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The Effect of Acetylation on Mechanical Properties of Biodegradable Plastic Made from Hipere Starch

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Abstract—**The study addresses the global problem of pollution caused by the long-term decomposition of plastic waste. It aims to explore the development of biodegradable plastics using Hipere starch and glycerol as a sustainable alternative, emphasizing their potential environmental benefits, abundance, and low cost. The primary materials used are Hipere starch, a natural polymer derived from plants, and glycerol as a plasticizer. These were selected for their compatibility and effectiveness in creating biodegradable plastics. Biodegradable plastics were synthesized through an acetylation process that modifies the starch, aiming to enhance its properties. Various concentrations of starch were tested to evaluate their impact on mechanical and physical characteristics. A soil burial test was conducted to assess biodegradability by monitoring mass reduction over seven days. The resulting plastics exhibited transparency, lightweight properties, insolubility in water, and mold-conforming shapes. Mechanical properties, including tensile strength and elongation, improved with higher starch concentrations. The soil burial test showed consistent mass reductions between 1-3% daily, with the most significant reduction occurring on day 7, demonstrating biodegradability. While improvements were observed, further research is needed to enhance mechanical properties by incorporating additional polymers or alternative modification techniques. This could expand the applications and durability of biodegradable plastics in various industries.**

Keywords—**Acetylation; mechanical properties; biodegradable plastic; hipere starch.**

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I. Introduction

Due to its strength, adaptability, and affordability, plastic has been used extensively worldwide in packaging [1]. Food, beverages, cosmetics, medications, and electronics are packaged in plastics [2]. With a CAGR of 4.3% over the projected period, the global plastic packaging market, valued at $265.8 billion in 2019, is anticipated to grow to $346.1 billion by 2025[3]. However, as plastic garbage takes hundreds of years to degrade, it can harm wildlife and pollute the oceans, and its use has expanded, giving rise to environmental worries [4].

From 234 million metric tons in 2000 to 460 million metric tons in 2019, the annual global production of plastics doubled. Under a status quo scenario, it is anticipated to quadruple to an estimated 1,231 million metric tons in 2060 [5]. The following regions produced plastic materials overall in compliance in 2020: Asia (49%), North America (19%), and Europe (14%) [6]. With an estimated 3.22 Mt of plastic garbage yearly, Indonesia is the nation that dumps the second-largest number of plastic debris into the oceans in the world [7]. Indonesian rivers are likewise not exempt from plastic garbage. According to data from Nature Communications, the Brantas, Solo, Serayu, and Progo rivers in Indonesia are four of the top 20 rivers in the world [8].

It's critical to lessen our reliance on plastic and encourage the use of environmentally friendly substitutes, including biodegradable plastic, to address these problems [9]. A synthetic or chemically altered plastic, known as a biodegradable plastic, is one that microbes can break down into harmless by-products like carbon dioxide, water, and biomass [10-11]. This plastic is considered more environmentally friendly than conventional plastics, which may take hundreds of years to degrade [9]. Starch-based plastics, or those derived from renewable resources like corn, potato, or tapioca starch, are one type of material that can be used to create biodegradable plastics [12-14].

Hipere is a sweet potato plant that grows in the central mountains of Papua province and has a high starch content [15]. Hipere is usually consumed by local people as a substitute for rice [16]. No research using Hipere starch to make biodegradable plastics has been reported.

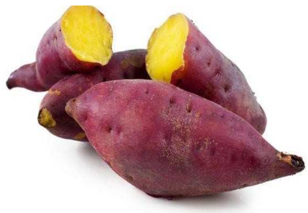

Fig. 1 Hipere, a yellow sweet potato

The chemical structure of starch is altered during acetylation by adding acetyl groups [17-19]. With this alteration, the starch becomes more hydrophobic and less moisture-prone, making it a good candidate for use in biodegradable plastic [20-21]. This study's objectives were to create biodegradable plastics using Hipere starch, analyze how acetylation affected the synthetic plastics' mechanical characteristics, and track the weight lost to biodegradation.

II. Material and Method

A. Starch Preparation

The preparation is intended to extract starch from Hipere. Wash the potatoes thoroughly to remove any dirt or debris. Peel the potatoes using a vegetable peeler or a knife. Cut the potatoes into small pieces and place them in a large bowl. Add enough water to cover the potatoes and let them soak for about 30 minutes. Drain the water and place the potatoes in a blender or food processor. Blend them until completely pureed. Pour the puree through a fine mesh strainer to separate the liquid from the solid potato pulp. Let the liquid sit for about an hour, allowing the starch to settle to the bottom of the container. Carefully pour off the liquid, careful not to disturb the starch sediment at the bottom. Add fresh water to the starch sediment, stir it, and let it settle again. Repeat the two last steps until the water and starch are clear. Spread the starch on a flat surface to dry completely under the sunlight.

B. Proximate Analysis

Proximate analysis is used to determine the basic composition of the starch. It involves the measurement of the percentage of moisture, ash, protein, fat, carbohydrates, sugar, and starch in a sample. These parameters are deliberated according to Indonesia's National Standard of Food and Drink Examination [22].

C. Starch Acetylation

Several parameters of Wet Sago Starch have been measured at Balai Besar Industry Agro Bogor with the results presented at Table 2 below. It is clearly shown that Raw Sago was originally in acid condition corresponding to pH of 3.44 and moisture content of 45%. Including Fat and some other important values measured, there were amylose and amylopectin consisted in Sago, making this feedstock theoretically feasible to produce biodegradable plastic.

Starch powder 8, 10, and 12 g were dissolved in water with a weight ratio of starch and distilled water of 1:10, stirred with a magnetic stirrer at 200 rpm/min for 60 minutes at 100^0 C. Then acetylation was carried out by adding 7 mL of 98% (v/v) acetic acid solution into each formulation and stirring with a magnetic stirrer at 200 rpm/min for 60 mins. The three formulations of acetylation of starch are shown in the following table.

TABLE I
THE CODE OF FORMULATION OF ACETYLATION

Code	Weight of starch powder (g)	Volume of water (mL)	Volume of acetic acid 98% (v/v) (mL)
A	8	80	7
B	10	100	7
C	12	120	7

D. Plastic Synthesis

The making of plastic was proceeded by mixing 2 mL glycerol into each of the three code formulations, stirred with a magnetic stirrer at 200 rpm/min for 60 minutes at a temperature of 100^0 Celsius. Moreover, the result of this plastic is poured into a plastic mold. Then, it dried for two days under sunlight.

E. Biodegradation Test

One type of plastic biodegradation test is the soil burial test. This test aims to determine the biodegradability of plastic materials in soil, i.e., the material is buried in soil and monitored for degradation over time. Synthetized plastic was weighed for 0.5 grams from each code of A, B, and C, then buried in the ground for 1 to 7 days. Moreover, measurements of the weight per day of each code after burial were carried out. The mass reduction was calculated as the percentage of weight loss due to consumption by bacteria. Weight loss was calculated using the following equation.

$$Weight\ loss\ (\%) = (W_0 - W_A)/W_0 \times 100\% \quad (1)$$

III. Results and Discussion

Based on the research conducted, it was found that biodegradable plastic films were successfully prepared using variations composition of chitosan, glycerol as plasticizer and acetic acid to obtain the optimum characterization of biodegradable plastic. The plastics produced were analyzed for tensile strength, elongation at break, biodegradable performance which is described as follows.

Extracted Hipere starch is a fine white powder, as shown in Figure 2. The proximate analysis results are shown in Table 2. Starch content is 71.08 % and is the main component of the Hipere powder. Saman et al [23] reported that the starch content in sweet potatoes cultivated in Jogjakarta was 85.23%. This relatively high starch content provides significant potential in making biodegradable plastics.

Fig. 2 Hipere starch

TABLE II
THE PROXIMATE ANALYSIS RESULT

Parameters	Results	Methods
Moisture (%)	16.47	SNI 01-2891-1992 point 5.1
Dush (%)	2.20	SNI 01-2891-1992 point 6.1
Fat (%)	0.83	SNI 01-2891-1992 point 8.2
Fiber (%)	2.51	SNI 01-4447-1998 point 11.1
Starch (%)	71.08	IK 7,2,3

A. *Plastic Synthetic*

Figure 3 shows the synthetic plastics for the three codes: code A, code B, and code C. The physical appearance shows that these plastics are transparent, lightweight, size follows the mold and are insoluble in water.

Fig. 3 Biodegradable plastic made from Hipere starch.

B. *Mechanical Properties*

The mechanical properties of synthetic plastics refer to their ability to resist deformation or breakage under various types of stress [24]. These properties are crucial in determining the suitability of a plastic for a particular application. Some of the mechanical properties of synthetic plastics include tensile strength and elongation at break. The following table shows these two properties.

Table 3 shows that increasing the weight of sweet potato starch in making biodegradable plastic leads to increasing its tensile strength and elongation at break properties. Ren X *et al* [25] reported that most starch-based plastics have poor physical properties such as tensile strength, stiffness, elongation at break, and poor moisture stability. However, this study found that both tensile strength and elongation improved with increasing concentration of starch in making plastic. This is due to the acetylation of starch by increasing intermolecular forces and hydrogen bonding between the acetylated starch molecules, which leads to a stronger and more flexible material [18],[19][26][27].

TABLE III
TENSILE STRENGTH AND ELONGATION TEST

Code	Force		Tensile Strength (MPa)	Elongation at Break (%)
	Gram	Newton		
A	658	6,45	3,00	32,3
B	780	10,20	5,63	43,2
C	960	21,32	8,34	61,3

C. *Biodegradation Test*

The soil degradation test, specifically, measures the material breaking down into natural elements, such as carbon dioxide, water, and biomass, through the action of microorganisms in the soil [28]. Figures 4 and 5 show the soil burial test of synthetic plastic for days 1 and 7.

Figure 6 shows the pattern of decreasing the mass of synthetic plastic codes A, B, and C from day 1 to day 7. The daily decrease ranges from 1-3%. For these three codes, the significant mass decrease was on day seven by approximately 6,05%. Arjun et al [29] reported that weight loss after ten days of burial was 6,28 g of biodegradable product made from banana peel starch. Another group [30] also recorded a maximum weight loss of 91,76% after 21 days buried in the soil of Mango seed starch films.

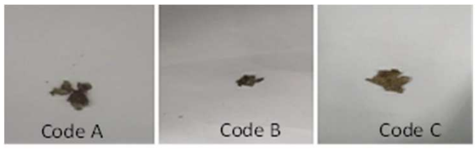

Fig. 4 Soil burial test for day 1

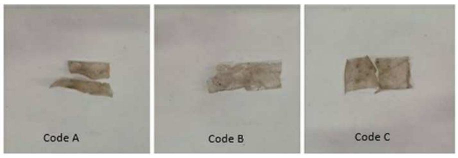

Fig. 5. Soil burial test for day 7

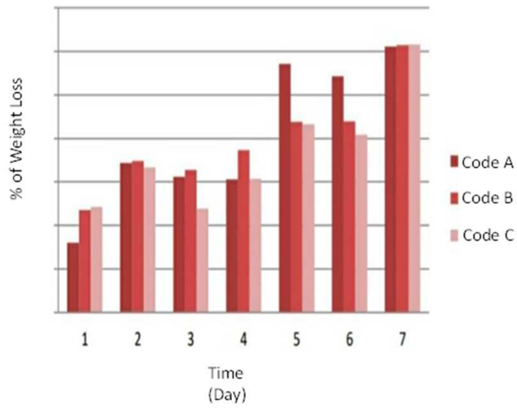

Fig. 6 Degradation Time

IV. CONCLUSION

Biodegradable plastics have been successfully made using Hipere starch as the main source of the polymer matrix. The physical appearance shows that these plastics are transparent, lightweight, size follows the mold and are insoluble in water. The acetylation process improves mechanical properties, i.e., tensile strength and elongation were corrected with increasing starch concentration. The Soil burial test shows the pattern of decreasing the mass of synthetic plastic codes A, B, and C from day 1 to day 7. The daily decrease ranges from 1-3%, with the significant mass decrease on day 7.

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