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Biodegradable Container for Planting Purpose

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Abstract

Amid growing environmental concerns and the escalating plastic pollution crisis, the use of containers made from natural fiber materials, which can decompose naturally over time, offers a promising solution to reduce the ecological impact of plastic waste. This study aligns with the global commitment to create a more sustainable and environmentally conscious future. It holds critical importance in the context of environmental sustainability and the advancement of sustainable agricultural practices. This research study aimed to identify suitable fibers for the fabrication of biodegradable containers and explored various materials such as recycled paper, rice straw, corn husk, and coconut fiber, analyzing their characteristics and properties once fabricated into containers. Several experiments were conducted to determine how different types of fiber containers influence soil moisture, soil pH, and soil salinity, as well as how they support plant growth by providing nutrients. It was found that the combination of rice straw and recycled paper containers facilitated the most significant plant growth, while the combination of coconut fiber and recycled paper containers demonstrated the fastest degradation rate. An overall comparison also shows that the sample containers mixed with natural fiber were able to yield better results compared to the sample with recycled paper only. Thus, the development of biodegradable materials from agricultural waste is not only able to reduce toxic plastic waste and alleviate the abundance of agrowaste, but it is also able to benefit plant growth and agricultural yield production.

1. Introduction

One of the most challenges in agriculture is the abundance of plastic materials that contribute to pollution and environmental problems. The use of plastic bags as medium for planting containers is widely used in agriculture activity as this material is quite flexible and cheaper than other materials. However, the pressing need for sustainable alternatives has fueled significant research interest in fiber-based biodegradable plant containers. Designed to degrade naturally over time, these containers minimize the long-term ecological footprint associated with conventional plastics [1]. In response to the growing concern over environmental issues and the worsening plastic pollution crisis, we have seen a significant increase in research and development focusing on biodegradable plant containers. This innovative approach was developed with the aim of overcoming the ecological impact arising from conventional plastic plant containers, which contribute significantly to the problem of non-degradable plastic waste. The importance of research on these biodegradable plant containers lies in their potential to transform the agricultural and horticultural industry by providing a sustainable alternative. Unlike conventional plastic containers that have remained in the environment for centuries, these biodegradable containers are able to undergo a natural breakdown process over time, helping to reduce the carbon footprint and reduce the long-term environmental impact associated with plastic waste. Infact, the use of natural fiber for planting purposes is not only able to minimize contamination but also more economical and able to reduce the abundant waste problem on the earth. The following fibers were chosen and used with the consideration as these fibers are among the agriculture waste that available abundantly in Malaysia.

a) Rice Straw

Although rice straw is seen as a waste product or byproduct of agriculture, it is a valuable raw resource used in the manufacturing of pulp and paper. Therefore, rice straw is suitable to be used in papermaking. The first agricultural waste to be used in Egypt to make paper and board was rice straw. Rice straw was used to make inexpensive packaging and wrapping paper in the 1930s. In the early 1960s, rice straw was first used to make stationery. Since then, the quantity of rice straw employed in this sector has gradually expanded to over 60,000 tons of pulp annually. In terms of biodegradability, a study demonstrated that rice straw is highly biodegradable in soil, with microbial communities being essential to the breakdown process. As rice straw decomposes over time, its organic content enriches the soil [2].

b) Corn Husk

A potential solution to this waste issue is corn husk, which has a high cellulose fiber content and can be utilized as a raw material for papermaking. Research indicates that corn husk film has a high rate of biodegradability, suggesting its potential as an environmentally benign substitute in agricultural practices [3]. Research has also been conducted on creating and utilizing biodegradable pots made from this film for planting seedlings. The outcomes demonstrate that these pots improve the microclimate for seedling growth while lessening negative environmental impacts.

c) Coconut Fiber

Coconut fiber, or coconut coir, is frequently utilized in structural fiber research. Its commercial application is widespread, ranging from traditional coconut husk products such as brushes, mattresses, and doormats to modern agricultural tools. Coir fiber is highly flexible, capable of being twisted without snapping while retaining its distinct curl [4]. Extracted from the coconut husk, this thick, coarse, and resilient natural fiber is largely impervious to water, salinity corrosion, and microbiological deterioration [5]. Consequently, it has become a popular choice for manufacturing biodegradable pots, offering excellent water retention, breathability, and natural resistance to fungi and bacteria. These pots provide optimal drainage suitable for a wide range of plants. Additionally, longer mattress fibers can be reclaimed from discarded bristle fibers in the coir industry; this specific fiber waste can then be effectively repurposed to stabilize soil. As a cultivation medium, coco coir is highly adaptable, featuring a neutral pH, a high cation exchange capacity, and an abundance of essential nutrients such as iron, potassium, copper, and zinc. Its exceptional absorbency further underscores its suitability for agricultural and planting purposes.

d) Other Materials in Papermaking and Planting Container Processing

Additives are incorporated into polymers during manufacturing to enhance performance, facilitate processing, or impart novel functional properties. Among these, binders serve as critical agents that mechanically or chemically adhere components together, utilizing either synthetic resins or natural ingredients like gums and starches. Natural polymers specifically starches derived from rice, potato, wheat, and maize are widely recognized for their excellent binding and dissolving capabilities. Beyond these conventional sources, alternative starches such as enset and banana starch have also proven effective as binding agents [6].

2. Methodology

The first procedure involves preparing the raw materials from various previously dried fibers. As outlined in Table 1, distinct samples were prepared according to the selected fiber types. Following sample preparation, multiple characterization tests were conducted, including tensile strength measurement, microstructure analysis via scanning electron microscopy (SEM), water absorption testing, and degradation assessment. Concurrently, during the plant growth phase, soil parameters specifically soil moisture, pH levels, and nutrient contentwere monitored. A standard soil survey instrument was used to measure soil moisture and pH within the planting containers, while the nutrient salt content was determined using a 3-in-1 LCD digital water quality test pen

Table 1 *Sample of experiment*

Types of Samples	*Types of plants*
A: Recycled paper	Mustard green/water spinach/mung bean
B: Rice straw + recycled paper + corn starch	Mustard green/water spinach/mung bean
C: Corn husk + recycled paper + corn starch	Mustard green/water spinach/mung bean
D: Coconut fiber + recycled paper + corn starch	Mustard green/water spinach/mung bean

3. Results and Discussion

3.1 Tensile Strength

Table 2 shows the results of tensile test of the sample for recycled paper (control), rice straw fiber paper, corn husk fiber paper and coconut fiber paper. The test is conducted to identify the tensile strength of the samples. There are 3 samples tested for each fiber paper and the average value is calculated.

Table 2 *Results of tensile strength*

Types of Samples	Tensile Strength (N/mm^2)
A: Recycled paper	1.54
B: Rice straw + recycled paper + corn starch	0.69
C: Corn husk + recycled paper + corn starch	0.42
D: Coconut fiber + recycled paper + corn starch	0.35

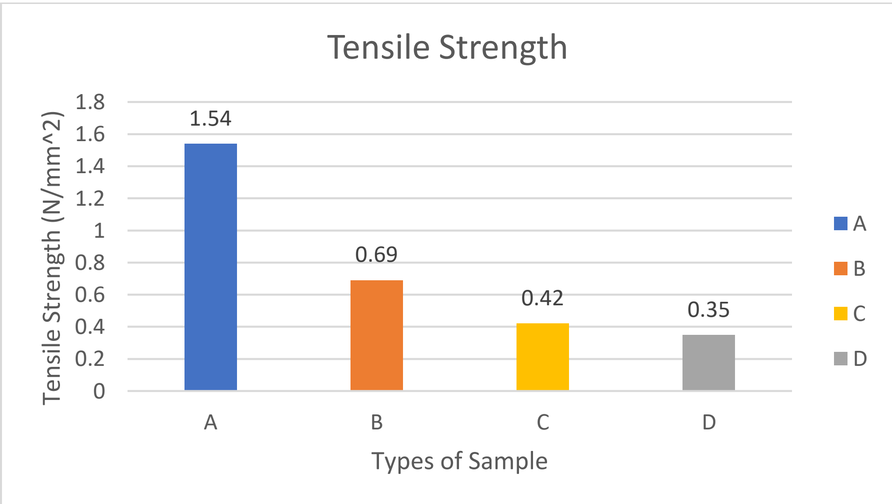

Fig. 1 *Bar graph of tensile strength*

Out of all the analyzed samples, recycled paper has the highest tensile strength. This outcome is expected since recycled paper has homogenous structure with well blended fiber inside it. In addition, recycled paper has gone through the real processing that follows the standard of industry production which frequently keeps the mechanical characteristics at the optimum level of its strength. Tensile strength in recycled paper can also be affected by differences in the manufacturing process and fiber properties. Meanwhile tensile strength for sample mixed with rice straw is slightly decreased as compared recycled paper. All the samples with mixed natural fiber show a decreasing trend of tensile strength as presented in Table 2 and Figure 1. In general, the fiber not only has high potential to disrupt the homogeneity of sample structure but also the binding between fiber and matrix sample also easily can be disturbed and potentially contribute to weak strength of property. As previously reported, most of the fiber used for the reinforcement in composite structure must be treated prior to its usage to improve the interface binding [7]. Different strength values of the different fiber have contributed to the different values in strength. Ultimately, these results emphasize how crucial it is to optimize fiber-matrix compatibility by incorporating natural fibers into recycled paper for manufacturing biodegradable planting containers.

3.2 Microstructure Analysis

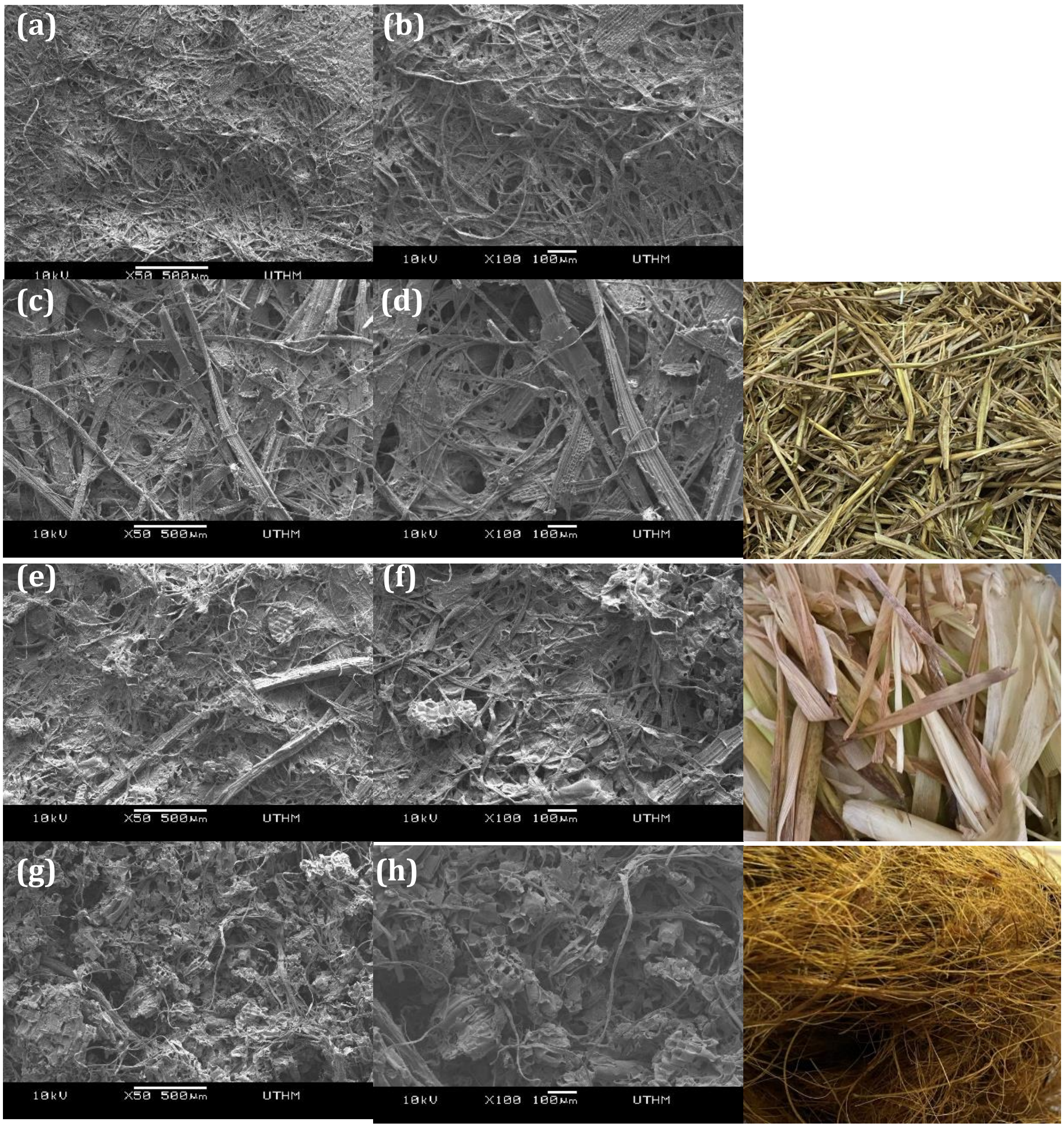

Fig. 2 *Microstructure analysis*

The SEM analysis is conducted to differentiate the porosity of the different samples, consisting of Sample A (100% recycled paper), Sample B (80% rice straw), Sample C (80% corn husk), and Sample D (80% coconut fiber). Figure 2 below shows the microstructure of each sample. The analysis was carried out at two different magnifications, namely 50x and 100x, to ensure accurate results. As can be seen in the figure below, visual proof of a robust and well-organized fiber structure can be found in the fibers of the rice straw. The long, elastic strings found in rice straw contribute to forming a sturdy, flexible structure when used to make paper. Because of their length, they stick to one another well, yielding a good paper structure. For the corn husk and coconut fiber, the distribution patterns are not evenly clustered, which influences the porosity of the paper. The paper's mechanical properties can also be impacted by this uneven clustering, which could lead to variances in strength and structural integrity throughout the material. The brittleness and short fibers of the coconut and corn husk have a major effect on the structure of the paper made from them. These fibers' short length restricts the material's ability to form robust interfiber bonds and alignment. Short fibers have a less cohesive structure because they have fewer contact points than longer fibers. This property tends to lower the overall strength of the paper composed of coconut fiber and corn husk. Furthermore, these fibers' brittleness makes them more likely to break under stress, further jeopardizing the material's structural integrity. This directly correlates with the tensile strength observations discussed in the previous section.

3.3 Water Absorption

The ability of a plant container to absorb and retain water is vital for plant health. Proper water absorption keeps the soil moist, ensuring an adequate water supply for the roots, which is essential for nutrient absorption and overall plant health. Containers that hold water well act as reservoirs, providing moisture even in dry conditions, strengthening roots, and enhancing plant resilience. Furthermore, containers with good water absorption reduce the frequency of watering, making plant care easier. Therefore, a container's water absorption capacity significantly influences plant health and well-being.

Table 3 *Water absorption*

Types of samples	*Time (min)*					*WA (%)*
	0	15	30	45	60	
A	30g	33.2g	39.3g	46.7g	50.9g	69.7
B	30g	36.2g	42.3g	46.7g	56.9g	89.7
C	31g	35.7g	43.3g	46.3g	54.6g	76.1
D	31g	35.7g	43.3g	46.3g	59.6g	92.3

Water absorption is crucial for plant growth as it determines the amount of water available to the plant over time. Containers with higher water absorption can hold more water, providing a consistent water supply to the plant. The study found that containers made of recycled paper and coconut fiber (Sample D) had the highest water absorption capacity, potentially making them the most effective at keeping plants hydrated. Containers made from recycled paper and rice straw (Sample B) were next in line. Meanwhile, containers made solely of recycled paper (Sample A) had the lowest water absorption capacity, possibly due to the presence of chemicals that make the paper hydrophobic.

3.4 Degradation Test

The degradation test for each sample has been observed within 14 days. Table 4 shows the physical condition after the degradation test was conducted.

Table 4 *Degradation test*

Types of samples	Before degradation	After degradation
Sample A		

Sample B		
Sample C		
Sample D		

Based on Table 4 above, Sample A appears heavily degraded with significant discoloration, while Sample B is partially degraded with visible dark spots indicating decomposition. Sample C shows significant signs of degradation, turning darker in color, and Sample D is heavily degraded, showing substantial darkening. Approximately 32–47% cellulose and 15–20% lignin makes up the majority of rice straw [8]. The cellulose percentage of corn husk is around 31 to 39% alpha-cellulose and 34 to 41% hemicellulose, with a lower lignin content of 2 to 14%. About 42.10% lignin and 36.69% cellulose are present in coconut fiber [9]. Plant cell walls are mostly composed of cellulose and lignin. Plant cells are strengthened and rigidized by the polysaccharide cellulose, and they are further resistant to rot and pests due to the complex organic polymer lignin. These constituents decompose throughout the deterioration process at various rates. While cellulose tends to degrade more quickly, lignin is more resistant to decomposition. Thus, the amount of cellulose and lignin in these samples can affect how quickly and how much they degrade.

3.5 Soil Measurement and Condition

3.5.1 Soil Humidity

Soil moisture determines how much water is in the soil inside the biodegradable container. Understanding drainage, water retention capabilities, and the container's capacity to provide the ideal growing environment for plants all depend on this soil moisture. These fibers have the potential to alter the soil moisture inside containers made with them.

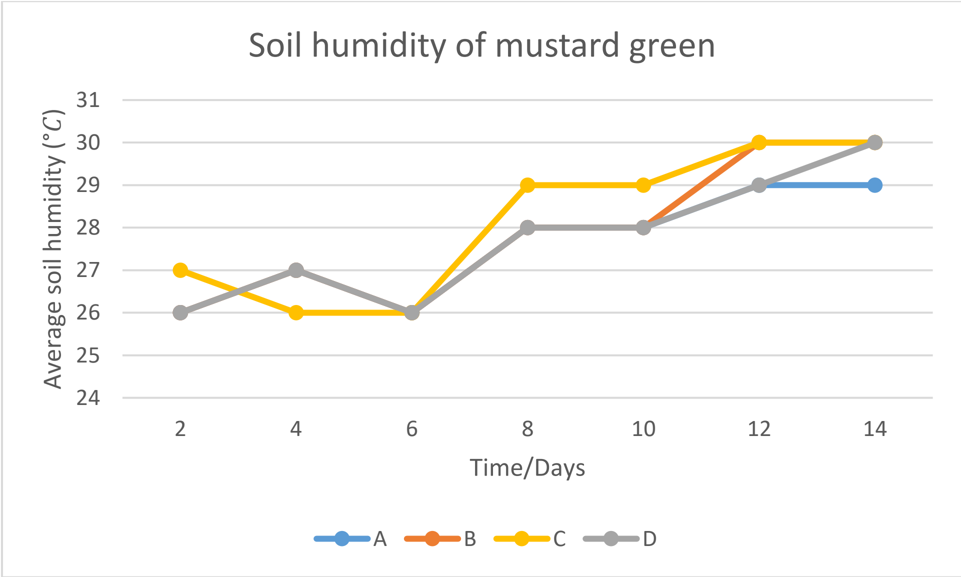

Fig. 3 *Graph of soil humidity of mustard green*

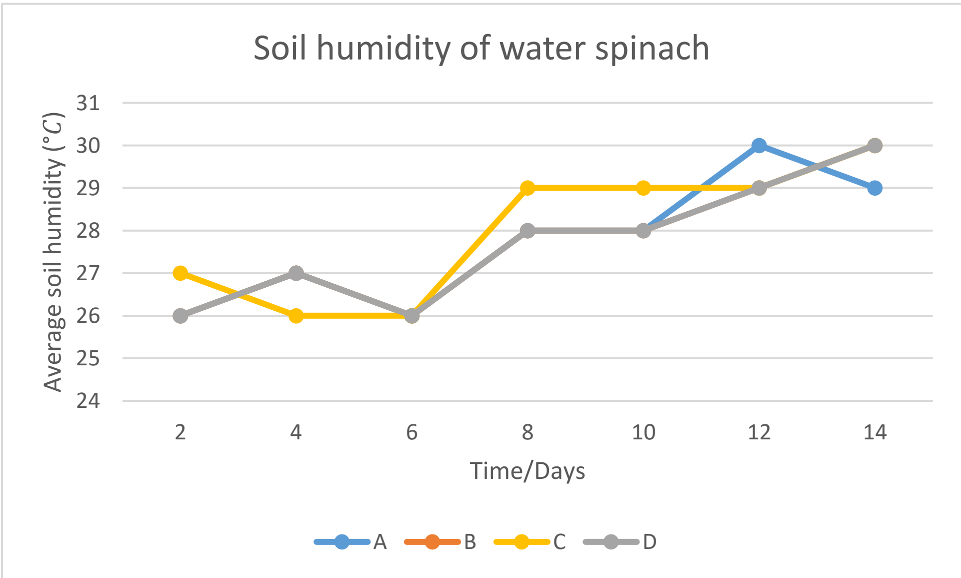

Fig. 4 *Graph of soil humidity of water spinach*

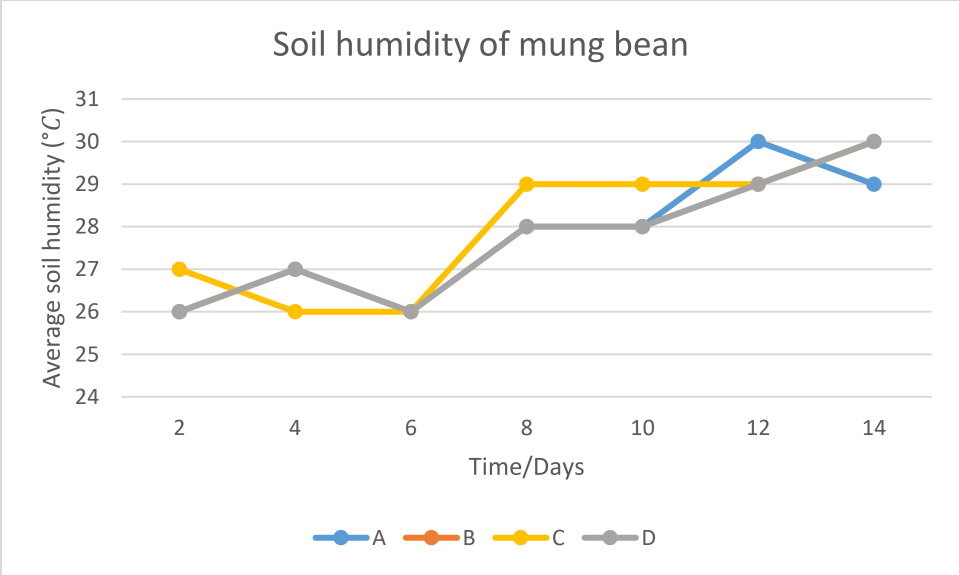

Fig. 5 *Graph of soil humidity of mung bean*

A comparison between samples composed of recycled paper only and a sample with recycled paper mixed with fiber indicates that the sample with fiber is able to sustain better soil moisture as compared to samples without fiber as shown in Figure 3 to Figure 5. This may be due to the ability of the fiber to absorb water as compared to recycled paper. The difference in moisture among fibers is not too significant for different types of plants and only shows slight changes, and the highest moisture level is measured when using corn husk, which could be due to the geometry of the fiber; its thin and small fibers, as compared to the others, provide a higher surface area for the effective absorption of moisture.

3.5.2 pH of Soil

There are significant differences in the pH of the soil in planting containers made of recycled paper, rice straw, corn husk, and coconut fiber. Soil pH is a crucial component that affects plant nutrient availability and overall growth. Because recycled paper is made of different materials, its pH usually ranges from neutral to slightly acidic. Many different types of plants can thrive in this pH range because it offers a stable environment for root development

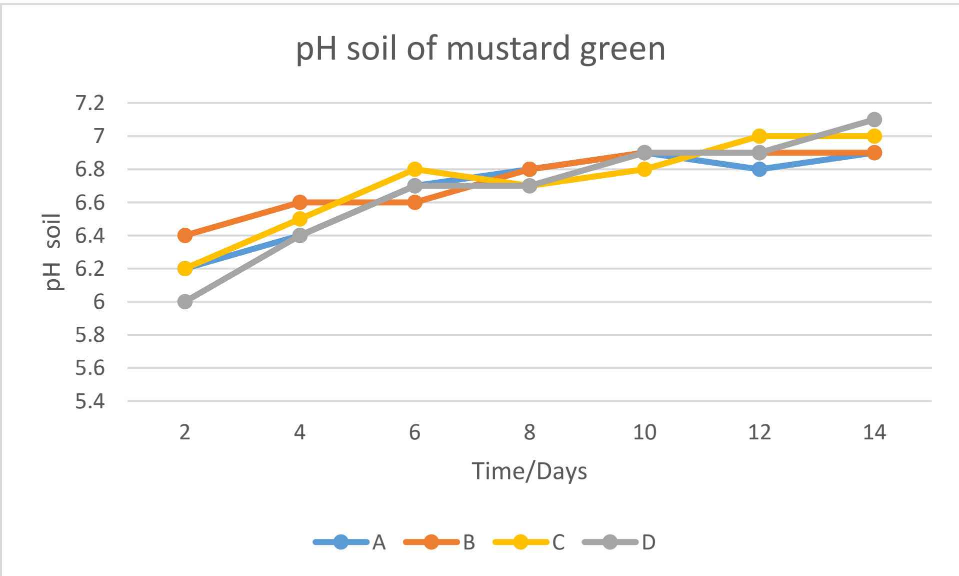

Fig. 6 *Graph of pH soil of mustard green*

As can be seen in Figure 6 above, mustard greens thrive in soil with a pH range of 6.0 to 7.5. The pH levels of the soil in pots made from these different materials, as per the data provided in Figure 6, fall within this range, making them suitable for growing mustard greens. Specifically, Sample A (Recycled Paper) has a pH range of 6.2 to 6.9, Sample B (Rice Straw and Recycled Paper) ranges from 6.4 to 6.9, Sample C (Corn Husk and Recycled Paper) varies from 6.2 to 7.0, and Sample D (Coconut Fiber and Recycled Paper) spans from 6.0 to 7.1. These pH ranges indicate slightly acidic to mildly alkaline conditions, which are ideal for mustard greens.

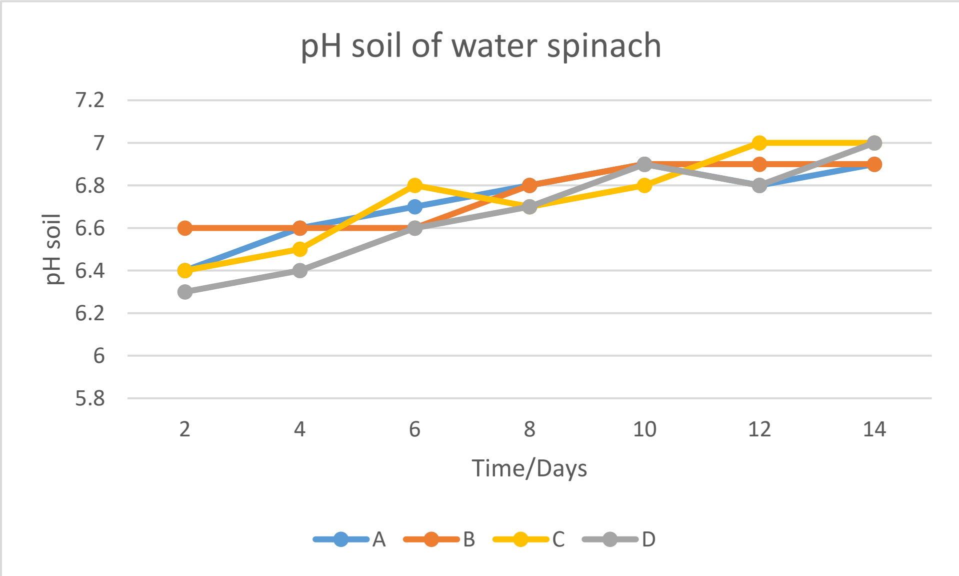

Fig. 7 *Graph of pH soil of water spinach*

Based on the figure above, the data indicates that the use of fibers as a soil amendment may contribute to an alkaline shift in soil pH over time. This suggests that the combination of rice straw and recycled paper has a moderate effect on increasing soil pH. For Sample C, the soil starts at a slightly higher pH level of 6.5 but remains relatively stable throughout the observation period, ending at a pH of 6.8 on day 14. This indicates that the combination of corn husk and recycled paper may not significantly alter the soil pH as compared to other fiber. The soil begins at a lower initial pH value for Sample D, but sees significant improvement over time to reach similar levels as the other samples by day 14. This suggests that the combination of coconut fiber and recycled paper can help to neutralize acidic soil conditions.

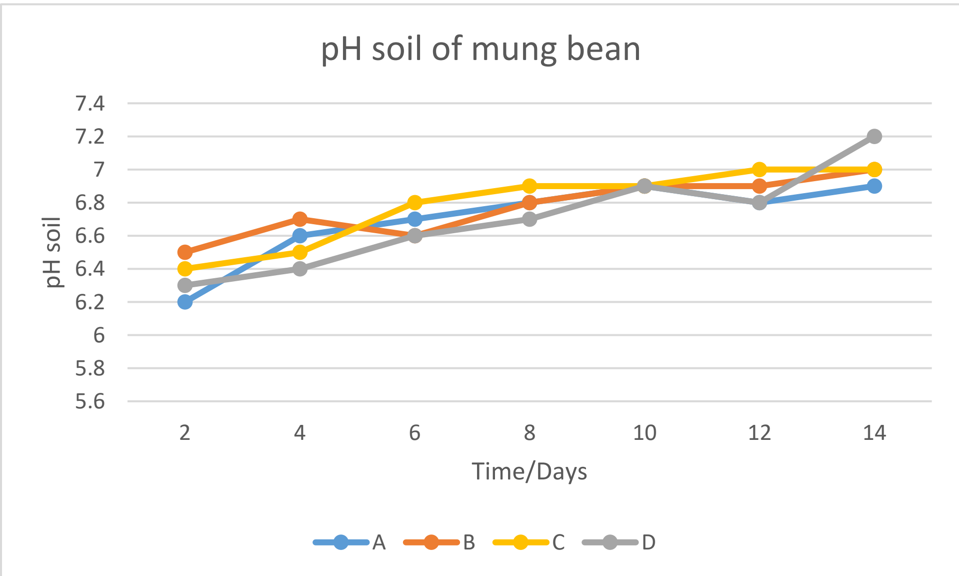

Fig. 8 *Graph of pH soil of mung bean*

The pH level of the soil for Sample A starts at 6.3 and shows a steady increase over the 14-day period, reaching a pH of 7.0. This indicates that the use of recycled paper as a soil amendment may contribute to an alkaline shift in soil pH over time. For Sample B, the soil begins with a pH level of 6.4. It experiences a slight increase in alkalinity over time but stabilizes around a pH of 6.9 on day 14. In Sample C, the soil starts at a slightly higher pH level of 6.5 but remains relatively stable throughout the observation period, ending at a pH of 6.8 on day 14. This indicates that the combination of corn husk and recycled paper may not significantly alter soil pH, while in Sample D, the soil begins at a lower initial pH value but sees significant improvement over time to reach similar levels as the other samples by day 14. This suggests that the combination of coconut fiber and recycled paper can help to neutralize acidic soil conditions.

3.5.3 Fertilizer Content pH of Soil

The ability of a plant to naturally tolerate high fertilizer nutrient concentrations in the root zone or on its leaves without suffering significant negative effects (such as fertilizer burn) is known as plant nutrient tolerance. The amount of excess, unabsorbed fertilizer minerals in the soil is referred to as its fertilizer salinity or electrical conductivity (EC).

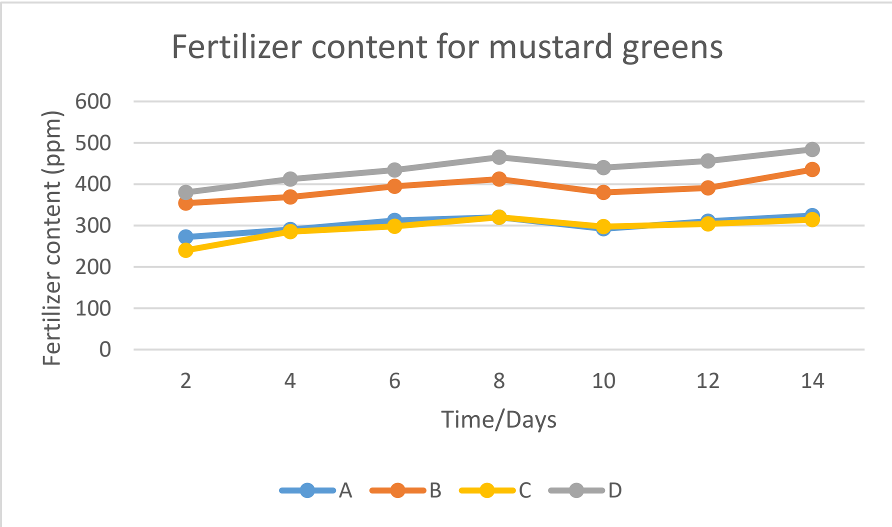

Fig. 9 *Graph of fertilizer content of mustard green*

In the present work, the fertilizer nutrient concentration in the soil was measured using electrical conductivity (EC) with consideration of the salt nutrient content. This is because the nutrient content has a significant impact on crop growth and yield production. Soil fertilizer concentration is therefore an important element. Based on Figure 9, the fertilizer nutrient concentration content in the soil for Sample A starts at 250 ppm and shows a steady increase over the 14-day period, reaching 317 ppm. This indicates that the use of recycled paper as a soil amendment may contribute to an increase in soil salinity over time. The decomposition of the recycled paper could also release some nutrients into the soil, which at the same time accelerates the degradation of the container. Meanwhile, for Sample B, the soil begins with a salt content of 320 ppm. It experiences an increase in salinity over time but stabilizes around 406 ppm by day 14. This suggests that the combination of rice straw and recycled paper has a moderate effect on increasing soil salinity. The varied microbial activity due to these organic materials might accelerate the degradation of the container. As for Sample C, the soil starts with a salt content of 300 ppm but remains relatively stable throughout the observation period, ending at a salt content of 350 ppm on day 14. This indicates that the combination of corn husk and recycled paper may not significantly alter the soil salinity, which slows down the degradation process of the container. For Sample D, the soil begins with a salt content of 280 ppm but sees significant improvement over time to reach 400 ppm by day 14. This suggests that the combination of coconut fiber and recycled paper can help to increase soil salinity, which accelerates the degradation of the container.

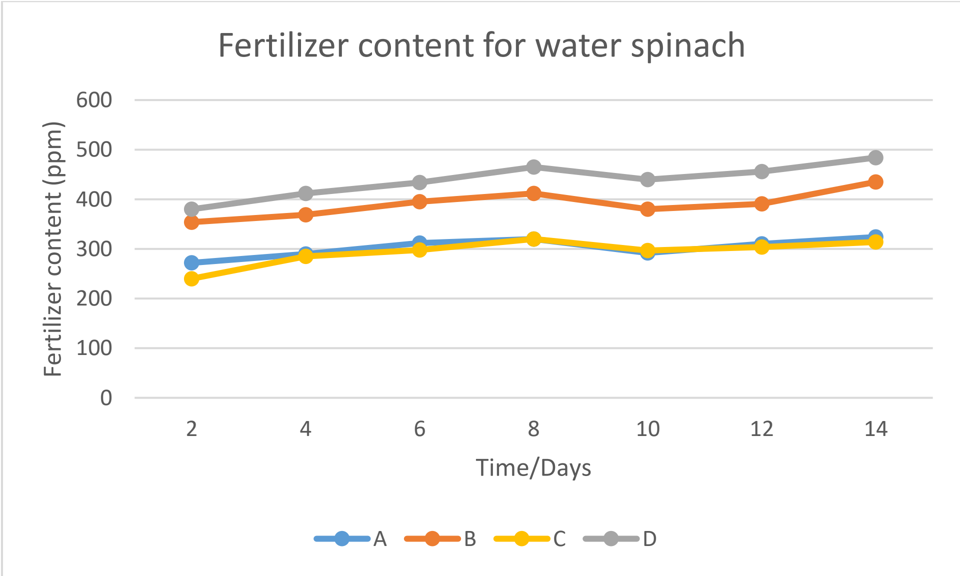

Fig. 10 *Graph of fertilizer content of water spinach*

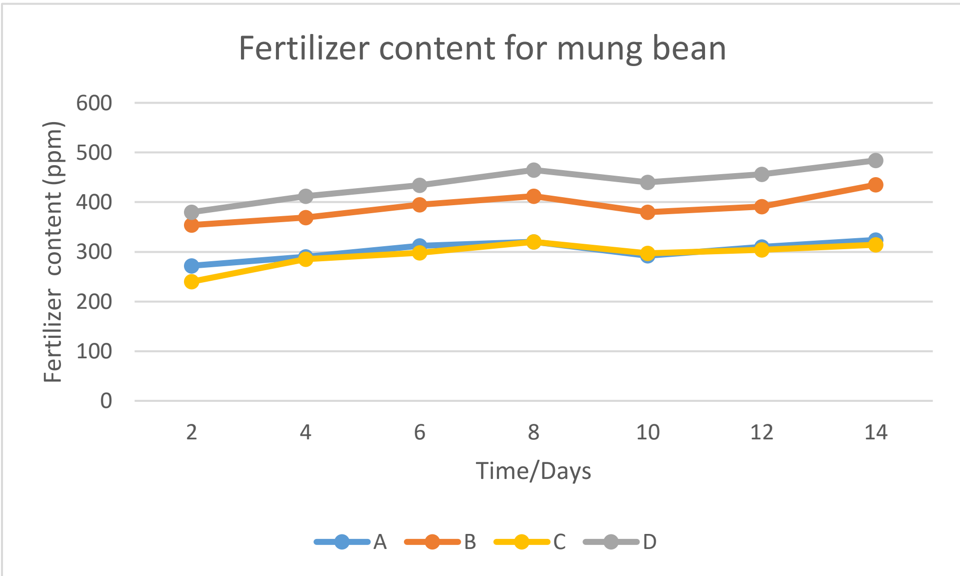

Fig. 11 *Graph of fertilizer content of mung bean*

Samples B and D exhibit among the highest values of fertilizer content as they have the most nutrients, and this correlates with the degradation test where they degraded quickly as shown similar trend in Figure 10 and Figure 11. The concentrations are influenced by degradation.

3.6 Plant Growth of Mustard Green, Water Spinach and Mung Bean

The plants' height and growth were noted during the 14-day observation. On day 3, the leaves of each sample began to grow and develop at varying rates during the experiment.

Fig. 12 *Plant growth after 14 days*

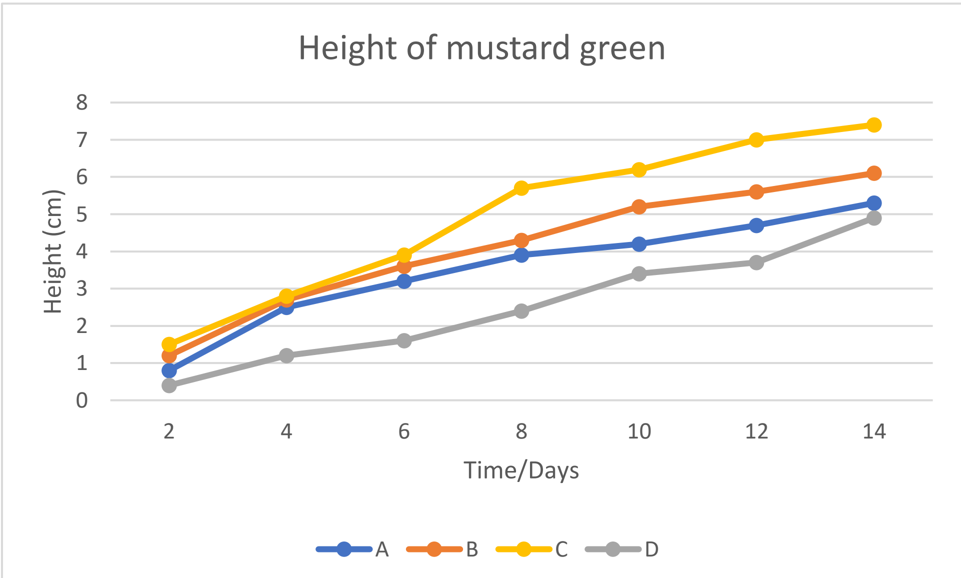

Fig. 13 *Graph of plant growth of mustard green*

By referring to Figure 13, Sample B with rice straw fiber seems to have a relatively good effect on plant growth, corn husk has the greatest positive effect and results in the tallest mustard greens. These findings imply that the type of natural fiber used in a container's composition can have a significant impact on how plants grow, possibly influencing things like nutrient availability, aeration, and moisture retention. Meanwhile, in Figure 14, the water spinach shows consistent growth in height in Sample A, but it is not as pronounced as in some of the other samples. It reaches a height of 7.7 cm by day 14. For Sample B, it exhibits the most significant growth among all samples, with a height reaching up to 8.8 cm by the end of day 14. As for Sample C, the plant's growth is steady but slightly less compared to Sample B, attaining a height of 7.4 cm. Growth starts out the slowest for Sample D but catches up over time, ending at a height of 7.2 cm on day 14. The rice straw and recycled paper pot (Sample B) appears to provide the most conducive environment for the growth of water spinach in terms of height.

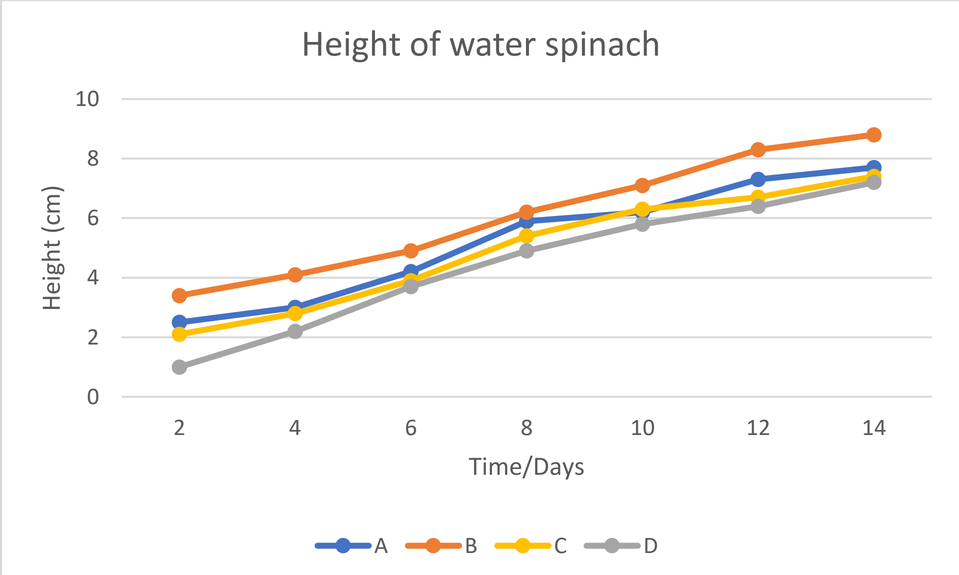

Fig. 14 *Graph of plant growth of water spinach*

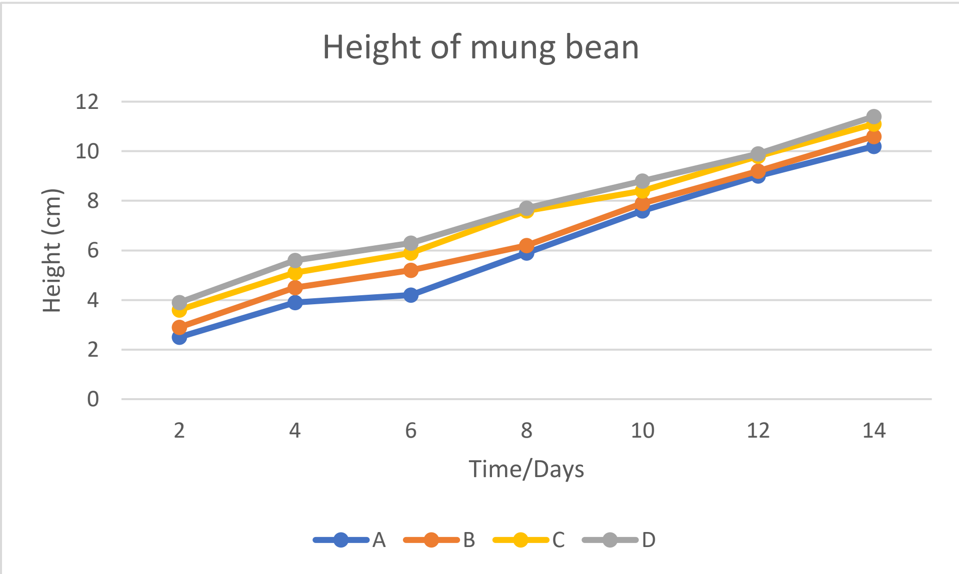

Fig. 15 *Graph of plant growth of mung bean*

A comparison of all the data based on the measurement of plant growth and plant height has shown that samples with mixed fibers contribute to a better growth rate in plants as compared to samples with only recycled paper. This indicates that natural fibers have a high potential to be used as plant container materials due to their compatible properties and characteristics.

4. Conclusion

In the present work, the proposed biodegradable container from natural fiber was successfully developed and can be considered as preliminary work in the development of biodegradable containers. Observations through experiments have shown that the results have a positive impact in terms of degradation, soil salinity, and moisture content as well as plant growth for all biodegradable containers as compared to containers from recycled paper. These biodegradable containers not only effectively support plant growth but provide better solutions in minimizing the current plastic solution problem. Furthermore, this study also has contributed to significant sustainable and waste management of agriculture by providing a solution to the abundant waste of fiber. It highlighted the potential of these containers in contributing to environmental sustainability, serving as a steppingstone towards a more sustainable and eco-friendly approach for gardening and commercial agriculture activities

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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:*** *Ain Afifa Abdullah Afendi;* ***data collection:*** *Ain Afifa Abdullah Afendi, Muhammad Fikri Shohur;* ***analysis and interpretation of results:*** *Zawati Harun, Rosniza Hussin; Norsuhailizah Sazali;* ***draft manuscript preparation:*** *Zawati Harun; Nur Hanis Hayati Hairom; Zakiah Kamdi; Maizatulazrina Yaakob, All authors reviewed the results and approved the final version of the manuscript.*

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References

[1] Johansson, C., Bras, J., Mondragon, I., Nechita, P., Plackett, D., Šimon, P., Svetec, D. G., Virtanen, S., Baschetti, M. G., Breen, C., Clegg, F., & Aucejo, S. (2012). Renewable fibers and bio-based materials for packaging applications – A review of recent developments: BioResources, 7(2), 2506-2552. https://doi.org/10.15376/BIORES.7.2.2506-2552

[2] Wang, E., Lin, X., Tian, L., Wang, X., Ji, L., Jin, F., & Tian, C. (2021). Effects of short-term rice straw return on the soil microbial community. Agriculture (Switzerland), 11(6). https://doi.org/10.3390/agriculture11060561

[3] Norashikin, M.Z & Ibrahim, M.Z. (2009). The Potential of Natural Waste (Corn Husk) for Production of Environmental Friendly Biodegradable Film for Seedling. International Journal of Environmental and Ecological Engineering, 3(10),1810-1814. https://doi.org/10.5281/zenodo.1085329

[4] Mazlan, S. A., Abang Hasbollah, D. Z., Legiman, M. K. A., Mohd Taib, A., Ibrahim, A., Ramli, A. B., Jusoh, S. N., Abdul Rahman, N., Md Dan, M. F., & Zukri, A. (2023). Effectiveness of coffee husk ash and coconut fiber in improving peat properties. Physics and Chemistry of the Earth, 130. https://doi.org/10.1016/j.pce.2023.103361

[5] Oladele, I. O., Adelani, S. O., Makinde-Isola, B. A., & Omotosho, T. F. (2022). Coconut/coir fibers, their composites and applications. In Plant Fibers, their Composites, and Applications, 181–208. https://doi.org/10.1016/B978-0-12-824528-6.00004-7

[6] Debnath, S., Navya Yadav, C., Nowjiya, N., Prabhavathi, M., SaiKumar, A., Krishna, P. S., Babu, M.N. (2018). A Review on Natural Binders used in Pharmacy. Asian Journal of Pharmaceutical Research, 9(1), 55-60. https://doi.org/10.5958/2231-5691.2019.00009.1

[7] Ahmad, R., Hamid, R., & Osman, S. A. (2019). Physical and Chemical Modifications of Plant Fibres for Reinforcement in Cementitious Composites. Advances in Civil Engineering, https://doi.org/10.1155/2019/5185806

[8] Yang, X., Zhao, J., Liang, J., & Zhu, J. (2020). Efficient and selective catalytic conversion of hemicellulose in rice straw by metal catalyst under mild conditions. Sustainability (Switzerland), 12(24), 1–14. https://doi.org/10.3390/su122410601

[9] Rahayu, A., Hanum, F. F., Amrillah, N. A. Z., Lim, L. W., & Salamah, S. (2022). Cellulose Extraction from Coconut Coir with Alkaline Delignification Process. Journal of Fibers and Polymer Composites, 1(2), 106–116. https://doi.org/10.55043/jfpc.v1i2.51