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Development of Green Polybag Innovation Products from Biomass Waste as Planting Media

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ABSTRACT

Green polybags offer an eco-friendly alternative to conventional plastic polybags, which pose environmental concerns due to their slow decomposition. This study explores the optimal composition of empty fruit bunches (EFB), sawdust waste (SW), and natural rubber latex (NRL) to develop biodegradable green polybags that function as both containers and planting media. The best formulation—EFB 140 g, SW 40 g, and NRL 60 g—exhibited a density of 0.6762 g/cm³, moisture content of 6.71%, water absorption of 45.28%, and biodegradation rate of 29.91%. Seedlings grew successfully in this medium, demonstrating its effectiveness. FTIR analysis confirmed the presence of hydroxyl, carbonyl, aliphatic, and ester groups, while SEM-EDX analysis indicated high carbon and oxygen content in EFB and SW. The results suggest that green polybags are a sustainable and biodegradable alternative, promoting environmental conservation and plant growth.

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1. INTRODUCTION

Green Polybag is a replacement for polybag as a planting medium in the plant nursery process. Green Polybags are derived from organic materials. Thus, when the process of planting plants in the field, the plants can be immediately moved without causing plastic waste like the use of poly bags [1]. The use of Green Polybags is the right solution to overcoming environmental problems related to the accumulation of waste by the use of polybags, this is because Green Polybags are environmentally friendly because they are made of biodegradable materials [2]. In this study, green polybags will be made using empty oil palm bunches (EFB), sawdust waste (SW), and natural rubber latex (NRL) as adhesives.

Indonesia is the country with the largest oil palm plantation with an area of 14.3 million ha. Oil palm plantations produce 53 million tons of oil palm waste per year with the amount continuing to increase every year, some of the waste produced from oil palm plantations are shells, fronds, coir, and empty fruit bunches of oil palm [3]. EFB from oil palm is a by-product of oil palm processing whose accumulation reaches 23% or 23 kg of 100 kg of fresh fruit bunches. EFB contains lignin (21.27-36.68%), cellulose (35.66-57.75%), hemicellulose (6.61-15.96%), moisture content (8.56%), and other components. The high cellulose content in EFB causes environmental problems [4]. The high cellulose content in EFB is beneficial for forming a strong and stable structure, good water absorption ability, and good chemical and physical stability in the green polybags produced. Indonesia is estimated to produce around 20.8 million metric tons per year of empty oil palm bunches [5].

SW is an organic waste produced from the carpentry industry during the sawing and cutting process, sawdust waste consists of wood particles and shavings of various shapes and sizes. [6]. The SW produced annually is 1.4 million m3/year, and this amount continues to increase every year without further management, of course, causes environmental problems [7]. The use of wood powder waste in the manufacture of Green Polybags provides a promising solution to overcome environmental and economic challenges related to waste management. The use of SW as raw materials in the manufacture of Green Polybags has several advantages because wood waste is environmentally friendly, easily decomposable, has high rigidity, low density, and relatively low price [8].

Tapping the bark of the Hevea Brasiliensis tree yields a milky white liquid known as natural rubber latex or NRL. NRL is considered valuable because it has high flexibility, elasticity, and resilience [9]. NRL contains organic components such as carbohydrates, proteins, and phospholipids, with a density from 0.97 to 0.98 with a pH of 6.5-7.0, inorganic compounds (1%), and a total solids content (25-50%) [10]. NRL is a good material for the production of various commercial products such as gloves, tires, gaskets, balloons, hoses, and condoms [11]. NRL is in demand because it is a renewable natural resource, inexpensive, odorless, and has good characteristics [12]. In this study, NRL will be used as an adhesive in the manufacture of Green Polybags. The use of NRL is more in demand due to its biodegradable properties which support an important factor for environmentally friendly applications [13].

The use of EFB, SW, and NRL as raw materials for making green polybags supports the principle of circular economy by utilizing biomass waste to add value to the waste. They are also renewable materials that ensure the availability of raw materials in a sustainable manner, reduce the volume of unused waste, and produce environmentally friendly products. Green polybags not only serve as containers for plants but also contribute to increasing soil and plant fertility.

This research will later utilize EFB, SW, and NRL in the manufacture of green polybags. The manufacture of green polybags from EFB and SW is one of the efforts to prepare a good

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medium for plant growth to help reduce the accumulation of organic waste in the environment and increase the economic value of the waste. So far, EFB is usually only used as compost and road reinforcement in oil palm plantation areas. Meanwhile, wood powder waste is just thrown away. This study will later investigate the composition of EFB:SW: NRL on green polybags produced through physical characteristics, including SEM-EDX testing on raw materials, density, moisture content, water absorption, biodegradation, plant seed planting, and FTIR.

2. METHODS

2.1. Materials

The materials used in this study were EFB from oil palm plantations in Medan, Indonesia, SW from wood craftsmen (Medan, Indonesia), natural rubber latex (Medan, Indonesia), aquadest, spinach seeds (market in Medan), EM-4 (Effective Microorganisms-4) (from market in Medan) which is a bacterium made from substances containing glucose. The tools used in this study were Erlenmeyer, beaker glass, 30 mesh sieve, chop, gloves, tarp, cylinder mold with a volume of 240 m3, oven, and hydraulic press.

2.2. Preparation and Production of Green Polybags

2.2.1. Process of compost from empty fruit bunches (EFB)

EFB was chopped into small pieces, 0.8 L of activated EM-4 solution was mixed into 10 kg of EFB, then tightly closed and incubated for 30 days until a blackish brown compost was produced, odorless and easy to crush.

2.2.2. Preparation of sawdust waste (SW)

SW was initially dried in the oven for 30 minutes, then blended and sifted using a 30-mesh sieve to produce fine particles.

2.2.3. Production of green polybags

The formulation of EFB compost and SW with the addition of NRL as an adhesive was prepared up to 240 g (**Table 1**). After that, a hydraulic machine pressed the created formulation into a cylindrical mold. Next, this mixture of raw materials was dried in the oven for 1 hour at a temperature of 105 °C. After drying, green polybags were tested to see the characteristics produced.

Table 1. Composition of green polybags

Variastions	EFB (g)	SW (g)	NRL (g)
1	140	60	40
2	120	80	40
3	140	40	60
4	120	60	60

2.3. Characterization of Green Polybags

2.3.1. Density testing

The density analysis of green polybags was carried out by taking each sample and then weighing it as the initial mass of the sample. Then the cylindrical sample was measured in height and diameter to find out the volume of the sample. The density of green polybags describes the density of the sample and the ability of the material to regulate the flow of air

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and water to the roots of plants to support optimal plant growth. Equation (1) is used to determine the density of green polybags:

$$\rho = \frac{m}{V} \tag{1}$$

where ρ is the density (kg/m^3), m is the mass sample (kg), V is the volume (m^3).

2.3.2. Moisture content

The purpose of the moisture of green polybags test was to ascertain how the moisture balance relates to the quality of green polybags. The moisture in green polybags was calculated using equation (2) with the mass of the sample before the oven drying process known as the wet mass, and the mass of the sample following an hour of drying at 105 °C known as the dry mass (Equation (2)).

$$\text{Water content } (\%) = \frac{wet\ mass - \text{dry mass}}{wet\ mass} \times 100 \tag{2}$$

2.3.3. Water absorption

Analysis of water absorption capacity on green polybags was done by soaking it until it sunk for 15 minutes. Green polybags were then drained for 2 minutes and weighed for their final mass after soaking. The water absorption capacity of green polybags was calculated using Equation (3):

$$\text{Water absorption } (\%) = \frac{m_b - m_a}{m_a} \text{ x } 100\% \tag{3}$$

where m_a is the Initial mass before soaking (g), m_b is the Final mass after soaking for 15 minutes (g).

2.3.4. Biodegradation

Green polybags were planted in the soil to calculate the rate of biodegradation, green polybags were planted for 30 days. After 30 days, it was then removed from the ground and weighed using a digital balance sheet. We calculated the weight changes that occurred before and after the green polybag was planted. The biodegradation analysis of green polybags was calculated by Equation (4).

$$\text{Biodegradation } (\%) = \frac{w_1 - w_2}{w_2} \text{ x } 100\% \tag{4}$$

where W_1 is the green polybags sample mass day 0 (g), W_2 is the green polybags sample mass day 30 (g).

2.3.5. Seed planting testing

Testing of planting seeds on green polybags was carried out to see the feasibility of green polybags as a planting medium on plants. This test was carried out by preparing the best sample then the green polybag was given a little hole to place the plant seedlings to be planted. After that, the hole was closed again and watered with a few drops of water. We placed the green polybag in a shaded area that was not directly exposed to sunlight. The seeds planted in this experiment were spinach. Every day, the samples were watered in the morning and evening, and the growth of spinach seedlings that had been planted for 14 days was observed.

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2.3.6. Analysis FTIR of green polybags

Following the acquisition of the green polybags, functional groups were identified by several analyses. The Agilent Cary 360 FT-IR spectrophotometer was used to examine the functional groups of green polybags. Important information regarding the suitability of using EFB, SW, and NRL as raw materials for the production of green polybags was provided by FT-IR analysis of the functional groups of green polybags.

2.3.7. Analysis SEM-EDX composition EFB and SW

In the manufacture of green polybags using EFB, SW, and NRL. The content of EFB and SW was initially examined using a scanning electron microscope-energy dispersive X-ray or SEM-EDX. This is necessary to know and support its application as a raw material for green polybags that can fertilize plants.

3. RESULTS AND DISCUSSION

3.1. Density of Green Polybags

The mass of the green polybag material per unit volume is referred to as its density. Density is an important parameter because it affects the mechanical properties, stability, and functionality of green polybags. The density of green polybags gives different values based on the composition of raw materials EFB, SW, and NRL.

In **Figure 1**, a green polybag with the composition EFB:SW: NRL (140:60:40) produces a density value of 0.5904 g/cm^3, the composition EFB:SW: NRL (120:80:40) produces a density value of 0.5833 g/cm^3, the composition EFB:SW: NRL (140:40:60) produces a density value of 0.6762 g/cm^3, and the composition EFB:SW: NRL (120:60:60) produces a density value of 0.6534 g/cm^3. The use of more EFB will increase the value of the green polybag produced because EFB has a denser structure, but when SW is increased, the density value will decrease, this is because SW has high porosity and fine particles. Thus, it creates a lot of space between particles, making green polybags more porous and causing the density value of green polybags to decrease.

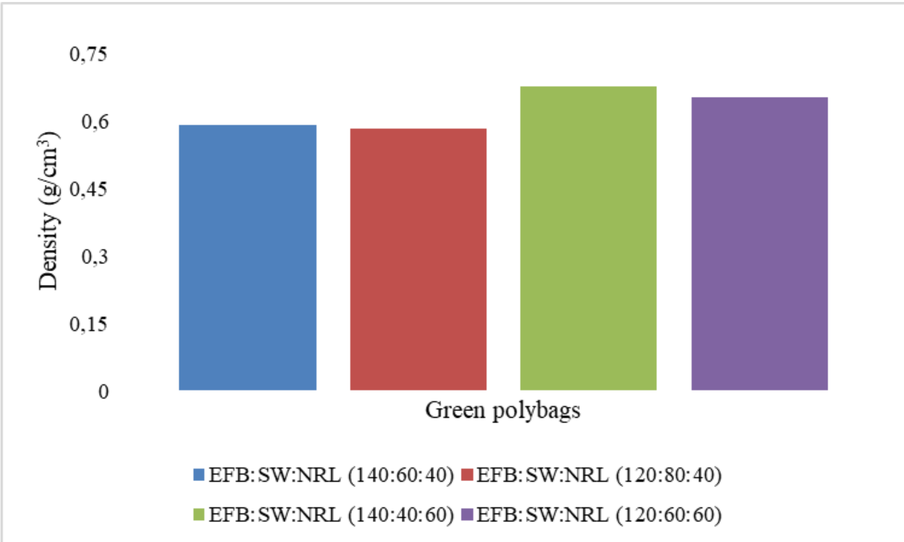

Figure 1. Density of green polybags.

Green polybags with the use of 60 g NRL as adhesive produce a higher density value than the use of 40 g adhesive because latex fills the pores between the EFB and SW fibers. Thus, when the use of adhesive is increased, the resulting green polybag becomes denser and

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denser because the number of blanks is reduced, thus increasing the density of green polybags. The use of latex in green polybags functions as a binder that combines fibers. Thus, the resulting green polybags become more solid and less hollow when pressed green polybags tend to be easier to compact and this also contributes to higher density values because the mixture of EFB and SW becomes more compact. The best density value is found in green polybags with a composition of EFB:SW: NRL (140:40:60) resulting in a density value of 0.6762 g/cm^3.

3.2. Moisture Content of Green Polybags

The percentage of water in the material of green polybags about its dry mass is known as the moisture content. Moisture content is an important parameter in the characterization of green polybags because it affects various physical, mechanical, and durability properties of green polybags during their use. The moisture content value in green polybags of different results is influenced by the composition of raw materials EFB:SW: NRL.

Figure 2 shows that the composition of EFB, SW, and NRL increases affecting the water content value produced. In green polybags with the composition EFB:SW: NRL (140:60:40) produced a moisture content of 7.93%, the composition of EFB:SW: NRL (120:80:40) produced a moisture content of 8.92%, the composition of EFB:SW: NRL (140:40:60) produced a moisture content of 6.71%, and the composition of EFB:SW: NRL (120:60:60) produced a moisture content of 6.86%. When the composition of SW increases and the composition of EFB decreases, the moisture content value also increases, this is because the increased composition of SW causes the porosity of the planting medium to be higher because SW particles tend to create more air space which increases the evaporation rate because more areas are exposed and exposed to air.

The use of 40 g of NRL produces a higher moisture content value than the use of 60 g of NRL because the use of lower latex provides lower protection. Thus, it does not provide a sufficient protective layer to cover the surface of the EFB and SW fibers. Green polybags that are not fully coated by the adhesive cause many empty spaces or pores to open, Thus, more water can be absorbed and retained in the green polybag structure and raise the green polybag's moisture value content. The best moisture value content is indicated in the composition of EFB:SW: NRL (140:40:60) which produces a moisture content of 6.71%.

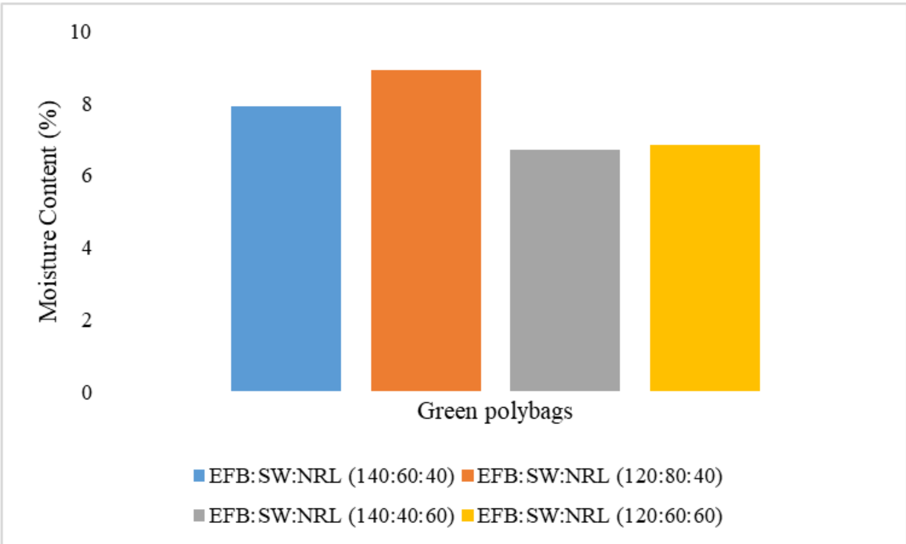

Figure 2. The water content of green polybags.

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3.3. Water Absorption of Green Polybags

The water absorption in green polybags is the ability of green polybag materials to absorb and retain water in their pore structures. Water absorption is an important parameter in assessing the quality of green polybags because it affects various functional aspects of green polybags such as humidity for plants, shape stability, and durability of green polybags against humid environments. The water absorption of green polybags gives different results influenced by the composition of raw materials EFB:SW: NRL.

From **Figure 3**, the composition of raw materials affects the water absorption produced in green polybags. In green polybags with the composition EFB:SW: NRL (140:60:40) produced water absorption of 54.39%, the composition of EFB:SW: NRL (120:80:40) produced 0% water absorption, the composition of EFB:SW: NRL (140:40:60) produced water absorption of 45.28%, and the composition of EFB:SW: NRL (120:60:60) produced water absorption of 51.58%. The increase in the composition of SW increases the water absorption value because SW is in the form of small particles with a larger surface area, while EFB has a more fibrous structure. Thus, the surface area per volume is smaller and affects the water absorption value produced.

The use of NRL 40 g green polybag is not too sturdy so, in variation 2, the green polybag becomes easily crushed and scattered when soaked in water for water absorption testing. The use of 60 g NRL produces a low value compared to the use of 40 g NRL, this is because the use of 60 g NRL produces a thicker and more even adhesive layer that coats and closes the fibers and pores better. This layer reduces the ability of green polybags with the use of 60 g NRL to absorb water. Thus, water absorption is lower. Another reason is that NRL is hydrophobic, where NRL particles reduce water absorption [12]. In the analysis of water absorption, it is indicated that Green polybags with the composition of EFB:SW: NRL (140:40:60) produce good water absorption of 45.28%

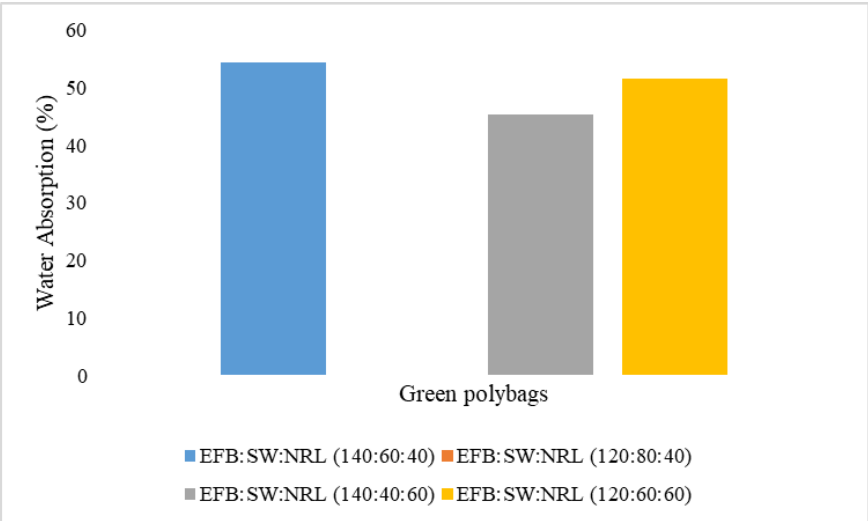

Figure 3. Water absorption of green polybags.

3.4. Biodegradation of Green Polybags

Biodegradation in green polybags is a natural process where green polybags break down into simpler compounds through the activity of microorganisms [14]. Green polybag components are transformed by this process into substances that the soil may absorb, including water, carbon dioxide, and other organic compounds. Biodegradation is important in the context of green polybags because green polybags are designed to decompose after

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their useful life is over. Thus, they do not leave plastic residues or synthetic materials that are difficult to decompose. The biodegradation value of green polybags is influenced by the composition of raw materials EFB:SW: NRL.

From **Figure 4**, the composition of EFB and SW affects the biodegradation value in green polybags. In green polybags with the composition EFB:SW: NRL (140:60:40) produced biodegradation of 28.41%, the composition EFB:SW: NRL (120:80:40) produced biodegradation of 26.42%, the composition EFB:SW: NRL (140:40:60) produced biodegradation of 29.91%, and the composition EFB:SW: NRL (120:60:60) produced biodegradation of 28.32%. The increase in SW composition increases the biodegradation value, this is because SW has denser fine particles and tends to reduce the space and pathway for microorganisms to decompose the materials in the green polybag. Thus, reducing microbial activity and ultimately decreasing the percentage of biodegradation.

The use of 60 g NRL produces a greater percentage of biodegradation compared to the use of 40 g NRL, this is because the use of 60 g NRL makes the fibers coated more thoroughly and the material becomes more stable in terms of composition and bonds between the fibers. This allows for a more even and regular biodegradation process and increases the overall decomposition percentage of green polybags. Meanwhile, with the amount of 40 g, NRL provides more vulnerable fiber but also increases the access for microorganisms to decompose EFB and SW fibers. However, due to the uneven adhesive layer, some parts may degrade faster while others remain intact thereby reducing the overall decomposition rate and affecting the lower biodegradation value of 40 g NRL use.

The best biodegradation value is indicated in the composition of EFB: SW: NRL (140:40:60) which produces a biodegradation of 29.91%, which does not produce a biodegradation value that is too low or too fast. Designed to be easily degraded, green polybags can be a sustainable alternative to non-environmentally friendly polybags [15]. Similar results were also obtained by Saepoo et al., 2023 where biodegradable pots made from TPS composites with 50wt% MPC degraded well after 28 days of planting.

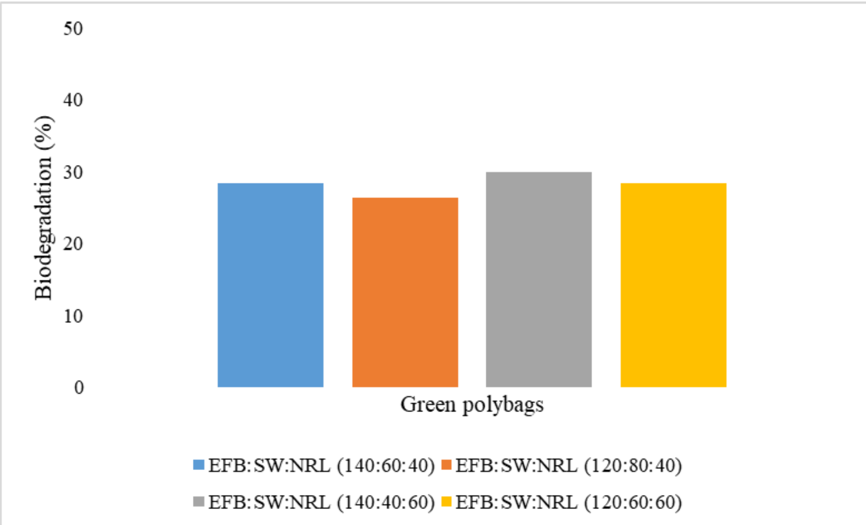

Figure 4. Biodegradation of green polybags.

3.5. Planting Seeds on Green Polybags

Planting seeds in green polybags is carried out to evaluate and ensure whether the resulting green polybags can support plant growth optimally [16]. Green polybags that have been planted with seeds can later be planted directly into the ground along with the plants without the need to move them from the green polybags. This minimizes transplant stress on the roots. In this experiment, the seeds planted were spinach seedlings.

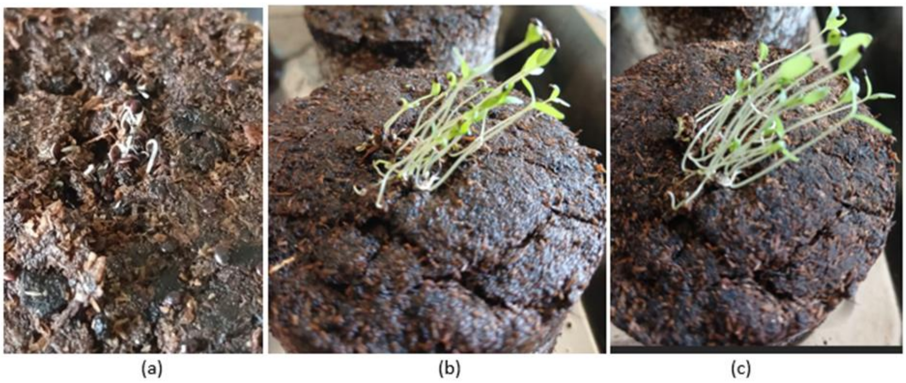

Figure 5. Planting spinach seeds for (a) 2 days (b) 7 days (c) 14 days.

The planting of spinach seeds in the resulting green polybags is presented in **Figure 5**. The green polybag that is planted with seedlings is a green polybag with optimal conditions, namely variety 3 with a composition of 140 g of EFB, 40 g of SW, and 60 g of NRL. Spinach seedlings can grow well from day 2 to 14 days. From the picture, it can be concluded that green polybags have succeeded in providing a conducive environment (such as porosity, aeration, and moisture) to support the growth of plant seedlings. Green polybags that successfully support plant growth allegedly have the right level of biodegradation, which is not too fast which can damage seedlings but also not too slow. Thus, it does not inhibit root development. The good growth shows that green polybags from EFB and SW can be an effective alternative to polybags, thus supporting the goal of reducing plastic waste and switching to more environmentally friendly options.

3.6. FTIR Analysis on Green Polybags

FTIR (Fourier Transform Infrared Spectroscopy) analysis on green polybags was carried out to study the chemical composition, interactions between materials, and changes in chemical structure that occur during the process of making green polybags. Green polybags are composed of cellulose, lignin, hemicellulose, and other components. The FTIR technique is used to determine the functional groups in these materials. **Figure 6** shows the results of the FTIR study on green polybags.

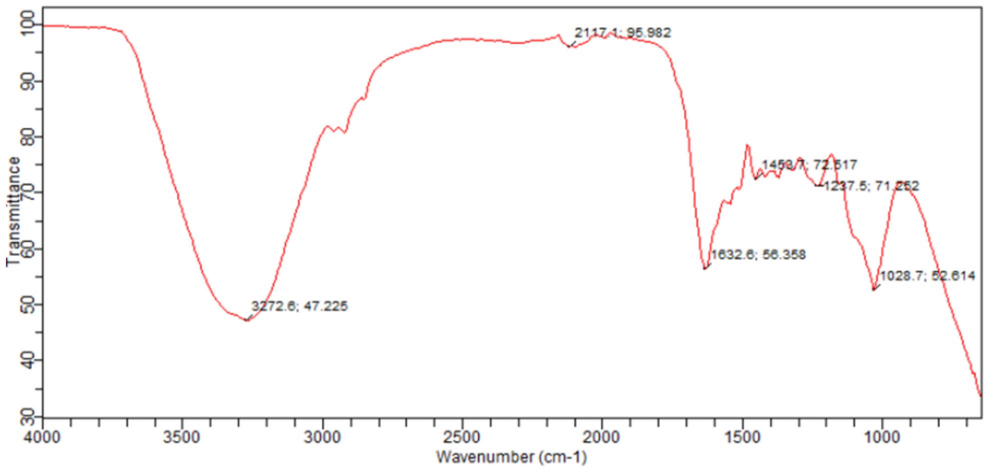

Figure 6. FTIR analysis on green polybags.

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Figure 6 illustrates how the FTIR examination of green polybags yields many peaks. At peak 3272.6 cm^{-1}, the hydroxyl group (-OH) is detected, this wave number is related to the stretching vibration of -OH in water [17]. At peak 2117.1 cm^{-1}, the carbon double functional group C=C is detected, this number indicates the stretching vibration of the triple bond. At peak 1632.6 cm^{-1}, the carbonyl functional group C=O is detected, which represents the conjugated C=O stretching vibration [18]. At peak 1458.7 cm^{-1}, the methyl group -CH3 is detected in the aliphatic compound, this number indicates the deformation vibration of the CH group. At peak 1237.5 cm^{-1}, the ester functional group (C-O) is detected, this number is related to the vibration with the C-O structure of the oxygen compound [19]. At peak 1028.7 cm^{-1}, the C-O functional group is detected, this number indicates the C-O stretching vibration in the polar compound. This spectrum shows the existence of hydroxyl, carbonyl, aliphatic, and ester functional groups from the components of EFB, SW, and NRL materials. The results of this spectrum support the application of materials in the development of environmentally friendly products.

3.7. SEM-EDX Analysis of EFB and SW

SEM-EDX analysis on green polybag raw materials, namely EFB and SW, is very useful for understanding the morphological characteristics and chemical composition of these two types of waste.

As shown in **Figure 7** and **Table 2**, the SEM-EDX results of EFB contain several elements. The most dominant elements are C and O. The presence of C and O in EFB mostly consists of cellulose and lignin which are rich in carbon and oxygen. The presence of other elements such as Ca, and Si indicates the presence of inorganic minerals contained in EFB. The elements Mg, Al, P, S, and K indicate organic minerals in EFB.

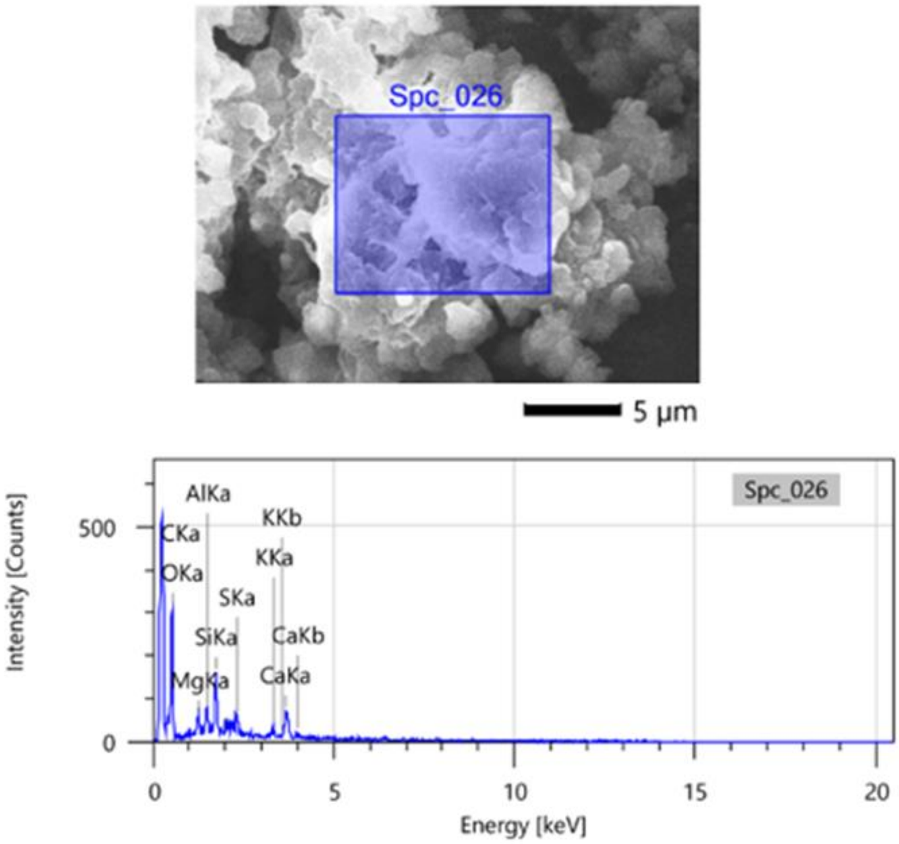

Figure 7. Analysis SEM-EDX of EFB.

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Table 2. Elements contained in EFB.

Element	Line	Mass%	Atom%
C	K	33.83 ± 1.39	43.97 ± 1.81
O	K	48.40 ± 2.83	47.22 ± 2.76
Mg	K	1.87 ± 0.34	1.20 ± 0.22
Al	K	1.88 ± 0.33	1.09 ± 0.19
Si	K	4.60 ± 0.49	2.56 ± 0.27
P	K	0.77 ± 0.22	0.39 ± 0.11
S	K	2.05 ± 0.33	1.00 ± 0.16
K	K	1.22 ± 0.31	0.49 ± 0.12
Ca	K	5.38 ± 0.67	2.10 ± 0.26
Total		100.00	100.00
		Fitting ratio 0.4098	

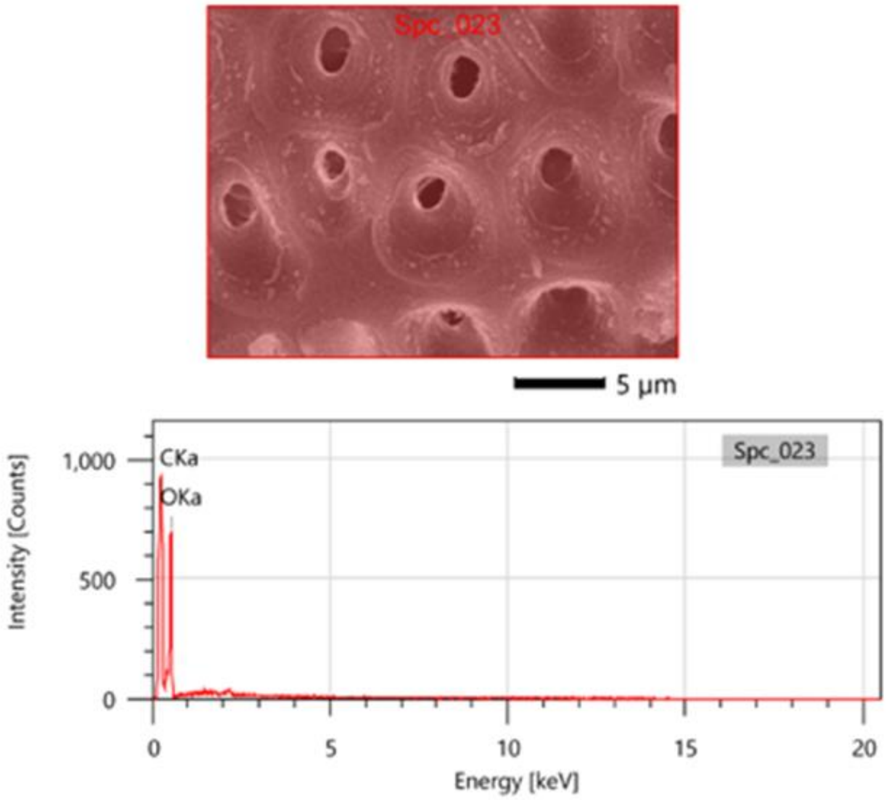

Figure 8. Analysis SEM-EDX of SW.

Table 3. Elements contained in SW.

Element	Line	Mass%	Atom%
C	K	33.60±0.98	40.27±1.18
O	K	66.40±2.60	59.73±2.34
Total		100.00	100.00
		Fitting ratio 0.4333	

As presented in **Figure 8** and **Table 3**, the SEM-EDX results of SW detected C and O elements of 33.60% and 66.40%. The C and O elements indicate that sawdust waste contains large amounts of carbon and oxygen derived from cellulose and lignin. SW contains high levels

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of cellulose and hemicellulose, thus providing intermediate tensile strength due to its adhesion and dispersion properties [20].

SEM-EDX analysis of EFB and SW provides a clear picture of the morphology and chemical composition of these materials. Both of these wastes have great potential as raw materials for green polybags because of their high cellulose content and elements that support plant growth. With this material, we can design green polybags that are more effective, environmentally friendly, and sustainable.

Based on FTIR and SEM-EDX analysis, Green Polybags can be applied effectively to support plant growth, are resistant to the environment, and are easily decomposable. The combination of C and O elements in EFB and SW raw materials supports the interpretation from the FTIR analysis, that green polybags contain polymer components that are potentially biodegradable or have chemical modifications to improve their functionality. In Green polybags, several groups were detected including esters, carbonyl, and hydroxyl (FTIR results) combined with the dominance of C and O elements (SEM EDX results) showing that the material has the potential to be biodegradable and has been by the relevance of research to design green polybags that are environmentally friendly and as a good planting medium.

4. CONCLUSION

Green polybags A good solution for maintaining environmental sustainability from plastic waste pollution caused by the use of polybags in the plant nursery process. Green polybags are made from natural materials such as EFB, SW, and NRL. This study formulated the composition of the three materials to find the best composition in its application as a planting medium. Green polybags with a composition of EFB 14 g, SW 40 g, and NRL 60 g gave the best results with a density of 0.6762 g/cm3, water content of 6.71%, water absorption of 45.28%, and biodegradation of 29.91%. In this variation, plant seedlings can grow well, FTIR results show that the green polybags produced contain hydroxyl, carbonyl, aliphatic, and ester. SEM-EDX results show that EFB and SW contain high amounts of C and O elements. In future research, we can replace sawdust with other raw materials that contain nutrients that are better for plant growth.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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