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Hylopoly-Bag: Environmentally Friendly Bioplastic Innovation Made from Dragon Fruit (*Hylocereus polarizes*) Peel Waste to Support Golden Indonesia 2045

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Abstract: Hylopoly-bag is a bioplastic bag from red dragon fruit (H. polyrhizus) skin waste. This research aims to discuss 2 things, namely the quality of hylopoly-bags and the realization of hylopoly-bags in supporting Golden Indonesia 2045. Experimental research uses descriptive quantitative methods. The independent variable is a ratio of dragon fruit peel extract and polyvinyl acetate of 2:1, 4:1, and 6:1, with the final quality of hylopoly-bag as the dependent variable. The analysis technique includes 6 methods: hylopoly-bag chemical content test, functional groups, permeability, elasticity, biodegradation rate, and SWOT. The results of the hylopoly-bag cellulose content were 6.32% and the functional groups consisted of C, H, and N. The analysis concluded that after the 28th day, the hylopoly bag had degraded the most, reaching 92 and 8% of the total initial weight of 7 grams. Hylopoly-bag has a water absorption capacity of up to 17% for 10 minutes and the average elasticity of hylopoly-bag is 4.65 x 10^4 N/m^2. Hylopoly-bag can support Golden Indonesia 2045, especially the sub-pillars of scientific contribution and commitment to the environment.

Keywords: Bioplastics; Dragon Fruit Peel; Golden Indonesia 2045; Hylopoly-bag.

Introduction

Plastic is a component that cannot be separated from human life, especially in Indonesia. Plastic is composed of monomers that bond to form polymers. These polymers include polyethylene, polypropylene, polyurethane, polystyrene, and nylon (Shofi & Anindita, 2022). The most widely used plastic is polyethylene, which is strong, durable, easy to shape, and not easily damaged. This type of plastic is often used in packaging and drink bottles (Mardila, 2021). The use of this type of plastic is increasing in society. However, this use is not commensurate with the degradation of plastic in the environment. Polyethylene plastic is non-biodegradable or challenging to break down by microorganisms, resulting in land and sea deposits (Ariantono, 2020).

The Ministry of Environment and Forestry of the Republic of Indonesia, through the National Waste Management Information System, stated that in 2021, plastic waste will contribute 17.73% to total national waste production. This amount is ranked second after organic waste (Kartika, 2022). Waste processing in Indonesia is still limited to recycling, landfilling, and burning. Plastic takes up to a hundred years to degrade under normal environmental conditions. Limited knowledge about plastic waste management encourages people to burn waste as an environmental management effort (Qomariah & Nursaid, 2020).

Burning plastic can release gas emissions such as CO, NOx, SOx, and CO_2 into the air (Iskandar & Armansyah, 2019). If these gases accumulate in the troposphere, they can increase the greenhouse effect.

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The greenhouse phenomenon will lead to global warming, where the earth's surface temperature increases. Global temperature changes result in extreme global climate change (Pratama & Parinduri, 2019). Plastic waste that is buried in the ground has the potential to be difficult to degrade or break down (non-biodegradable). This plastic waste takes several generations of life, including hundreds of years, to break down or decompose entirely in the soil (Gunadi et al., 2020). The accumulation of pollution and landfills can damage the balance of the ecosystem and threaten human life (Mojibayo et al., 2020). Mitigation can be done to overcome the impact of plastic waste.

An alternative solution that can be used to mitigate this is to make plastic that is environmentally friendly and can be biodegraded. Biological degradation uses microorganisms to break down the natural compounds of the substrate into nutrients for the microorganisms. This process can decompose compounds without causing environmental damage (Aska, 2021).

Bioplastics are made from renewable materials such as microbiota, plant raw materials, and animal-vegetable fats. These materials contain natural polymers such as carbohydrates, proteins, and starch, which are capable of forming materials such as plastic (Cinar et al., 2020). Starch is one of the natural polymers most strategically used as a bioplastic. Starch has biodegradable properties, is easily modified, and is abundantly available in nature at a relatively low cost (Mojibayo et al., 2020). Starch can be found in various parts of plants, such as seeds, tubers, and peels (Melani et al., 2018).

The peel of red dragon fruit (*Hylocereus polyrhizus*) contains natural nutrients: cellulose, carbohydrates, protein and dietary fiber. The dietary fiber content in red dragon fruit peel is around 46.7% (Susanto, 2023). Dragon fruit peels have various primary colors, such as bright red, dark red, and yellow, depending on the type of dragon fruit plant. The thickness of the fruit peel is around 3-4 mm (Ussmandoyo, 2017). The abundant production of dragon fruit in Indonesia shows the potential for its use in making bioplastics. Dragon fruit can be peeled and processed to extract the starch as a natural polymer. Dragon fruit peel (*H. polyrhizus*) contains carbohydrates (cellulose) around 6.5% (Yuliana, 2020). Apart from that, this processing can also be an alternative to reduce organic waste from dragon fruit peel waste. This aligns with the sub-pillar of Indonesia Emas 2045, which contributes to science and commitment to the environment. Bioplastics have the potential to support environmental sustainability from the threat of conventional plastics.

The creation of bioplastics has long been attempted using various materials and methods. The essential ingredient for bioplastics that is popularly used is cassava starch. This is similar to research conducted by (Widyaningrum et al., 2020; Yang et al., 2023; Zoungranan et al., 2020). Making bioplastics from cassava is less effective, because cassava is more suitable as a food product. Researchers are trying to innovate bioplastics with a new primary material in the form of red dragon fruit (*H. polyrhizus*) skin waste. According to the Central Statistics Agency, Indonesia will produce 3,673,002 quintals of red dragon fruit in 2022. High production means that dragon fruit skin waste will also increase. Researchers also reflect on the novelty and simplicity of creating bioplastic innovations. Specifically, by adding red dragon fruit peel cellulose and polyvinyl acetate, researchers can create renewable herbal compositions. Abundant basic materials and a simple manufacturing process will create dragon fruit peel (*H. polyrhizus*) bioplastic products with good quality based on several physical, chemical, and biological analyses.

Based on these problems, researchers conducted experiments using red dragon fruit peel (*H. polyrhizus*) as an environmentally friendly bioplastic. This bioplastic product is named "hylopoly-bag" or "hylopoly plastic bag". This research aims to determine the biodegradation rate in the environment, conduct a water resistance analysis, and determine the hylopoly bag's elasticity level. It is hoped that the results of this research can become a source of literature and essential reading for the development of similar research in the future, as well as provide real hylopoly-bag innovation that can support Golden Indonesia 2045.

Method

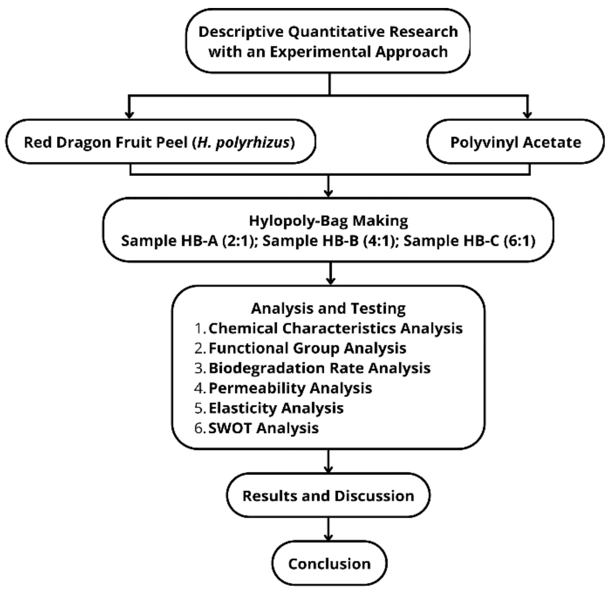

Figure 1. Research method flow diagram

Types and Research Approaches

The research method uses a quantitative method, which is carried out to obtain the composition and quality of the hylopoly-bag in the form of final results in numerical data. This type of research is supported by an experimental approach, which seeks to manufacture and test hylopoly-bags with different mixture compositions. An experimental approach determines how a variable can influence other variables within the scope of experiments and trials (Creswell & Guetterman, 2019).

Research Variable

This research has 2 types of variables: independent variable and dependent variable. Variable details are presented in Table 1.

Independent Variable

The composition of hylopoly-bag is made from dragon fruit peel extract and polyvinyl acetate. Bioplastics are processed with polyvinyl acetate (PVAc) as a monomer. Polyvinyl acetate (PVAc), which functions as a plasticizer, binds the cellulose content of dragon fruit peel extract.

Table 1. Details of independent variables

Composition Sample	Dragon Fruit Peel Extract	Polyvinyl Acetate
HB-A	40 mL	20 mL
HB-B	80 mL	20 mL
HB-C	120 mL	20 mL

Dependent Variable

Hylopoly-bag quality results. This quality is based on physical conditions, chemical characteristics, functional groups, biodegradation testing, permeability, and elasticity.

Tools and Materials

The tools used in this research were a blender, beaker, stirrer, tray, soft cloth, and PCS-200A hand sealer machine. Meanwhile, the ingredients needed include red dragon peel (*H. polyrhizus*), Rajawali brand polyvinyl acetate, and distilled Water.

Procedure for Making Hylopoly-Bag

Making a hylopoly-bag begins by cleaning the dragon fruit peel and smoothing it with a blender. In the next stage, mix dragon fruit peel extract and polyvinyl acetate according to HB-A, HB-B, and HB-C composition. After mixing thoroughly, the solution is filtered using a soft cloth and placed into a tray. This filtering stage helps obtain a smooth texture in the hylopoly-bag solution. The tray and its contents are heated/removed from their water content using hot sunlight for 2-4 hours until they dry and form a bioplastic sheet. Next, the final stage is printing the bioplastic sheet into a plastic bag called "hylopoly-bag" using a PCS-200A hand sealer machine.

Data Analysis Technique

This research uses several data analysis techniques to test chemical characteristics, functional groups, biodegradation, permeability, elasticity, and SWOT. These four tests were carried out to test the chemical, physical quality, and opportunities of hylopoly-bags in supporting Indonesia Gold 2045.

Testing the chemical characteristics of hylopoly-bag includes several parameters as follows: Cellulose, Fiber, Water Content, and Ash Content. Test cellulose content using the "Datta Method" proposed by Chesson. The cellulose content of test samples was measured by refluxing and immersing them in 72% sulfuric acid (Chesson, 1981). The hylopoly-bag fiber content test uses the gravimetric method by adding acid and base solutions. The test material was added with H_2SO_4, rinsed with NaOH, K_2SO_4, and 95% alcohol, and placed in an oven at 110°C for 1-2 hours (Sudarmadji et al., 1997). The hylopoly-bag water content test uses the gravimetric method, which refers to SNI 01-2891-1992. The hylopoly-bag was heated at 105°C for 3 hours using an oven, so the loss in sample weight was considered water content. Meanwhile, the ash content is heated at a temperature of 550°C for 1 hour using a furnace.

Hylopoly-bag functional group identification was carried out using an Agilent Cary 630 FTIR Spectrometer. The FTIR test uses a wavelength range ranging from 648 – 4004 cm^{-1}. The location for testing the functional groups for the three samples HB-A, HB-B, and HB-C is the Sanitation and Remediation Laboratory, UIN Sunan Ampel Surabaya. The FTIR tool determines the functional group components in dragon fruit peel bioplastic, such as C-O, O-H, C=O, and others (Listyarini et al., 2020).

Biodegradation rate testing was done by measuring the weight loss in the hylopoly-bag. Hylopoly-bag is inserted into the soil with a mixture of organic waste for 28 days. The biodegradation rate formula based on weight loss is as follows:

$$\text{Lossing weight} = \frac{W_i - W_f}{W_i} \times 100\% \quad (1)$$

Information:

Wi = Initial weight of hylopoly-bag (grams)

Wf = Final weight of hylo polybag after degradation (gram) (Mardila, 2021).

Permeability testing was carried out by measuring the water absorption capacity of the hylopoly-bag film. Hylopoly-bag film measuring 5 cm x 5 cm was placed in

Water for 10 minutes. The permeability formula is as follows:

$$A = \frac{W - W_0}{W} \times 100\% \quad (2)$$

Information:
A = Water absorption percentage (%)
W_0 = Initial weight of hylopoly-bag (gram)
W = Final weighing the weight of hylopoly-bag (gram) (Azwar & Simbolon, 2020).

Elasticity testing is carried out by measuring the Young's modulus of the hylopoly bag. Hylopoly-bags are given loads of 1 kg, 2 kg, and 3 kg. Young's modulus formula is as follows:

$$\text{Modulus Young (Y)} = \frac{\text{Tension } (\sigma)}{\text{Strain } (\varepsilon)} = \frac{F/A}{\Delta l / l_0} \quad (3)$$

Information:
Y = Young's modulus value (N/m^2)
F = Given energy (N)
A = Cross-sectional area of hylopoly-bag (m^2)
Δl = $l - l_0$ (m)
l_0 = Initial length of hylopoly-bag (m) (Azwar & Simbolon, 2020).

SWOT this research is analyzes opportunity analysis and hylopoly-bag strategic planning to support Golden Indonesia 2045, especially in the science and environmental sectors. In-depth analysis of detailed evaluation of strengths, opportunities, weaknesses and threats (Nadlir et al., 2022).

Result and Discussion

Formation of hylopoly-bags from red dragon fruit (*H. polyrhizus*) peel waste. The peel of red dragon fruit (*H. polyrhizus*) has a natural polymer in the form of cellulose. Cellulose is helpful as a raw material in making bioplastics, with the help of polyvinyl acetate (PVAc) as a trigger for the formation of monomers. PVAc, as a plasticizer, can provide elastic properties to bioplastics.

The research showed that mixing dragon fruit peel extract cellulose and PVAc produces elastic, solid, clear plastic. Special conditions are experienced if the PVAc content is added to a lesser extent; it can create a hylopoly-bag, which requires a longer drying time, and the condition of the bioplastic sheet is too elastic or tears easily. The opposite also happens; if too much PVAc is added, the hylopoly bag becomes more rigid and less elastic. The role of PVAc is vital in making cellulose-based bioplastics because it contains substances that trigger the formation of a polymer, which is the initial form of plastic.

The composition samples (HB-A, HB-B, and HB-C) produced different physical characteristics of red dragon fruit peel bioplastic. The physical characteristics of the hylopoly-bag are in Table 2. The physical characteristics were assessed through the researcher's subjective assessment and explained in detail in each discussion subsection. Sample HB-B, with a ratio of 4:1 with a reference of 80 mL of red dragon fruit peel extract (*H. polyrhizus*) and 20 mL of PVAc, creates a bioplastic better quality than HB-A and HB-C. This was obtained by comparing the results of the three sample formulations used to make a hylopoly bag.

Table 2. Physical characteristics of hylopoly-bag

Physical Elements	Hylopoly-Bag Physical Characteristics		
	HB-A	HB-B	HB-C
Color	Transparent Dark Red	Transparent Red	Transparent Red
Smell	Smells of Dragon Fruit	Smells of Dragon Fruit	Smells of Dragon Fruit
Texture	Quite Rough and Textured	Smooth and Slightly Textured	Smooth and Slightly Textured

The cellulose content of dragon fruit peel (*H. polyrhizus*) is relatively very high, namely around 6.5% carbohydrates (cellulose) (Yuliana, 2020). Cellulose makes bioplastics, bioethanol, and biofuel (Handayani & Amrullah, 2018). This substance is used as an alternative medium in making hylopoly-bags. Bioplastic films or sheets produced by this material are classified as good-quality plastic. This is obtained by comparing several parameters such as texture, odor, color, water resistance, biodegradation rate, and elasticity of bioplastics.

Based on research results and data analysis in the form of calculated numbers, it can be seen that the bioplastic produced has quite good water resistance. The thickness value of hylopoly-bag is classified as good because it is below the international standard for maximum bioplastic thickness, especially according to Japanese Industrial Standards, namely 0.25 mm (Ihsan & Ratnawulan, 2023). Bioplastic films that do not dissolve easily in Water are caused by adding PVAc as a plasticizer. Apart from that, bioplastic from the peel of red dragon fruit (*H. polyrhizus*) has the potential for good environmental safety, especially for the soil and surrounding organisms. This is based on observations of the hylopoly-bag's condition, which decomposes quickly within 28 days. Apart from that, the high elasticity makes hylopoly bags able to compete with conventional plastic bags widely circulated in society.

Chemical Characteristics of Hylopoly-Bag

The results of the characteristic test showed slight differences in the content of each sample of HB-A, HB-

B, and HB-C. The most significant factor for this difference is due to the varying composition of dragon fruit peel extract and polyvinyl acetate, namely: 2:1, 4:1, and 6:1. Detailed characteristics of cellulose, lignin, fiber, water content, and ash content of hylopoly-bag are in Table 3.

Table 3. Details of the chemical characteristics of hylopoly-bag

Parameter	Hylopoly-bag Sample		
	HB-A (%)	HB-B (%)	HB-C (%)
Cellulose	6.12	6.24	6.61
Fiber	33.76	35.01	39.85
Water Content	1.39	1.49	2.20
Ash Content	0.57	0.59	0.63

Based on testing, it was found that, on average, hylopoly-bag contained 6.32% cellulose, 36.21% fiber, 1.69% water content, and 0.60% ash content. The cellulose content of hylopoly-bag differs significantly from the initial cellulose content of dragon fruit peel. Dragon fruit peel (*H. polyrhizus*) contains about 6.5% cellulose (Yuliana, 2020). Dragon fruit peel contains more lignin than cellulose, namely 80%, while the rest is cellulose (Safitri et al., 2018). Cellulose plays an essential role in the polymer bonds that form bioplastics. However, this substance's presence also increases the crystallinity effect, which makes the bioplastic degradation process take longer (Abe et al., 2021). However, cellulose can still be degraded by enzymes, such as glucosidase, which belongs to glycoside hydrolase. The content of hylopoly-bag fiber mixed with the result of polymerization between cellulose and polyvinyl acetate can create bioplastics with relatively high resistance and tensile strength.

The shallow water content allows hylopoly-bags to last long at dry room temperature. Excessive water content can cause odors, color changes, and humidity due to enzyme and fungal activity in organic materials (Septian et al., 2021). Meanwhile, the average ash content of the hylopoly-bag was 0.60%, indicating that most of the bioplastics consisted of organic substances. Ash content is an inorganic mixture component contained in the test sample and does not evaporate or burn when heated to a temperature of 550°C (Fikriyah & Nasution, 2021).

Hylopoly-Bag Functional Group

Hylopoly-bags with samples HB-A, HB-B, and HB-C have functional group compositions that are almost the same. Hylopoly-bag functional group identification was carried out using an Agilent Cary 630 FTIR Spectrometer. The FTIR test uses a wavelength range ranging from 648 – 4004 cm^{-1}. Bioplastics containing starch or cellulose are identical to the C=O functional group (Hidayat et al., 2023). The results of the FTIR hylopoly-bag test are in the graph Figure 2, and details of functional group identification are in Table 4.

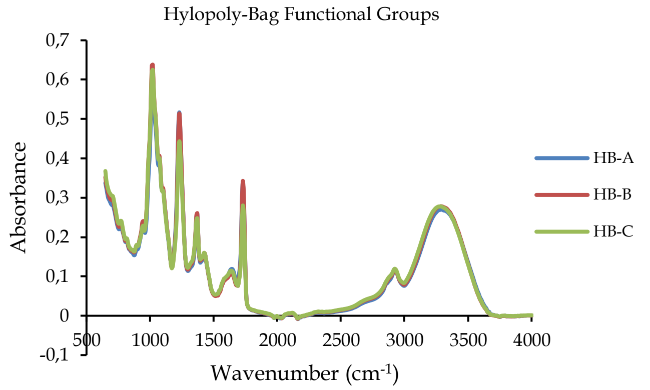

Figure 2. Graph of FTIR test results for hylopoly-bag functional groups

Table 4. Identification of hylopoly-bag functional groups

Wave Number (cm^{-1})	Functional Groups	Hylopoly-bag Sample		
		HB-A	HB-B	HB-C
1021	C-O stretching	Sharp	Sharp	Sharp
1230	C-N stretching	Sharp	Sharp	Sharp
1371	C-H stretching	Sharp	Sharp	Sharp
1729	C=O stretching	Sharp	Sharp	Sharp
2922-2944	C-H stretching	Wide	Wide	Wide
3302-3324	O-H and N-H stretching	Wide	Wide	Wide

The FTIR test of hylopoly-bag plastic produces several wave numbers peaks within a specific range. The results found peak 1 at wave number 1021 cm^{-1}, indicating that the C-O bond caused absorption. The wave number area between 815 – 1070 cm^{-1} indicates the C-O absorption band (Yupa et al., 2021). The second peak is at wave number 1230 cm^{-1} in absorption by C-N bonds. The 4th peak is at wave number 1729 cm^{-1}, which means that absorption occurs by the C=O bond. The absorption bands at around 1750 cm^{-1} and 1370 cm^{-1} are carbonyl groups (C=O) (Abdullah et al., 2021). The 3rd and 5th peaks both have absorption caused by the C-H bond, namely a sharp wave number of 1371 cm^{-1} and a width of 2922 – 2944 cm^{-1}. The C-H bond absorption band at wave numbers around 2931.8 cm^{-1} is of the alkene compound type (Handayani & Wijayanti, 2015). The 6th peak is obtained as a vast wave, namely in the wave number range 3302 – 3324 cm^{-1}. There are O-H and N-H bond absorption bands (Christian et al., 2014). The wave number range of 3313.87 cm^{-1} has bond types of O-

H compounds in the form of phenol and hydrogen, as well as N-H compounds in the form of amines and amides (Handayani & Wijayanti, 2015).

The hylopoly-bag film made from the dragon fruit peel and PVAc has functional groups according to its constituent components. The functional groups identified include C-O, C-N, C=O, C-H, O-H, and N-H. Hylopoly-bag contains an amide functional group and is a degradable component. Cellulose contains essential functional groups, including -OH, C-C, and C-O (Handayani & Amrullah, 2018). Bioplastics containing starch or cellulose are identical to the C=O functional group (Hidayat et al., 2023). These two studies strengthen the results of hylopoly-bag, including standard bioplastics based on functional group tests.

Hylopoly-Bag Biodegradation Rate

Biodegradation rate testing was done by measuring the weight loss in the hylopoly-bag. Hylopoly-bags are inserted into the soil with a mixture of organic waste for 28 days. The initial weight of the hylopoly-bag tested was 7 grams. This is done together to get more optimal and easy-to-read calculation results. The final weight calculation is carried out every 3 days, periodically for 28 days. The biodegradation rate of hylopoly-bag is slow, because it decomposes in natural soil without adding any chemical or biological substances such as EM 4, decomposing bacteria, and others. Adding EM 4 to the soil will accelerate the decomposition of bioplastics for up to 3 days (Hidayat et al., 2023). The results of the hylopoly-bag biodegradation rate are in Figure 3 and Table 5.

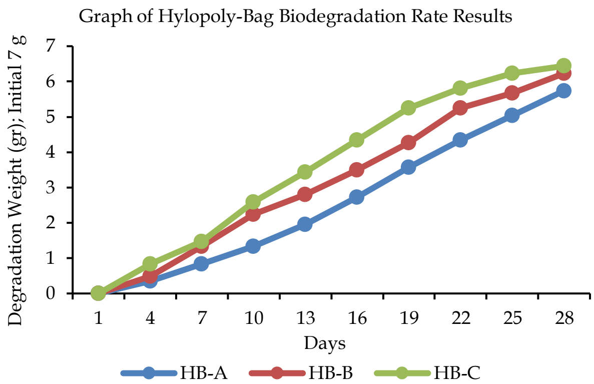

Figure 3. Graph of hylopoly-bag biodegradation rate results

Table 5. Results of biodegradation rate of hylopoly-bag

Day		HB-A			HB-B			HB-C		
		Final Weight (gr)	Accumulation (%)	Degrada-tion (gr)	Final Weight (gr)	Accumulation (%)	Degrada-tion (gr)	Final Weight (gr)	Accumulation (%)	Degrada-tion (gr)
1	Initial Weight = 7 grams	7.00	100	0.00	7.00	100	0.00	7.00	100	0.00
4		6.65	95	0.35	6.51	93	0.49	6.16	88	0.84
7		6.16	88	0.84	5.67	81	1.33	5.53	79	1.47
10		5.67	81	1.33	4.76	68	2.24	4.41	63	2.59
13		5.04	72	1.96	4.20	60	2.80	3.57	51	3.43
16		4.27	61	2.73	3.50	50	3.50	2.66	38	4.34
19		3.43	49	3.57	2.73	39	4.27	1.75	25	5.25
22		2.66	38	4.34	1.75	25	5.25	1.19	17	5.81
25		1.96	28	5.04	1.33	19	5.67	0.77	11	6.23
28		1.26	18	5.74	0.77	11	6.23	0.56	8	6.44

Hylopoly-bag is made from red dragon fruit peel (*H. polyrhizus*), which contains natural nutrients, namely cellulose, carbohydrates, protein, and dietary fiber. The dietary fiber content in red dragon fruit peel is around 46.7% (Susanto & Saneto, 1994). Cellulose is a polysaccharide consisting of monomers in the form of glucose. However, cellulose is connected by powerful -glycosidic bonds, making cellulose a material that is more resistant and difficult to decompose than other substances in dragon fruit peel. In nature, cellulose is found in high quantities, especially as the main structural component in plant cell walls. Eubacteria and fungi form the most significant part of cellulolytic microorganisms as cellulose degraders (Polman et al., 2021). The enzymes most responsible for degrading extracellular cellulose are cellulases, which are glucosidases and glycoside hydrolases (Warren, 1996).

Bioplastics are degraded due to damage or reduction in quality due to the breaking of polymer chain bonds (Telussa et al., 2023). Damage to the hylopoly-bag polymer chain linkage occurs due to the activity and number of fungi or other microorganisms. The increase in the percent weight loss of biodegradable plastic occurs due to the activity of microorganisms such as fungi and bacteria found in the soil (Ihsan & Ratnawulan, 2023). Note that the existence of mycorrhizal fungal populations is strongly influenced by plant vegetation, geographical location, humidity, and soil type (Warman et al., 2022).

Biodegradation is defined as the mineralization of organic material by microorganisms, namely fungi, archaea, and bacteria so that it ultimately produces the final product of carbon dioxide and Water in aerobic conditions (Polman et al., 2021). Mineralization of organic compounds produces carbon dioxide and Water under aerobic conditions and methane and carbon dioxide under anaerobic conditions. When mineralization is incomplete, the biotransformation that occurs creates organic and inorganic metabolites in the form of transformation products. The metabolites produced from this process are not toxic to the environment and are redistributed through the carbon, nitrogen, and sulfur cycles (Singh & Sharma, 2008). Hylopoly-bag biodegradation produces compounds that are non-toxic to the environment with the help of fungi, archaea, and bacteria in the soil.

Hylopoly-Bag Permeability

Permeability testing was carried out by measuring the water absorption capacity of the hylopoly-bag film. Hylopoly-bag film measuring 5 cm x 5 cm was placed in Water for 10 minutes. The initial weight of the hylopoly-bag film tested was 1 gram. This is done together to get more optimal and easy-to-read calculation results. The final weight calculation is performed every 2 minutes, periodically for 10 minutes. The results of hylopoly-bag permeability are presented in Figure 4 and Table 6.

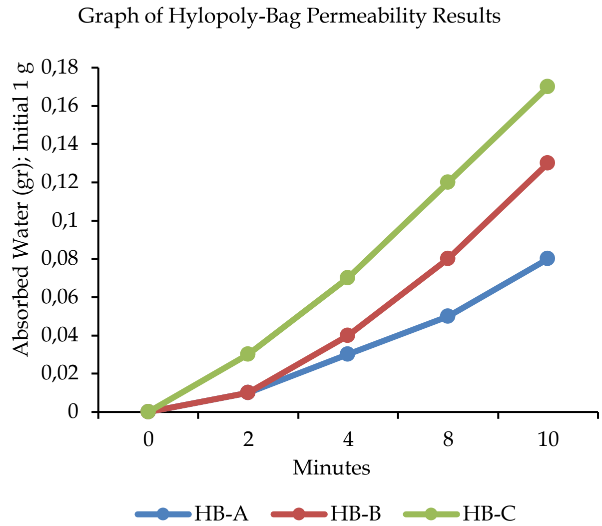

Figure 4. Graph of hylopoly-bag permeability results

Table 6. Hylopoly-bag permeability results

Day		HB-A			HB-B			HB-C		
		Final Weight (gr)	Accumulation (%)	Absorbed Water (gr)	Final Weight (gr)	Accumulation (%)	Absorbed Water (gr)	Final Weight (gr)	Accumulation (%)	Absorbed Water (gr)
0	Initial Weight = 1 gram	1.00	0	0.00	1.00	0	0.00	1.00	0	0.00
2		1.01	1	0.01	1.01	1	0.01	1.03	3	0.03
4		1.03	3	0.03	1.04	4	0.04	1.07	7	0.07
8		1.05	5	0.05	1.08	8	0.08	1.12	12	0.12
10		1.08	8	0.08	1.13	13	0.13	1.17	17	0.17

Water molecules are generally hindered by the more excellent orientation of the crystalline regions of a polymer, whereas they can easily penetrate less oriented regions (Asem et al., 2018). This is in line with data from this study, HB-A is more difficult to penetrate because it has a more significant amount of PVAc polymer than samples HB-B and HB-C. Vice versa, HB-C samples are more susceptible to water penetration than HB-A and HB-B samples.

The speed and volume of water absorption can be related to the chemical structure of a material with functional groups (OH), which function to adsorb water (Hidayat et al., 2020). This aligns with the results of the previous identification of functional groups containing O-H bonds. O-H bonds that create a low average hylopoly-bag water absorption capacity. The hydrophilic nature of bioplastic sheets may also help the natural degradation of the material by facilitating the operation of microorganisms. This is because all PVAc components for plasticizers in bioplastic films are known to be decomposable in Water and soil (Haque & Naebe, 2021).

Hylopoly-Bag Elasticity

Elasticity testing is carried out by measuring the Young's modulus of the hylopoly bag. Hylopoly-bags are given loads of 1, 2, and 3 kg. The use of loads in units of kg is converted to F in units of Newtons. 1 kg is equal to 10 Newtons. The test was carried out on a hylopoly-bag, a plastic bag with a bottom cross-sectional area of 20 cm long x 4 cm wide. The detailed results of the hylopoly-bag elasticity data are presented in Table 7.

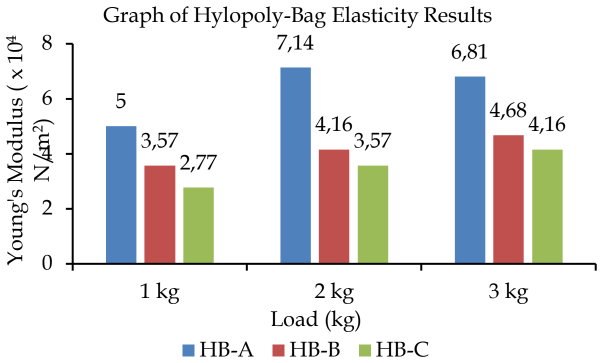

Figure 5. Graph of hylopoly-bag elasticity results

Table 7. Hylopoly-bag elasticity results

Calculation Aspect	HB-A			HB-B			HB-C		
	Load 1 kg	Load 2 kg	Load 3 kg	Load 1 kg	Load 2 kg	Load 3 kg	Load 1 kg	Load 2 kg	Load 3 kg
A (m^2)	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}	8×10^{-3}
l_0 (m)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Δl (m)	0.05×10^{-1}	0.07×10^{-1}	0.11×10^{-1}	0.07×10^{-1}	0.12×10^{-1}	0.16×10^{-1}	0.09×10^{-1}	0.14×10^{-1}	0.18×10^{-1}
Tension	1.25×10^{3}	2.5×10^{3}	3.75×10^{3}	1.25×10^{3}	2.5×10^{3}	3.75×10^{3}	1.25×10^{3}	2.5×10^{3}	3.75×10^{3}
Strain	0.25×10^{-1}	0.35×10^{-1}	0.55×10^{-1}	0.35×10^{-1}	0.60×10^{-1}	0.80×10^{-1}	0.45×10^{-1}	0.70×10^{-1}	0.90×10^{-1}
Modulus Young	5.00×10^{4}	7.14×10^{3}	6.81×10^{3}	3.57×10^{3}	4.16×10^{3}	4.68×10^{3}	2.77×10^{3}	3.57×10^{3}	4.16×10^{3}
Average	6.32×10^{4} N/m²			4.13×10^{4} N/m²			3.50×10^{4} N/m²		

Based on Table 7, you can see the comparison of Young's modulus of the three hylopoly-bag samples. The elasticity quality results obtained were an average of 4.65×10^4 N/m². Calculation data showed that HB-C had the lowest Young's modulus value, averaging 3.5×10^4 N/m². The greater the Young's modulus value of a solid object, the stiffer the solid object (Sahu, 2017). This means bioplastics made with the HB-C formulation are more elastic than those with the HB-A and HB-B formulations. The elasticity value can be found using manual Young's modulus calculations. The strength and flexibility of hylopoly-bag is influenced by plasticizer mixed with red dragon fruit skin cellulose. The addition of plasticizers such as HDPE seeds (Zulkarnain, 2023) and Carboxymethyl Cellulose (CMC) (Ihsan & Ratnawulan, 2023) affects the strength and elasticity of a product or item. This is in line with the research results, which showed that HB-A with a composition of 2:1 was stronger (hard) than HB-C with a composition of 6:1, which was more elastic.

SWOT of Hylopoly-Bag for Indonesia Emas 2045

Table 8. Hylopoly-bag SWOT analysis results

Analysis	Explanation
Strength	Raw materials are continuously available and can be renewable-sustainable. The product is environmentally friendly because it can decompose in 28 days, compared to conventional plastic.
Weakness	The size cannot be large, and it is only a bag measuring 20 cm x 20 cm x 4 cm. This is due to limited production equipment.
Opportunity	Attract the interest of people who care about environmental sustainability. New ideas and ideas related to the minimal use of dragon fruit peel waste as bioplastic. Incessant environmental issues to tackle waste, plastic, Water, and air throughout the world.
Threats	There are many innovative producers of bioplastics and conventional plastics. Hylopoly-bag innovation is less well known because the majority of people still use conventional plastics

SWOT analysis is used to identify hylopoly-bag opportunities in supporting Indonesia Emas 2045. In the SWOT analysis technique, you can plan a strategy to evaluate strengths, opportunities, weaknesses, and threats. The details of the hylopoly-bag SWOT analysis are listed in Table 8.

Based on the SWOT relationship analysis, the potential of hylopoly-bag in supporting Indonesia Emas 2045, especially the sub-pillars of scientific contribution and commitment to the environment. Sub-pillar contribution to knowledge, the hylopoly-bag innovation has the potential to be a sub-pillar of "Increasing Contributions to Science." This is because the bioplastic produced has a simple composition and varying variable dosages. Apart from that, there is a detailed process regarding making hylopoly-bags, which can later be developed again by other researchers. This can encourage the creation of bioplastics that are of higher quality than conventional plastics. The diversity of variable compositions, manufacturing processes, and testing can contribute to the knowledge of the utilization of red dragon fruit (*H. polarizes*) peel waste.

Sub-pillar of commitment to the environment, the hylopoly-bag innovation has the potential to be a sub-pillar of "Commitment to the Environment". This is because hylopoly-bag utilizes biomass waste such as red dragon fruit peel (*H. polyrhizus*). Waste that is not managed can potentially rot and become organic waste. If this waste is simply thrown away, it can increase the accumulation of excess waste in final disposal sites (TPA). Even if organic waste is dumped into water bodies, it can pollute the waters and increase TSS and BOD levels. The use of red dragon fruit waste (*H. polyrhizus*) can be a solution to environmental problems in the field of organic waste and piling plastic waste.

Conclusion

The concluded of the hylopoly-bag cellulose content were 6.32% and the functional groups consisted of C, H, and N. The analysis concluded that after the 28th day, the hylopoly bag had degraded the most, reaching 92 and 8% of the total initial weight of 7 grams. Hylopoly-bag has a water absorption capacity of up to 17% for 10 minutes and the average elasticity of hylopoly-bag is 4.65 x 10^4 N/m^2. Hylopoly-bag can support Golden Indonesia 2045, especially the sub-pillars of scientific contribution and commitment to the environment.

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Author Contributions

Conceptualization, T.S.A. and B.S.S.Z.; methodology, T.S.A.; software, T.S.A and B.S.S.Z.; analysis, T.S.A., B.S.S.Z. and S.W.A; writing—original draft preparation, T.S.A. and B.S.S.Z.; writing—review and editing, T.S.A. and S.W.A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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