MARI

MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

Vol. 7 No. 3 (2026) 23-28
https://publisher.uthm.edu.my/periodicals/index.php/mari

Encapsulation of Coffee Ground/Banana Peel in Corn Starch-Based Polymer for Enhanced Organic Fertilizer Production

Ma'az Baghawi A. Sahar[1], Siti Noraiza Ab Razak[1,2]*

[1] *Department of Science and Mathematics, Centre for Diploma Studies*
Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA

[2] *Mathematics and Application (MAP), Centre for Diploma Studies*
Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author: noraiza@uthm.edu.my
DOI: https://doi.org/10.30880/mari.2026.07.03.004

Article Info

Received: 01 September 2026
Accepted: 15 October 2026
Available online: 01 December 2026

Keywords

Food waste, repurpose, slow-release, reduce chemical fertilizer, sustainability

Abstract

This study shows the use of food waste such as coffee grounds, banana peel and corn starch being repurposed into a slow-release organic fertilizer. The aim was to reduce the usage of chemical fertilizer which can be harmful to the soil if used excessively. This modified fertilizer was then encapsulated in three different concentrations of corn starch-based polymer (0.04, 0.06, and 0.08 g/ml) and labelled as Sample A, Sample B and Sample C, respectively. The process is done by heating the mixture of corn starch in 100 ml of distilled water at 90°C. The pellet consist of the mixture of coffee grounds and banana peels was coated with the corn starch and dried in an oven at 65°C for three hours. The nitrogen (N) release rate from the fertilizer is monitored over a course of 7 days period using Fourier Transform Infrared Spectroscopy (FTIR). The reading of FTIR was focused on the N-H bond peak at a wavenumber 1627 cm^{-1}. The results show an increasing number of days in which the fertilizer takes to release its nutrient, corresponding with the increased corn starch concentration. Sample A shows N presence after two days, while Sample B and Sample C show N presence after five days and seven days, respectively. This result can demonstrate the effectiveness of corn starch as a natural-based polymer for a slow-release fertilizer. Each encapsulated fertilizer sample will help to produce better crops for different types of plants and promote environmental sustainability by using biodegradable materials.

1. Introduction

Fertilizer that is made using organic material such as seaweed extracts, food waste, or anything that is derived from living organisms can be counted as an organic fertilizer [1]. Organic fertilizer will release nutrients into the soil that will be absorbed by plants to use as nutrients for growth. The risk of nutrient wastage, water pollution and risk of harming soil organisms can be reduced because of the characteristics of organic fertilizer which is a slow-release nutrient. Because of the positive impacts, such as improving soil fertility and maintaining soil pH, organic fertilizer has gained popularity. Organic fertilizers are renewable, since the materials that are used are mainly from waste, which makes it a sustainable alternative [2]. The type of fertilizer used in the article is

This is an open access article under the CC BY-NC-SA 4.0 license.

enhanced efficiency fertilizer (EEF), which shares its characteristic with coffee ground fertilizer such as being a soluble fertilizer product, not treated by reaction, occlusion or addition of inhibitors. EEF also has the characteristic of slow-release nutrients which will be achieved by encapsulating the coffee ground fertilizer.

Excessive usage of non-organic fertilizer will result in an environmental problem because some fertilizer contains heavy metals such as cadmium (Cd) and chromium (Cr). After a certain amount of time, the accumulation of heavy metals in the soil will result in the soil being polluted. Non-organic fertilizer also has a higher nitrogen (N) content, which, with excessive N in the soil, can have harmful effects on the environment. Excess N and nitrate (NO_3) from agricultural areas can reach the water environment by drainage, leaking or water flow, which will contaminate the water [3]. The usage of organic fertilizer will help to reduce the chance of the soil being polluted, but excessive usage of it without any clear limitations will also make the soil contaminated. Excess N in the soil that is not absorbed by the plant because of excessive usage will cause harmful effects on the water environment. The excess N in the soil will get into the underground water system and contaminate it.

Fig. 1 shows an example of slow- and controlled-release fertilizer. Based on the study, it shows that by using different synthesis methods, fertilizer with several types of nutrients and efficient prolonging shells can be obtained. A recent example is nitrogen-rich granules coated with poly (3-hydroxy-butirate). By using a selected filler, such as poly (3-hydroxy-butirate), struvite, or dry biomass, a nitrogen fertilizer (calcium-ammonium nitrate) has been granulated. To form a high-quality and thin polymer coating, the poly (3-hydroxy-butirate) solution in dioxolane was applied onto the granules. This process results in the coating's ability to biodegradable into the soil and release the nitrogen at a slower and steady rate [4].

The encapsulation techniques will help to turn the fertilizer into a slow-release type fertilizer. By incorporating this technique, it will ensure there is no excessive amount of N in the soil. The coating around the fertilizer will prevent the N to be absorb immediately into the soil and be absorbed at a slow rate. This will help the plant to efficiently absorb the nutrient, thus eliminating the chances of excessive N in the soil [5], [6]. Corn starch can be used because it is a biodegradable, non-toxic and cost-effective material, which makes it a possible alternative to a synthetic polymer. It will help to create a controlled-release system that optimizes the nutrient uptake by plants while reducing environmental pollution [4], [7], [8]. Hence, the main objective of this study is to produce an organic fertilizer using waste coffee grounds using the encapsulation technique as an alternative to harmful chemical fertilizer.

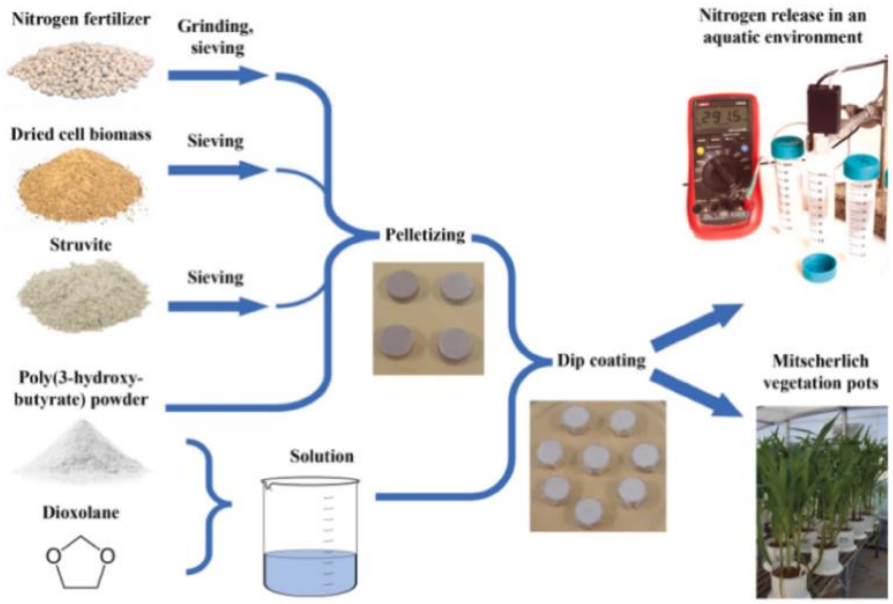


Fig. 1 *Illustrative scheme of encapsulation of nitrogen fertilizer (calcium-ammonium nitrate) in poly (3-hydroxy-butirate)* [4]

2. Materials and Method

Fig. 2 shows the process flow of making the encapsulated fertilizer in this project. Raw materials that are used to make the fertilizer are coffee grounds with the addition of banana peel to help accelerate the decomposition process. Approximately 450 g of coffee grounds and 150 g of banana peel were placed into an earthen pot for seven days. The ratio of coffee grounds to banana peel fertilizer is 3:1. The sample was pressed into a sphere-

shaped pellet with a diameter of 1 to 2 cm and separated into three samples, labelled as Sample A, Sample B and Sample C.

Next, samples were encapsulated using a corn starch-based polymer. Three different concentrations of the polymer were made with 4 g, 6 g and 8 g of corn starch that were mixed with 100 ml of distilled water.

$$\text{Concentration} = \frac{\text{mass}}{\text{Volume}} \tag{1}$$

The concentration of the corn starch polymer was calculated using equation (1). Each polymer was heated at temperature 90°C in separate beakers. The fertilizer pellet was then dipped into the corn starch solution with three different concentrations, separately. The samples were then dried for two hours at ambient temperature to become an encapsulated fertilizer. Finally, each encapsulated fertilizer was distributed on three different soil samples that were placed inside separate pots.

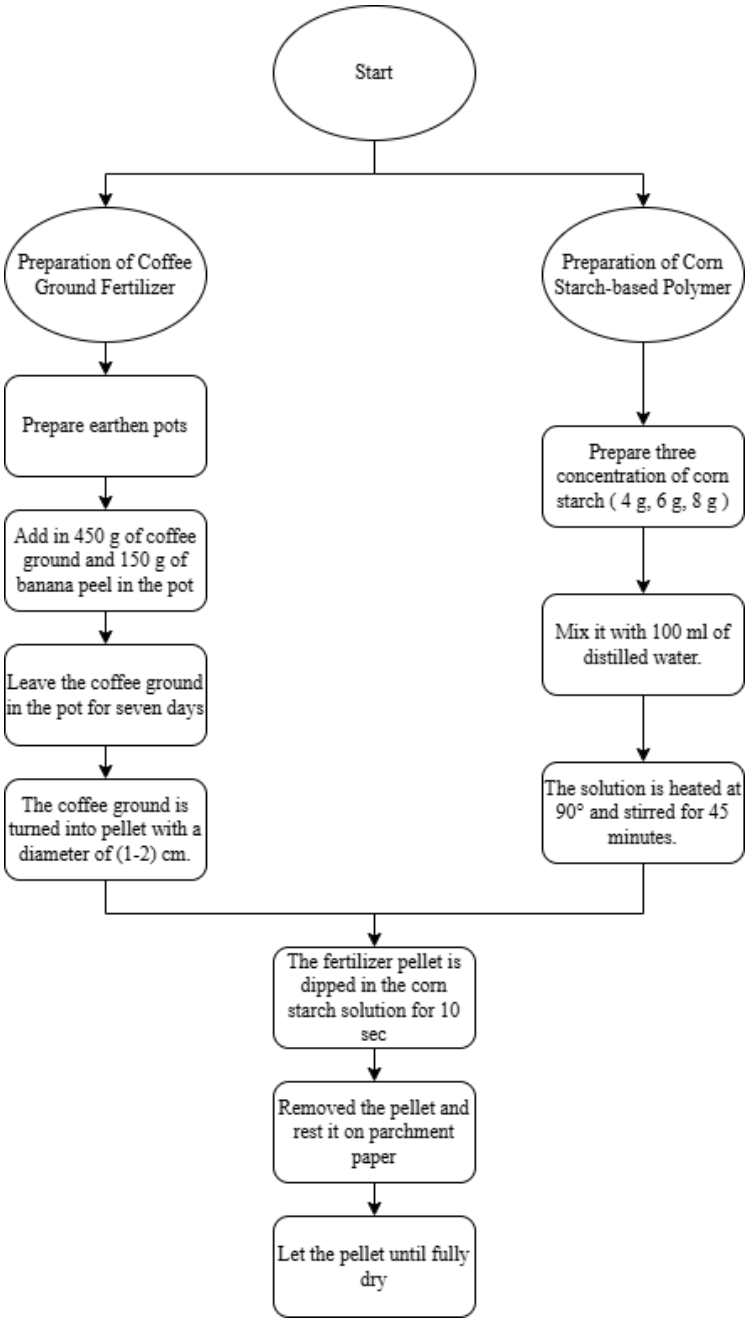
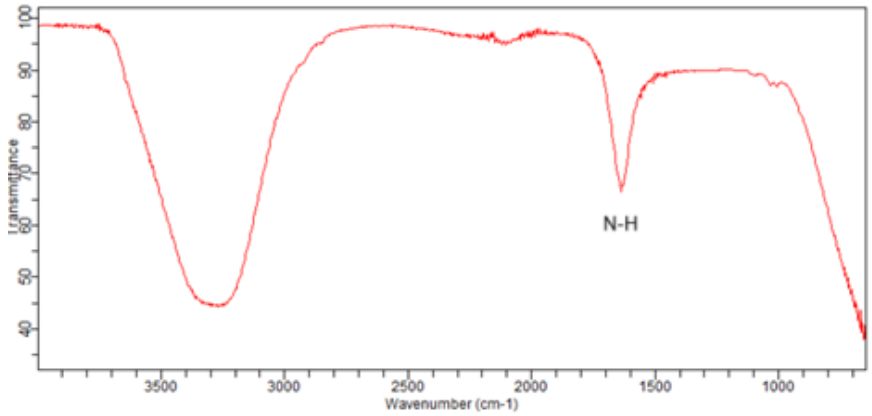


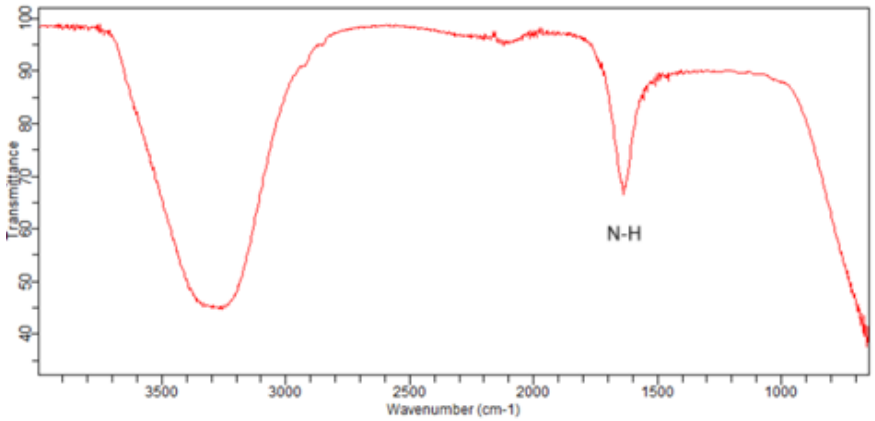
Fig. 2 *Flowchart of the process from the making of fertilizer until the encapsulation process*

3. Result and Discussion

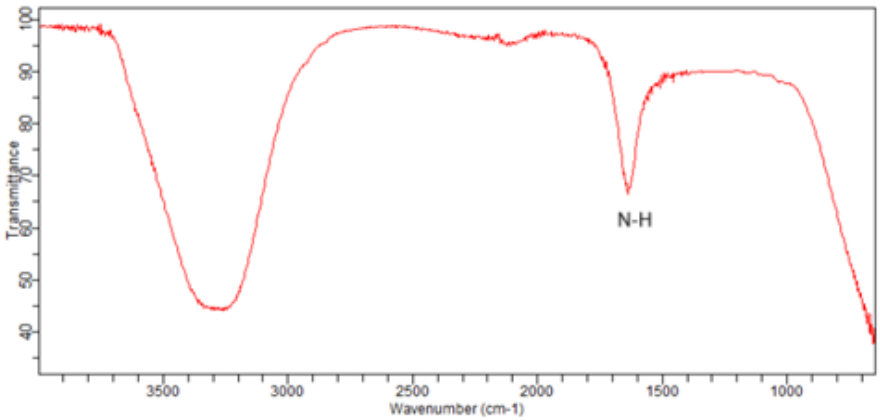
Fourier Transform Infrared Spectroscopy (FTIR) is an analytical technique used to analyze materials and their chemical composition. This analysis was used to detect the presence of N in the soil after being fertilized using the encapsulated fertilizer of Sample A, Sample B, and Sample C. Fig. 3 shows that there is presence of N in the soil, more specifically ammonia (NH_3), that is a group of N-H bonds. The transmittance of infrared (IR) radiation dropped on wavenumber around 3000-3500 cm^{-1} because that's the range that N-H bond will absorb the IR radiation resulting in a downward peak. The functional group of amines (1° amines) theoretically lies in the bending vibrations range of 1550 – 1650 cm^{-1}.



(a)



(b)



(c)

Fig. 3 *FTIR spectroscopy of soil fertilized by (a) Sample; (b) Sample B; and (c) Sample C*

The peak that appears in the range of 1627 cm^{-1} alongside the peak around the wavenumber 3500 cm^{-1} will show that there is N-H bond in the soil. The duration (days) of N to be released into the soil is different for each sample mostly due to difference concentration of the corn starch-based polymer that act as the coating to the granule fertilizer. In short, all fertilizer samples will eventually provide N into the soil with different time release. Fig. 3(a) shows the presence of N in the soil after two days, while Fig. 3(b) and Fig. 3(b) after five days and seven days, respectively. As the concentration of the polymer increases, the time taken for the N to release into the soil will also increase. The different release duration of N will vary the application of encapsulated fertilizer for various types of plant.

Table 1 *Suggestion of plants to be fertilized using Sample A, Sample B, and Sample C fertilizer*

Sample	Corn starch concentration (g/ml)	N Release Duration (days)	Suggested Plant(s)
A	0.04	2	Lawn grass, tomato, cucumber
B	0.06	5	Rice, maize, apples
C	0.08	7	Orchids, alfalfa

From the analysis, each sample of fertilizer can give a benefit for different types of plants, as summarized in Table 1. Sample A is suggested to be used on fast-growing plants because those plants require very fast nitrogen absorption to growth. Meanwhile, Sample B can be used on medium duration of growing plants that need a steady absorption of nitrogen and other nutrients, such as rice, maize, and apple trees. For longer-growing plants, Sample C is highly recommended since this plant needs a slow and sustained nitrogen supply in soil.

4. Conclusion

By using food waste, this project has successfully produced a slow-release fertilizer that will help to enhance the growth of plants. The usage of coffee ground is beneficial as a fertilizer because of its compounds, which is N. N, which is essential for plants growth and development. By incorporating the encapsulation technique used to detect the presence of N in the soil into this fertilizer, its effect can be further enhanced by making it into a slow-released type fertilizer. When a fertilizer slowly releases its nutrient, it will allow the plant to absorb the nutrient slowly which is more efficient and less likely for the nutrient to be wasted. Different samples have been produced, and Sample C is considered the most optimal one for its slow-released capabilities. The time that Sample C takes to release N into its surrounding soil will help the plant to efficiently absorb the nutrient slowly.

Acknowledgement

The author would like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design****: Ma'az Baghawi A. Sahar, Siti Noraiza Ab Razak;* ***data collection****: Ma'az Baghawi A. Sahar;* ***analysis and interpretation of results****: Ma'az Baghawi A. Sahar;* ***draft manuscript preparation****: Ma'az Baghawi A. Sahar, Siti Noraiza Ab Razak. All authors reviewed the results and approved the final version of the manuscript*.

References

[1] Y. Lee, H. An, S. Yoon, S. T. Jeong, C. H. Lee, S. Das, S. Y. Kim, "*Simultaneous reduction of greenhouse gas and ammonia (NH_3) emissions by combined application of organic and inorganic fertilizers in maize-cabbage cropping systems*," Journal of Environmental Management, vol. 373, 2025.

[2] J. Lu, M. Wu, L. Luo, R. Lu, J. Zhu, Y. Li, Y. Cai, H. Xiang, C. Song, B. Yu, "*Incorporating iron oxide nanoparticles in polyvinyl alcohol/starch hydrogel membrane with biochar for enhanced slow-release properties of compound fertilizers*," Carbohydrate Polymers, vol. 348, 2025.

[3] S. Sair, S. Aboulhrouz, O. Amadine, I. Ayouch, I. Jioui, Y. Essamlali, K. Danoun, B. Ouadil, M. Zahouily, "*Bio-based alkyd urethane formulations: Advancing sustainable agriculture and environmental protection through slow-controlled release of NPK fertilizers*," European Polymer Journal, vol. 199, 2023.

[4] A. P. Dovzhenko, O. A. Yapryntseva, K. O. Sinyashin, T. Doolotkeldieva, and R. R. Zairov, "*Recent progress in the development of encapsulated fertilizers for time-controlled release*," Heliyon, vol. 10, no. 15, p. e34895, Jul. 2024, doi: 10.1016/j.heliyon.2024.e34895.
[5] Q. Lv, T. Xiao, G. Dong, X. Tan, Z. Zhang, M. Zhao, M. Zhu, & J. Li, W. Zhang, "*Preparation and characterization of starch carbamate modified natural sodium alginate composite hydrogel blend formulation and its application for slow-release fertilizer*," International Journal of Biological Macromolecules, vol. 278, no. Pt 2, p. 134713, Aug. 2024, doi: 10.1016/j.ijbiomac.2024.134713.
[6] E. M. Eddarai, M. El Mouzahim, B. Ragaoui, S. El Addaoui, R. Bousse, I. Warad, A. Bellaouchou, & A. Zarrouk, "*Chitosan/kaolinite clay biocomposite as a sustainable and environmentally eco-friendly coating material for slow release NPK fertilizers: Effect on soil nutrients and tomato growth*," International Journal of Biological Macromolecules, vol. 242, no. Pt 3, p. 125019, May 2023, doi: 10.1016/j.ijbiomac.2023.125019.
[7] D. H. H. Sim, I. A. W. Tan, L. L. P. Lim, E. T. Lau, and B. H. Hameed, "*Synthesis of tapioca starch/palm oil encapsulated urea-impregnated biochar derived from peppercorn waste as a sustainable controlled-release fertilizer*," Waste Management, vol. 173, pp. 51–61, Nov. 2023, doi: 10.1016/j.wasman.2023.11.006.
[8] Z. Żołek-Tryznowska, A. Jeznach, E. Bednarczyk, T. Murawski, K. Piłczyńska, S.Sikora, & M. Tryznowski, "*Effect of hydrophobic nano-silica content on the surface properties of corn-starch films,*" Industrial Crops and Products, vol. 214, p. 118582, Apr. 2024, doi: 10.1016/j.indcrop.2024.118582.