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Fabrication of Biodegradable Mango-Banana Waste Planting Bag: A Sustainable Alternative to Polyethylene

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ABSTRACT

Polymer-based planting bags are presently employed in nurseries and commodity plantations for cultivation. A notable drawback associated with the use of these bags in agriculture is the difficulty in their proper disposal once they have completed their intended function. The continued presence of polybags in the soil contributes to heightened levels of toxicity. In response to environmental concerns, biodegradable planting bags have been introduced on a global scale. Hence, this research had been conducted to characterize the properties of the mango-banana waste planting bag prepared. Three difference sample was fabricated with and without the presence of glycerol and with difference ratio of glycerol. The purpose of this project is to design biodegradable planting bags made from mango peel and banana stem that are more environmentally friendly. The study on mechanical properties focused on water absorption test and bursting test whereas the biodegradation ability of mango-banana waste planting bag had been analysed using soil burial degradation test. The results shown that the highest water absorption test is Sample 1, followed by sample 2 and 3. The visual inspection from bursting test shown that all sample exhibited an excellent root growth from biodegradable planting bag after 30 days. The highest weight loss percentage in composting is Sample 1 with 67% as compared to sample 2 and 3 with 75% and 86%. This study analysis emphasis that mango-banana planting bag with and without glycerol can function as an alternative in replacing the polyethylene planting bag and help in addressing environmental issue.

1.0 Introduction

The fabrication of biodegradable planting bag using organic waste shows the process of recycling waste to useful products. In Malaysia, over 1.2 million tonnes of organic waste are disposed into landfills annually. In order to reduce the organic waste, the idea of using mango peel (Mangifera indica) and banana stem (Musa paradisiaca) to be incorporated into biodegradable planting bag as well as to evaluate its mechanical properties.

The use of Polyethylene grow bags is commonly used in nurseries for producing seedlings because they are cheap and readily available. However, a significant drawback of using polyethylene plastic bags (polybags) in agriculture lies in the challenge of proper disposal once they have fulfilled their purpose either being thrown out in the soil or burned after transplant due to high amount of organic material attached to the bag makes recycling difficult. Moreover, the continuation of polybag use must cease, as their persistence in the soil can escalate toxicity levels. Furthermore, the act of removing seedlings from the bags during transplanting carries the risk of root damage, compromising the subsequent development of the plants. Therefore, one alternative method of disposal is substituting plastic with biodegradable materials, promoting the process of natural decomposition. Mango peel and banana stems are natural organic waste: thus, they can be composted in the soil. This natural waste has nutrient values as it may provide some nutrient suppliers to promote the biodegradation process.

1.1 Research Objective

The primary objective of this research is;

i. To fabricate a biodegradable planting bag from banana stem and mango peel with and without the presence of glycerol.

ii. To study the mechanical performance of biodegradation for planting bag by doing tests such as Soil Burial Degradation Test, Water permeability test and Bursting test.

2.0 Literature Review

The present pace of worldwide plastic manufacturing is not viable, given that over 400 million tons of waste are produced annually. Moreover, projections indicate that this rate will quadruple by 2050 (OECD.,2018), alongside a simultaneous rise in agricultural plastic waste (Vox et al., 2016). An issue arises from the fact that only a fraction of the plastic material such as polyethylene planting bag utilized in agriculture undergoes recycling. The majority of the plastics are being left in the soil which causes an irreversible contaminant or being incinerated, releasing harmful substances into the air (Bilck et al., 2014). On the other hand, because they are non-degradable, plastic materials made from petrochemicals would have a negative influence on the environment (Abu, R et al., 2022).

Biodegradable planting bag is made from biodegradable polymers such as organic waste that can decomposed to the environment and would not harm the environment. These bags can be made with various type of waste. Biodegradable planting bags for organic farming have been studied in several papers (Ruide et al., 2014) developed a direct burial biodegradation plant transplanting bag made of biodegradable plastic that can be conveniently transplanted, buried, and biodegraded to protect soil ecology.

Mango peel is indeed a rich source of nutrients such as potassium and phosphorus, which are major components found in common fertilizers. Studies have shown that mango peel contains valuable compounds like phytochemicals, polyphenols, carotenoids, enzymes, vitamin E, and vitamin C, along with dietary fibre, cellulose, hemicellulose, lipids, protein, and pectin (Iszhan et al., 2021; Kiran et al., 2022). Additionally, the chemical composition analysis of mango peel powder revealed the presence of potassium and phosphorus, along with other nutrients like calcium, iron, and zinc (Sun et al., 2018). Furthermore, the utilization of mango peel as an organic base fertilizer has been explored, where it has been found to effectively improve soil quality, promote plant growth, inhibit harmful microorganisms, and reduce the need for pesticides (Rajeswari et al., 2017). Therefore, it can be concluded that mango peel does contain nutrients like potassium and phosphorus, making it a potential source for organic fertilizers (Baddi et al.,2015).

The utilization of banana pseudostem as a planting container has shown positive effects on plant development and productivity, particularly in lettuce cultivation (Iriany et al., 2022). Additionally, banana peel has been incorporated into biodegradable planting bags as a replacement for synthetic materials, resulting in a new value-added biodegradable plastic (Huzaisham et al., 2020) The mechanical and physical properties of these biodegradable bags have been evaluated, and it has been found that the concentration of banana peel in the bioplastic affects its density, porosity, and tear resistance (Huzaisham et al., 2020). Furthermore, the biodegradability of banana peel-based biodegradable plastic has been observed to be faster compared to commercial biodegradable plastic (Chanan et al., 2019). These findings suggest that banana pseudostem and peel can be effectively utilized in the development of biodegradable planting bags, offering environmentally sustainable alternatives to conventional planting containers.

3.0 Methodology

3.1 Sample Preparation

3.1.1 Mango Peel Preparation

Mango peel samples were acquired from a local mango float business owner. The initial step involved washing 3kg of mango peel with tap water and subsequently allowing it to air-dry at ambient temperature for 24 hours. This step was crucial for the removal of soil and debris adhering to the peel surfaces. Following this, the mango peels were manually cut into smaller dimensions measuring approximately 3×3cm each. Subsequently, the peel segments underwent a drying process, initially exposed to direct sunlight for a duration of one week, followed by further drying in an oven (UF110) set at 100°C for a period of 48 hours to eliminate residual moisture content. To facilitate enhanced extraction efficiency, the dried mango peels were then finely pulverized using a heavy-duty grinder machine until a fine powder consistency was achieved (Figure 1.1a)

3.1.2 Banana Stem Preparation

Banana stem, it was trimmed into segments measuring 16 cm in length and subjected to oven drying (UF110) at 100°C for a duration of 24 hours (Figure 1.1b). The stem serves a pivotal role as the structural support within the polybag, harnessing its nutrient content and fibrous composition to reinforce the mold's integrity.

(a) (b)

Figure 1.1 shows the preparation of (a) Dried mango peel and (b) Dried banana stem

3.1.3 Binding Preparation

The materials were mixed according to the ratios specified in Table 1.1 and were added with 150ml of distilled water. The mixture was heated up to 300℃ and stirred continuously until the viscosity increased. Next, the mixture was moulded onto baking paper with the banana stem placed on top and left to dry at room temperature.

Table 1.1: Sample preparation based of ratio

Sample	Banana stem (BS)	Mango peel (MP)	Tapioca Starch (S)	Glycerol (G)
Sample 1	1	1	1	-
Sample 2	1	1	1	1
Sample 3	1	1	1	2

3.2 Analysis

Soil Burial Degradation Test: The soil burial test serves as a means to assess the environmental degradation of a sample. The sample size is reduced to its smallest dimensions (10cm × 10cm). This assessment spans 6 days, during which the sample is retrieved every 2 days for weight measurement analysis before being replanted. The percentage of weight loss is determined using the equation provided below.

$$\%\,Weight\ Loss = \left[\frac{W2-w3}{w2}\right] x\ 100 \qquad [1]$$

Water Absorption Test: The sample is cut into dimensions of (10mm × 1mm) and immersed in a beaker containing 300 ml of tap water. After being submerged for 24 hours, the sample is removed from the water, gently dried at room temperature for 10 minutes, and immediately weighed to determine its final weight. This procedure is repeated continuously for 5 consecutive days. The percentage of water absorption is calculated using the following equation:

$$\%\,Water\ Absorption = \left[\frac{W1-w0}{w1}\right] x\ 100 \qquad [2]$$

Root Bursting Test: This analysis spans over 30 days. The sample utilized is tailored to replicate the shape of a polybag, with dimensions measuring 10cm × 9cm. The saplings employed in this investigation are chili trees (Capsicum annuum). Visual inspection is conducted to observe any root penetration outside the polybag, and the condition of the roots is thoroughly examined.

4.0 Discussion of Analysis And Findings

4.1 Soil Burial Degradation Test

The degree and rate of aerobic biodegradability of planting bag in the environment determines the extent and period to which waste may be mineralized. For this study, three different sample have been used to determine the weight loss percentage as burial progressed. The results in Figure 1.2 shown that the weight percentage for all sample has been reduce significantly.

Sample 1 without the presence of glycerol shown a highest weight reduction followed by sample 3 and 2 of the composites. The escalating weight loss percentage associated with the presence of starch (Amer & Saeed., 2015). Naturally, starch consists of highly complex polymer chains. These polymer chains may undergo enzymatic cleavage, breaking down in the soil. This process results in the creation of monomers, short chains that can permeate microorganism membranes, subsequently acting as a carbon source for microorganism attacks (Obasi et al., 2013). Consequently, microorganisms consume starch, creating pits and voids on the planting bag surface and weakening the structure of the planting bag over time. In addition to that, the banana stem contains an abundance of nutrients, including carbohydrates, proteins, and various others that also could support microbial growth and enhance degradation process (Kadir et al., 2016).

However, the rate of weight loss does not only depend on the starch content, but also on the glycerol content. Sample 2 and 3 shown the presence of glycerol with high aspect ratio could hampered the ability of weight reduction due to lower concentration of starch carbon source. Thus, this result supported by the research done by (Fauziyah et al., 2021) stated that glycerol affected biodegradability and incorporation of glycerol subsequently contributed to the mechanical properties of the sample.

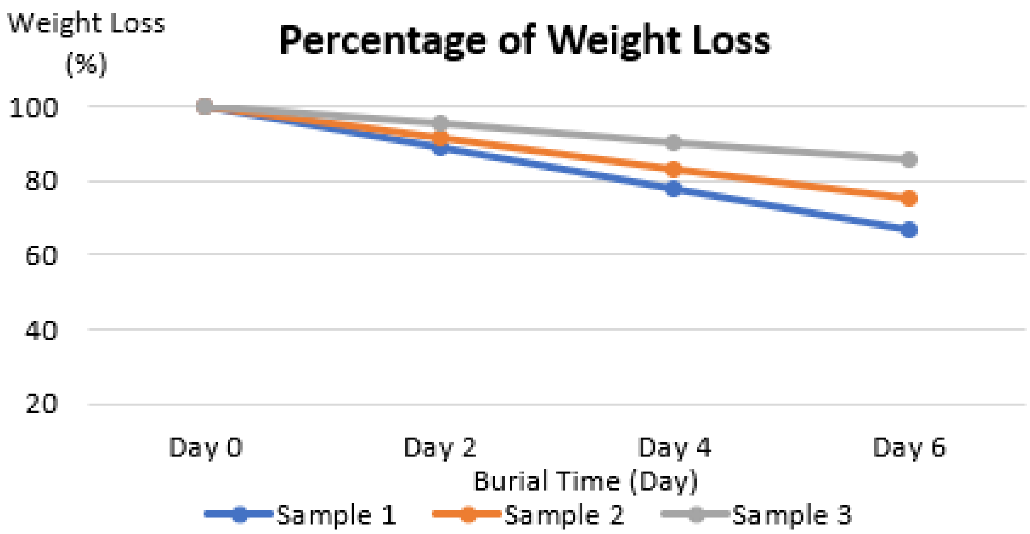

Figure 1.2: Shown the Percentage of weight loss for day 0 until day 6

4.2 Water Absorption Test

This testing is important to investigate the stability composite under humid and moisture conditions. When the composite was immersed into the distilled water, water molecules permeated into the network chains of the composite. As a consequent, the composite absorbed water and started to swell. In the early stage of the absorption process, the composite's mass increased gradually due to the abundance of vacant sites. Over time, water absorption reached an equilibrium state where the composite could no longer absorb water molecules due to saturation of active sites (Mali et al., 2005), thus there is fluctuation of water absorption after days 4.

Figure 1.3 illustrate the percentage of water absorption for various samples synthesized using different ratio of glycerol. The findings indicate that the water absorption capacity decreased as the concentration of glycerol increased. Notably, the sample with 0% glycerol exhibited a high-water absorption rate, attributed to the hydrophilic properties of the starch-based composite. When glycerol was used as the plasticizer, at the ratio of 1:1 the water absorption characteristics were insignificantly different from the composite without glycerol. However, with an increased concentration to a 1:2 ratio, a substantial reduction in water absorption percentage was observed. This confirms that the addition of glycerol minimizes the hydrophilic nature of the biodegradable composite, resulting in a decreased water absorption ability. In other words, composite contained a high amount of glycerol could be made more water resistance. This was similar to the work of (Ng et al., 2022) who reported that the addition of plasticizers effectively reduced the swelling and water retaining capacity of potato-based biodegradable plastic. In addition, research by (Chuayjuljit et al., 2009) also mention that increasing amount of additive in starch composite could serve as a barrier and reduce the water-uptake ability of materials.

Based on water absorption results, it exhibits a positive correlation with the outcomes of soil burial degradation testing, suggests that the material's performance in terms of water absorption aligns well with its degradation characteristics in a soil environment.

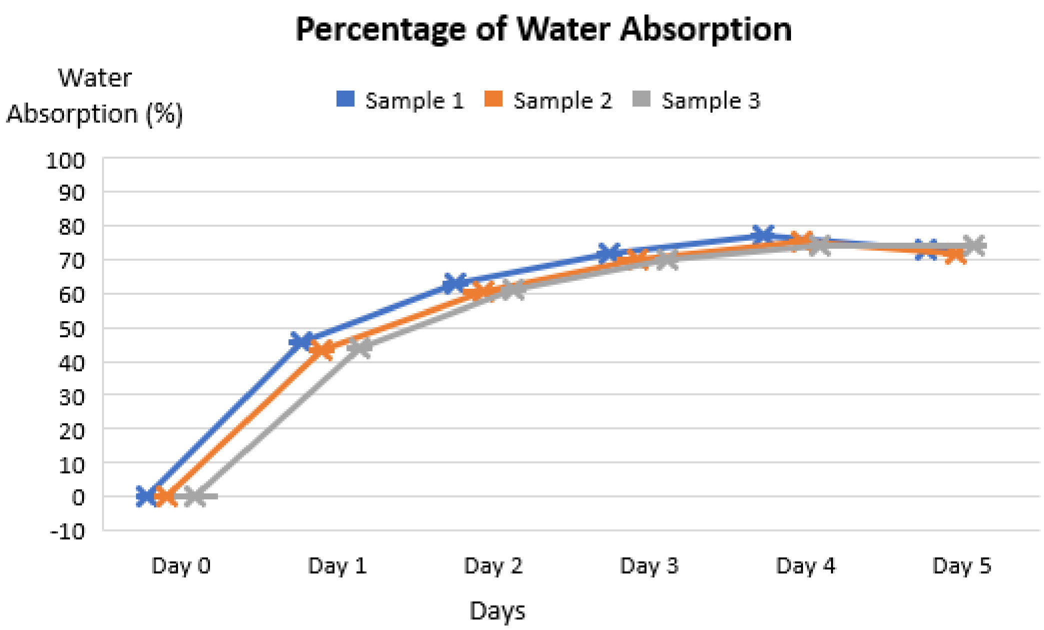

Figure 1.3: Shown the Percentage of water absorption for day 0 until day 5

4.3 Root Bursting Test

This test aims are to observe the penetration of roots through sample after 30 days. Based on Table 1.2, a planting bag sample 2 and 3 with the presence of glycerol show a longer root and more diverge as compared to planting bag sample 1 with no presence of glycerol. According to review paper done by (Sathiyavani et., al 2017) states that mineral nutrition is an important factor influencing the growth of plant roots. It mentions that roots with adequate nutrient supplies may have more root hairs compared to nutrient-deficient roots. The production of organic planting bag from banana stem- mango peel with the aid of starch and glycerol help in the development of root of planting tree. Previous research on banana stem as planting media for kangkong and mustard green state that banana stem can provide water for plant for certain duration, indicating that banana stem has high water retention capacity (Saputro et al., 2017). In addition, the used of mango peel function as organic fertilizer to promote root growth. This statement supported by (Iszhan et al., 2021) which highlight the potential of using mango fruit peel as organic fertilizer to enhance the growth of spinach, providing sustainable agriculture practise.

Based on result, it also can see that the planting bag was degrediate after 30 days of burial. This result is contradicted with the results of (Bilck et al., 2014) plant that were cultivated without being removed from the polyethylene bags had root development difficulties, and the polyethylene bags showed no signs of degradation. Thus, the use of biodegradable planting bag is an alternative for the production of bags for seedlings, as these can then be transplanted directly into the soil without removing the bag, reducing the risk of damage to the roots during the moment of transplant.

Table 1.2: Shows the result of roots grows after 30 days

Before	After 30 Days		
	Sample 1	Sample 2	Sample 3
			

5.0 Conclusion and Future Research

Based on this research, it is evident that the study has effectively achieved its objectives. The findings demonstrate the feasibility of producing planting bags from a combination of mango peel and banana stem. Additionally, the incorporation of glycerol influenced various properties of the composite. In the root bursting test, all three samples exhibited positive results, with roots able to penetrate after 30 days without any damage. The positive root bursting results suggest that these bags are not only feasible but also functional for supporting plant growth. Moving forward, several recommendations can be proposed to further enhance the results. Firstly, considering mixing the sample with other types of natural organic waste could potentially improve the properties of the planting bags. This approach may lead to enhance the overall performance and durability of the composite material.

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Author Contributions

Syed Zainol Abidin S. N. J.: Conceptualization, Methodology, Writing- Original Draft Preparation; **Bachok S.**: Data Curation, Validation, Supervision; **Samat S.**: Validation, Writing-Reviewing and Editing. **Moreno M. L.:** Data validation

Conflicts of Interest

The manuscript has not been published elsewhere and is not being considered by other journals. All authors have approved the review, agree with its Submission and declare no conflict of interest in the manuscript.

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