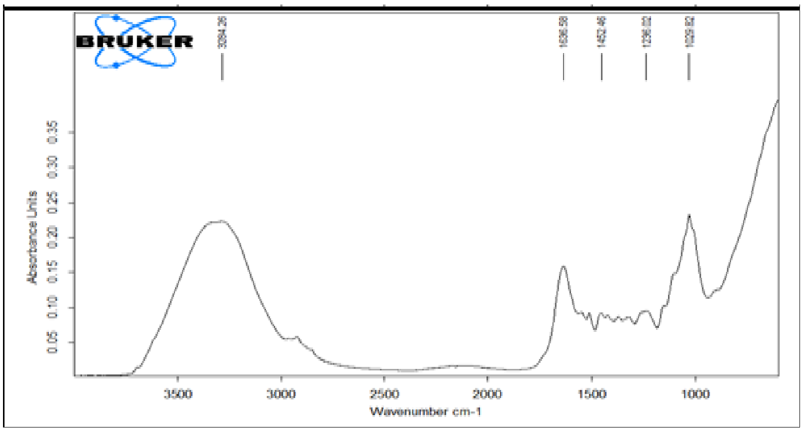
Fig. 5. FTIR testing result between BMF and CF.

4.2. Performance of biodegradable fertilizer

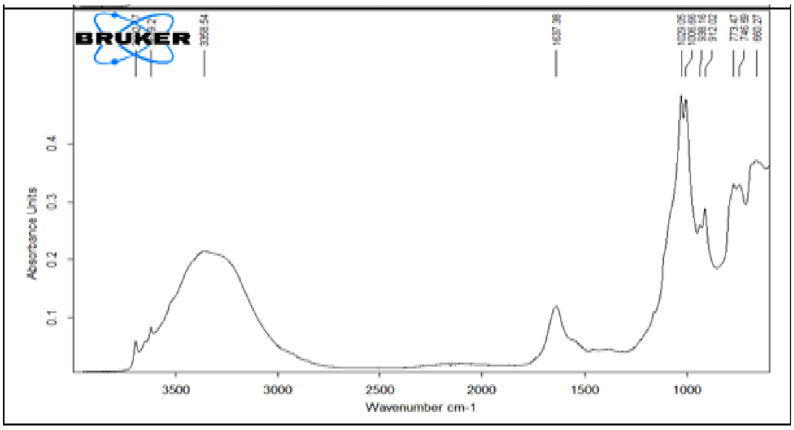
According to the results, BMF has better performance than the CF. After completing all of the experiments, testing, and observations thoroughly, it was found that there are several nutrients, which would not exist in other fertilizers and have a more significant number of functional groups, such as N-H (amines), P-H (phosphorus) and CH_4N_2O (urea), within the BMF.

Comparing to similar research conducted by Khalid et al. [5], they used the Bokashi and Berkeley method to produce food wastes-based fertilizer. Based on the conducted research, they produced two types of fertilizer, which are composted fertilizer (Berkeley method) and fermented fertilizer (Bokashi method). These fertilizers are analysed by using FTIR-ATR equipment and yield two different IR-charts, as illustrated in Fig. 6.

Khalid et al. [5] stated that, at peak 1, both composted and fermented fertilizer emerged the same functional group of O-H (alcohol) stretch as BMF fertilizer at the range of 3200-3600 cm^{-1}. However, the values of absorbance are different from each other. At peak 2 of both composted and fermented fertilizer, they found C = C (alkenes) and N-H (amines) emerged at the range of 1620-1680 $cm^{-1,}$ and the results are precisely the same as BMF IR-chart, at which, both C = C (alkenes) and N-H (amines) emerged at 1645 cm^{-1}. Based on the observation, the results produced by Khalid et al. [5] and this study are tallied and corresponded each other. It can be concluded that the findings produced by this study are valid and soundness.



(a) Composted fertilizer.



(b) Fermented fertilizer.

Fig. 6. FTIR absorbance spectra of fertilizer [5].

Carbon (C) and nitrogen (N) functional group have been focused and analysed as these elements appeared in both samples. Nitrogen is a major component of chlorophyll that is used by plants to convert sunlight and produce sugars from water and carbon dioxide. Nitrogen combines with C, H, O, and S to create amino acids, which are used to form protoplasm or cell division. Amino acids (special kind of carboxylic acid) are needed for the growth of plants as it can produce protein molecules [8]. In order to develop the plant effectively in the optimum environment, the protein must create an enzymatic reaction by producing enzymes, which will be supplied to the plant. Thus, the production of protein is essential for a plant to grow; amino acids and nitrogen, at this point, have to play important roles to make sure protein is continuously produced as it helps plant with rapid growth, increasing seed, fruit production and improving the quality of crops' leaves and forages [9].

The presence of ester in the compost is due to the presence of leftover fruits, such as apple in the food wastes during hot composting. Ester is the compound responsible for the distinct smell and flavour characteristics of different fruits. Amines, on the other hand, is needed for growth and development; its metabolism appears to be coordinated with the cell cycle [10]. It is also stated from other studies about the importance of amine in fertilizer [8]. The next component is alkenes. Alkenes typically contain hydrocarbons, which can be directly derived from fatty acids and present in all living matters [11]. Hydrocarbons (alkanes/alkenes) are ubiquitous in plants and insects as it prevents water loss. They are vital as they absorb light, which is essential for the photosynthesis process.

Lastly, the most important functional group inside the BMF is urea, CH_4N_2O. Urea plays an essential role as a fertilizer and feeds supplement, as well as a starting material for the manufacture of plastics and drugs [12]. A colourless, crystalline substance melts at 132.7 °C (271 °F) and decomposes before boiling. Urea has a high amount of nitrogen, which is needed for plant development [12]. Phosphorus is part of NPK. At 2363.3 cm^{-1}, the BMF result showed that there is a strong presence of P-H (phosphorus). Hence, the fertilizer has all the nutrients needed by the plant, which are nitrogen, phosphorus, and calium (potassium) [13].

5. Conclusions

The objective of this project is to determine the suitability and effectiveness of blackstrap molasses as an additional item in fertilizer made from food wastes, to study the effect of nitrogen and carbon content in fertilizer from food wastes towards the development of the plant, and to study the effect of blackstrap molasses for plants. All of the testing and analyses have shown excellent and encouraging results.

FTIR testing also showed good feedback from the graph displayed. The results showed that BMF fertilizer contains almost all-important nutrients such as amines, phosphorus, and urea as these three components possess an essential element for every plant, which is nitrogen. Nitrogen combines with C, H, O, and S can eventually yield amino acid-low carboxylic acid that can develop plant growth and produce protein. This research is significant as it can produce convincing results for the reference of different parties.

Acknowledgement

The authors would like to acknowledge the Ministry of Higher Education of Malaysia (MOHE) and Universiti Teknikal Malaysia Melaka (UTeM) for the facilities and financial support under Tabung CRIM.

Abbreviations

ATR	Attenuated Total Reflectance
BMF	Blackstrap Molasses Fertilizer
CF	Conventional Fertilizer
CFT	Compost Free Technology
FTIR	Fourier Transform Infrared Spectroscopy
IR	Infrared
NPK	Nitrogen, Phosphorus, Calium

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Appendix A

Representation and Figures of Design Charts

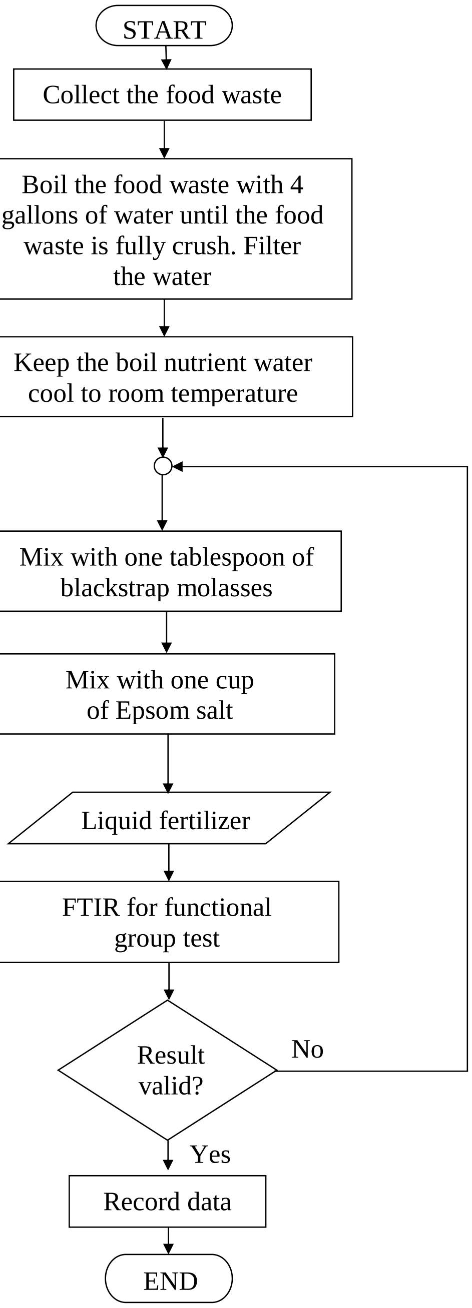

Fig. A-1. Main flow chart of the biodegradable fertilizer production and testing process used in this study.