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Research Article

Enhancing Mechanical Biodegradable Bioplastic Performance of Taro Starch Composites with Castor Oil, Stearic Acid, and Egg White

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Abstract

Optimizing bioplastics from renewable resources is crucial for addressing global plastic pollution. This is done to address the waste problem that has severely disrupted the environment because it cannot degrade in the soil for hundreds of years. This research, based on taro starch and other polymer materials, is expected to address the impact of plastic waste in the future. The purpose of this study was to determine the effect of the ratio of bioplastic materials and the type of plasticizer and to determine the best treatment and its characteristics. This taro starch-based bioplastic research was combined with carrageenan and glucomannan at ratios of 25:75 and 50:50 (total material 6 grams) and with 3 types of plasticizers: castor oil, stearic acid, and egg white, each 1 gram. The observed bioplastic variables included mechanical properties, including tensile strength, elongation, and elasticity, as well as biodegradability, and functional group analysis for the best treatment. The results showed that the treatment of bioplastic material ratio and plasticizer type showed an effect on the variables of tensile strength, elongation at break, elongation and did not affect biodegradation. The best bioplastic was formulated with a ratio of taro starch and carrageenan of 25:75 and 1% castor oil with characteristics of tensile strength of 18.33 MPa; elongation of 4.96%, and complete biodegradation in 6 days. Although it did not meet the SNI (Indonesian Standart National) mechanical property standards, this composite showed potential as an environmentally friendly packaging material. Further optimization of plasticizer concentration and crosslinking strategy is recommended to improve its performance.

Keywords

Biodegradable, Bioplastics, Composite, Mechanical Properties, Thermoplastics

1. Introduction

The rising awareness of environmental issues, particularly the pervasive problem of plastic pollution, has fueled global research efforts to develop biodegradable materials as sustainable alternatives to conventional synthetic plastics. Synthetic plastics, despite their convenience, are non-biodegradable, leading to long-term environmental ac-

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cumulation and harmful ecological consequences. To combat this challenge, bioplastics have emerged as a promising solution. Bioplastics, derived from renewable resources, are designed to degrade naturally in the soil without leaving harmful residues, making them an environmentally friendly option for replacing traditional plastics in various applications.

Among the many renewable resources available for bioplastic production, tubers such as suweg, gadung, gembili, and taro have gained significant attention due to their high starch content, which ranges from 17% to 30% [20, 22, 24]. These starch-rich tubers not only provide a sustainable and renewable raw material for bioplastic production but also possess the advantage of being relatively easy to cultivate, even in regions with limited agricultural resources. Their versatility makes them an attractive choice for developing countries aiming to contribute to the bioplastic revolution while utilizing locally available resources.

Taro starch, in particular, has demonstrated significant potential in diverse applications, including the production of liquid sugar and as a base material for bioplastic production [7, 8, 12]. Despite its potential, however, bioplastics derived from starch, including taro starch, have faced challenges in meeting the mechanical property requirements necessary for commercial use. For instance, one critical parameter, tensile strength, often fails to meet the minimum threshold of 24.7 MPa required by the Indonesian National Standard (SNI) for packaging materials [2]. This limitation highlights the need for further research and innovation to enhance the mechanical properties of starch-based bioplastics to align with industrial standards.

To address these shortcomings, researchers have explored the use of composite materials to improve bioplastic performance. Composites are formed by combining two or more distinct materials with complementary physical and chemical properties, which, when used together, can significantly improve the overall functionality of bioplastics [37]. For example, [11] achieved a tensile strength of 27.35 MPa by blending cassava starch with carrageenan at a 25:75 ratio. Similarly, [30] reported a tensile strength of 19.33 MPa using a composite of gadung starch and carrageenan. While these studies demonstrate the potential of starch-based composites to enhance tensile strength, challenges remain in meeting other critical parameters, such as elongation at break and elasticity, which are essential for practical use.

Building on these advancements, this study seeks to develop bioplastic composites using taro starch as the primary raw material, combined with other polysaccharides such as carrageenan, glucomannan, and chitosan. These polysaccharides are chosen for their compatibility with starch and their ability to enhance the mechanical properties of bioplastics through crosslinking and intermolecular bonding. Additionally, the study incorporates hydrophobic plasticizers, including castor oil, stearic acid, and egg white, to further improve flexibility and durability. Plasticizers play a crucial role in reducing brittleness and enhancing the elongation at break, which are key limitations in many starch-based bioplastics [10].

To reinforce the structural integrity of the bioplastics, polyvinyl alcohol (PVA) is also included in the formulation. PVA is a biodegradable, hydrophilic polymer renowned for its excellent film-forming capabilities, water solubility, and biocompatibility [32]. Its inclusion ensures that the final bioplastic has improved mechanical properties, such as elasticity and tensile strength, while maintaining its biodegradability.

The objective of this research is to create a bioplastic composite that not only meets the mechanical and physical standards required by SNI but also demonstrates its suitability for practical applications, particularly in the packaging industry. By addressing the limitations of existing starch-based bioplastics and leveraging the unique properties of taro starch, polysaccharides, and innovative plasticizers, this study aims to contribute to the development of sustainable and eco-friendly packaging materials. Furthermore, the findings of this study could provide valuable insights into the broader application of starch-based bioplastics in other industries, such as agriculture and medical packaging, where biodegradable materials are increasingly in demand.

2. Methods

The research was conducted at the Industrial Environmental Laboratory and the Biochemistry and Nutrition Laboratory, Faculty of Agricultural Technology, Udayana University, from June to August 2023. The study employed a Randomized Block Design, exploring six composite variations of taro starch combined with two polysaccharides (glucomannan and carrageenan) in ratios of 25:75 and 50:50. These combinations were tested with three different plasticizers: castor oil, stearic acid, and egg white. Each treatment was grouped into two based on the preparation time, resulting in a total of 24 experimental units like shown in Table 1. Data analysis included variance evaluation, followed by Duncan's multiple range test for treatments showing significant differences.

The materials used in the study included taro starch, prepared following [22], along with carrageenan, glucomannan, chitosan, castor oil, stearic acid, and polyvinyl alcohol (PVA), sourced from commercial suppliers. Additional chemicals, such as glacial acetic acid (1%) and distilled water, were utilized for composite preparation and analysis. Equipment oven (Blue M), analytical balance (SHIMADZU), water bath (nvc thermology), P-1 refractometer 0-32% brix, spectrophotometer (turner SP-870), volumetric flask (Pyrex), blender (miyako), knife, filter cloth, Erlenmeyer flask (Pyrex), graduated cylinder (Pyrex), beaker glass (Pyrex), volumetric pipette, dropper pipette, and filter paper.

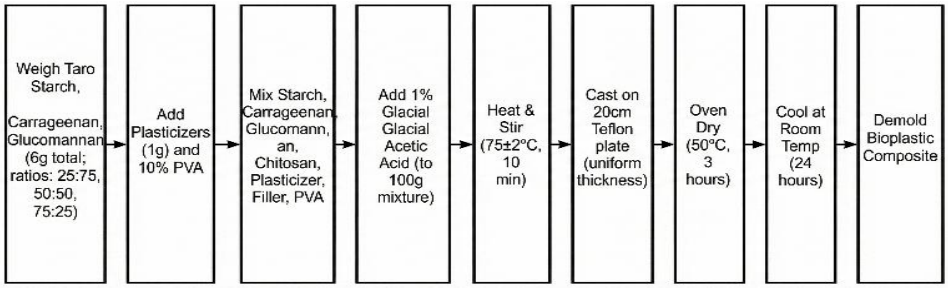

Figure 1. *Flowchart of the bioplastic composite synthesis process.*

The steps illustrated in the process flowchart (Figure 1) are further elaborated upon as follows: taro starch was extracted by peeling, washing, and slicing fresh tubers, which were then blended in a water-to-tuber ratio of 6:1. The resulting mixture was filtered, and the extract was allowed to settle for 12 hours. The supernatant was removed, leaving the sediment, which was dried at 80 ℃ ± 2 ℃ until the moisture content was reduced to a maximum of 11%. The bioplastic composites were prepared by mixing taro starch with selected polysaccharides and plasticizers according to treatment ratios. PVA (10%) was added as a reinforcing agent, and glacial acetic acid (1%) was used as a solvent to achieve a total mixture weight of 100 grams. The mixture was heated at 75 ℃ ±2 ℃ with continuous stirring for 10 minutes, poured onto a Teflon mold, and dried in an oven at 50 ℃ for 3 hours. After cooling at room temperature for 24 hours, the bioplastic sheets were removed from the mold.

The overall picture of the materials and also the preparation for testing bioplastics such as taro, taro starch, refining taro into starch and the process of making bioplastics as well as preparation for testing such as tensile strength, elongation at break, elongation, swelling and biodegradation are shown in the following figure (Figures 2 and 3)

Figure 2. *The process of making taro starch.*

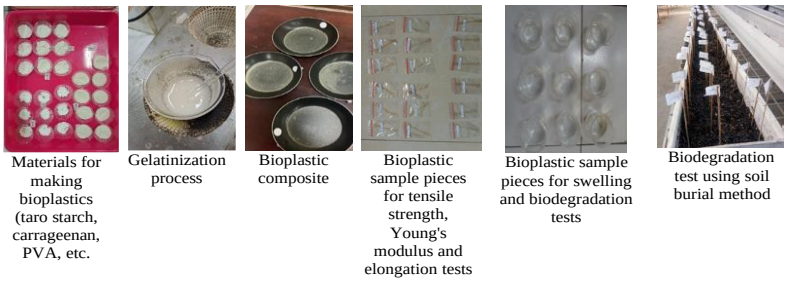

Figure 3. *Preparation for testing such as tensile strength, elongation at break, elongation, swelling and biodegradation.*

Table 1. *Combination of research treatments.*

Treatment			**Plasticiser (1g)**	
Taro starch composite with	**Ratio**	**Castor Oil (P1)**	**Stearic Acid (P2)**	**Egg Whites (P3)**
Glucomanan (G)	25:75 (R1)	GR1P1	GR1P2	GR1P3

Treatment		Plasticiser (1g)		
Taro starch composite with	**Ratio**	**Castor Oil (P1)**	**Stearic Acid (P2)**	**Egg Whites (P3)**
Glucomanan (G)	50:50 (R2)	GR2P1	GR2P2	GR2P3
Caragenan (K)	R1	KR1P1	KR1P2	KR1P3
Caragenan (K)	R2	KR2P1	KR2P2	KR2P3

2.1. Tensile Strength Test

Tensile strength testing was performed using equipment adhering to ASTM D 695-90 standards [9]. Samples were cut to dimensions of 3 cm width and 8 cm length, with a testing length of 4 cm clamped in the tensile test holder. The dial gauge was set to zero before being activated, and the handle was turned slowly to the right until the sample broke. The applied force was recorded from the dial gauge. The tensile strength was calculated using the following formula.

$$\text{Tensile Strength (N/mm}^2\text{)} = \frac{\sigma}{A}$$

Where σ= Force (N), A= Area (mm^2).

2.2. Elongation at Break

Elongation testing followed the same procedure and standards as the tensile strength test (ASTM D 695-90) [9]. Samples were prepared to dimensions of 3 cm width and 8 cm length, with a testing length of 4 cm. The gauge was set to zero and then activated while the handle was turned until the sample break. The elongation percentage was calculated based on the change in length of the sample using the formula.

$$\text{Elongation(\%)} = \frac{\text{Elongation of Film (mm)}}{\text{Initial Length (mm)}} \text{ x } 100\%$$

2.3. Elasticity (Young's Modulus)

Elasticity measures the stress at which a material deforms under maximum load. This parameter was calculated as the ratio of tensile strength to elongation, reflecting the material's ability to resist deformation before fracture [9]. The elasticity was computed using the following formula.

$$\text{Elasticity} = \frac{\text{Tensile Strength } \left(\frac{\text{N}}{\text{mm2}}\right)}{\text{Elongation (\%)}}$$

2.4. Biodegradability

The biodegradation rate of the bioplastic samples was determined using the established *Soil Burial Test* method [36]. This test is designed to measure how quickly a material degrades due to the action of natural microorganisms present in the soil. To perform the test, plastic samples were cut into small pieces measuring *1x1 cm* and their initial weight was measured before burial. The samples were then planted directly into the soil and observed every day until they showed signs of complete degradation. To quantify the process, the buried samples were retrieved daily. Upon retrieval, they were cleaned, dried in an *oven* to remove moisture, and immediately weighed again. This daily preparation and weighing of the samples continued until they were completely degraded in the soil, allowing for the calculation of the percent weight loss and Moisture content (%) was calculated using the formula.

$$\text{Moisture Content (\%)= Initial Weight} \times \text{Moisture Content (\%)}$$

$$\text{Mass Loss (\%)} = \frac{\alpha 1 - \alpha 2}{\alpha 1} \text{ x } 100\%$$

Where. α1 = Initial weight before burial, α2 = Final weight after burial.

2.5. Functional Grup Analysis (FT-IR)

Fourier Transform Infrared (FT-IR) spectroscopy was used to identify functional groups present in the biodegradable bioplastic [35]. Samples were cut to dimensions of 5 cm width and 8 cm length, fitting the spectrometer holder. The FT-IR analysis was conducted at a wavelength range of 4000–650 cm^{-1} at room temperature. Spectra were recorded to display the relationship between transmittance and wavenumber. The functional groups in the bioplastic were determined by comparing the obtained wavenumber data with standard functional group ranges.

3. Results and Discussion

3.1. Tensile Strength

The tensile strength of bioplastic composites ranged from 4.88 ± 0.48 MPa to 18.33 ± 0.24 MPa, as shown in Table 2. Statistical analysis confirmed that variations in raw material ratios, types of plasticizers, and their interactions significantly influenced tensile strength ($p < 0.01$). The highest tensile strength (18.33 ± 0.24 MPa) was observed in the 25:75 taro

starch-to-carrageenan composite with 1% castor oil as a plasticizer. This value surpassed previous studies by [34], which reported maximum tensile strengths of 17.60 MPa, and [3], which observed a tensile strength of 10.29 MPa in taro-based bioplastics. Despite this improvement, none of the bioplastics met the Indonesian National Standard (SNI) requirement of 24.7 MPa for packaging materials [2]. The increased tensile strength observed in certain formulations can be attributed to strong intermolecular bonding between amylose, amylopectin, and carrageenan, facilitated by plasticizers such as castor oil. Castor oil, a hydrophobic plasticizer, contributed to improved polymer flexibility and molecular interactions, leading to enhanced mechanical strength [3]. These findings align with [26], who demonstrated that higher carrageenan content enhances film-forming ability and tensile properties due to its ionic crosslinking interactions.

The type of plasticizer used played a crucial role in determining tensile strength variations. Castor oil (P1) consistently resulted in the highest tensile strength values, followed by stearic acid (P2) and egg white (P3). This suggests that plasticizers with better starch interaction capabilities, such as castor oil, provide superior mechanical reinforcement. In contrast, stearic acid and egg white resulted in lower tensile strength, likely due to poor polymer compatibility and limited crosslinking potential [26]. Studies by [6] further confirm that incorporating hydrophilic plasticizers improves polymer flexibility while maintaining structural integrity, but excessive plasticization can reduce tensile strength.

These results indicate that taro starch and carrageenan bioplastic formulations can be optimized by adjusting polymer ratios and plasticizer types to achieve the required mechanical properties for commercial applications.

Table 2. *Average tensile strength of bioplastic composites (MPa).*

Treatment	Plasticizer (%)		
	P1 (castor oil)	P2 (stearic acid)	P3 (egg white)
GR1 (25:75)	14,69 ±0,17 b	9,71 ±0,66 e	9,88 ±0,49 de
GR2 (50:50)	11,67 ±0,37 cd	8,18 ±0,84 ef	6,46 ±0,18 fg
KR1 (25:75)	18,33 ±0,24 a	6,77 ±0,37 fg	5,94 ±0,56 g
KR2 (50:50)	12,34 ±0,07 c	5,24 ±0,99 g	4,88 ±0,48 g

Different letters in the superscript indicate a statistically significant difference between the means based on post-hoc analysis (e.g., Duncan's Multiple Range Test or Tukey's HSD) at a significance level of ($p < 0.01$)

3.2. Elongation at Break

Elongation at break, which represents the bioplastic's ability to stretch under tension before failure, ranged from 3.93 ± 0.51% to 9.29 ± 1.01% (Table 3). Significant differences were observed across treatments ($p < 0.01$), with the highest elongation at break (9.29 ± 1.01%) occurring in the 50:50 taro starch-to-glucomannan composite using 1% egg white as a plasticizer.

However, none of the formulations met the SNI requirement of 21–220% elongation, indicating that the bioplastic composites lacked sufficient flexibility and homogeneity [2]. The low elongation values can be attributed to poor molecular compatibility between starch and polysaccharides, differences in macrostructure and microstructure, and processing conditions that influenced polymer crystallinity and crosslinking [33, 15].

The plasticizer type significantly influenced elongation at break. Egg white (P3) produced the highest elongation values, followed by stearic acid (P2) and castor oil (P1). The protein structure of egg white may have contributed to enhanced elasticity, while stearic acid and castor oil limited polymer mobility, leading to lower elongation values [5].

The highest elongation at break (9.29%), observed in the GR2 (50:50 taro starch–glucomannan composite with egg white), suggests that higher glucomannan content contributed to increased flexibility. However, all samples remained well below industrial elongation requirements, indicating the need for further improvements such as nanofiber reinforcement, enzymatic modifications, or polymer blending [28].

Table 3. Average Elongation at breakoff bioplastic composites (%).

Treatment	Plasticizer (%)		
	P1 (castor oil)	P2 (stearic acid)	P3 (egg white)
GR1	6,43 ±1,01 abc	4,29 ±0,00 bc	5,63 ±1,99 abc
GR2	5,36 ±2,53 abc	5,00 ±1,01 abc	9,29 ±1,01 a
KR1	4,96 ±0,95 bc	4,29 ±0,00 c	6,43 ±1,01 ab
KR2	3,93 ±0,51 c	8,57 ±0,00 a	5,00 ±1,01 abc

Different letters in the superscript indicate a statistically significant difference between the means based on post-hoc analysis (Tukey's HSD) at a significance level of ($p < 0.01$)

3.3. Elasticity (Young's Modulus)

The elasticity (Young's modulus) of the bioplastic composites ranged from 61.17 ± 11.51 MPa to 344.78 ± 23.20 MPa, as shown in Table 4. The highest elasticity was observed in the 25:75 taro starch-to-carrageenan composite with 1% castor oil, while the lowest was found in the 50:50 taro starch-to-carrageenan composite with 1% stearic acid. Despite this variation, all elasticity values fell below the SNI 7818:2016 standard range of 400–1120 MPa, which is the minimum requirement for packaging materials [2]. This suggests that intermolecular forces and compatibility among the composite materials were limited, affecting the overall mechanical strength and elasticity. [23], emphasized that elasticity increases with stronger intermolecular interactions, while low elasticity indicates poor compatibility among polymer chains. These findings are consistent with the poor elasticity results observed in the current study, which may be due to inadequate crosslinking and phase separation between different components in the composite materials.

The high elasticity observed in the castor oil-based formulations (P1) suggests that castor oil enhanced crosslinking and molecular interactions, improving the overall stiffness of the bioplastic composites [21]. Conversely, stearic acid (P2), known for its hydrophobic nature, led to lower elasticity due to reduced polymer chain interaction and weaker intermolecular forces [25].

The type of plasticizer played a key role in determining the elasticity of the composites, with castor oil providing the highest modulus, followed by stearic acid, and finally egg white. This suggests that hydrophobic plasticizers like castor oil help to stabilize the polymer network, improving rigidity and tensile resistance. However, egg white, despite being a protein-based plasticizer, did not significantly enhance elasticity, likely due to insufficient crosslinking and molecular compatibility with the starch and carrageenan matrix [29].

Table 4. Average Elasticity of bioplastic composites (%).

Treatment	Plasticizer (%)		
	P1	P2	P3
GR1	231,20 ±33,65 abc	226,52 ±15,46 abcd	156,33 ±29,71 bcd
GR2	145,05 ±30,99 bcd	165,32 ±16,60 bcd	70,14 ±9,62 d
KR1	344,78 ±23,20 a	157,85 ±8,75 bcd	92,83 ±5,89 cd
KR2	316,49 ±38,91 ab	61,17 ±11,51 d	98,67 ±10,29 cd

Different letters in the superscript indicate a statistically significant difference between the means based on post-hoc analysis (Tukey's HSD) at a significance level of ($p < 0.01$)

3.4. Biodegradability

Biodegradability Analysis of Starch-Based Bioplastics with Plasticizers. The biodegradation analysis demonstrated that all bioplastic formulations degraded completely within 6 to 7 days (Table 5). No significant differences were observed across treatments, indicating that the polymer composition and plasticizer type did not substantially influence the degradation rate. This aligns with SNI 7188: 7 [2], which requires bioplastics to lose at least 60% of their mass within 7 days to be classified as biodegradable. Additionally, these results comply with ASTM D5338, which mandates complete degradation within 60 days under composting conditions [17]. The rapid biodegradation is attributed to the enzymatic and microbial breakdown of starch and polysaccharides, leading to the production of CO_2, H_2O, and organic compounds. Similar studies by Atere et al., [1] on rice-based bioplastics confirmed that higher plasticizer concentrations accelerate biodegradation due to increased water absorption and microbial colonization.

While the type of plasticizer had no significant impact on degradation time, hydrophilic plasticizers (such as glycerol and egg white) are known to enhance biodegradation, whereas hydrophobic plasticizers (such as stearic acid and castor oil) may slightly delay microbial decomposition [16]. The interactions between starch and plasticizer molecules may also affect the long-term environmental stability of the bioplastic. Botha et al., [4] suggested that bioplastics containing biodegradable plasticizers exhibit faster degradation rates than those with synthetic additives. This study confirms that all formulations achieved high biodegradability, reinforcing their potential as eco-friendly packaging alternatives. Future research should explore enzymatic modification and composite reinforcement to balance mechanical strength and biodegradability for industrial applications.

3.5. Functional Group Analysis

The FT-IR spectroscopy analysis of starch-based bioplastics demonstrated the distinct role of each plasticizer stearic acid as shown in Figure 4, egg white, and castor oil in influencing functional group interactions, mechanical performance, and biodegradability. The broad O-H stretching peak (3200–3657 cm^{-1}) observed in all samples indicates strong hydrogen bonding, which is essential for polymer stability and mechanical reinforcement [13]. Stearic acid, a long-chain fatty acid, contributes to hydrophobic interactions, leading to enhanced water resistance but reduced flexibility due to weaker hydrogen bonding [31]. The C=O stretching peak (1650–1800 cm^{-1}) further confirms the presence of ester and carbonyl groups, supporting crosslinking between starch and the plasticizer. The hydrophobic nature of stearic acid limits excessive water absorption, improving bioplastic stability but reducing elasticity [18].

Conversely, egg white, a protein-based plasticizer, introduces amide (N-H) stretching peaks (3100–3500 cm^{-1}), which indicate protein-polysaccharide interactions that enhance flexibility [14]. The C-H stretching peak (2800–3000 cm^{-1}) further suggests the presence of protein-based crosslinking, which improves elongation at break and elasticity. Meanwhile, castor oil, rich in ricinoleic acid, disrupts starch crystallization, leading to greater flexibility and reduced brittleness [19]. The C=C stretching peak (1269–1650 cm^{-1}) in the castor oil-based sample confirms the presence of unsaturated bonds, which improve bioplastic flexibility without compromising strength. These findings align with previous studies that emphasize the significance of plasticizer selection in determining the mechanical, hydrophobic, and biodegradable properties of starch-based bioplastics [27].

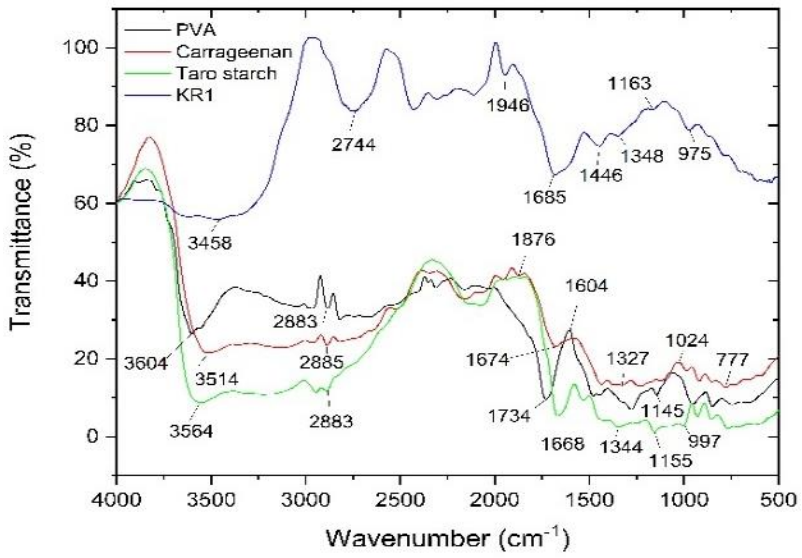

Figure 4. *Wave number spectra of taro starch, carrageenan, starch-carrageenan bioplastic composite with castor oil and the best taro starch-carrageenan bioplastic composite.*

Table 5. Biodegradation value of taro starch and other polysaccharide bioplastic composites (days).

Treatment	Plasticizer (%)		
	P1	P2	P3
GR1	6	6	7
GR2	7	7	6
KR1	7	7	6
KR2	6	7	7

4. Conclusion

The bioplastic composites exhibited enhanced mechanical properties compared to previous studies; however, they did not fully meet the SNI standards for tensile strength, elongation at break, and elasticity. Despite these mechanical limitations, the composites demonstrated exceptional biodegradability, achieving complete degradation within 7 days, aligning with both national (SNI 7188: 7) and international (ASTM D5338) standards. To further improve their industrial applicability, future research should focus on enhancing polymer compatibility and optimizing crosslinking mechanisms to improve mechanical strength and flexibility without compromising biodegradability. Potential strategies include the incorporation of nanofillers, enzymatic modifications, andadvanced plasticizer formulations to achieve an optimal balance between durability and environmental sustainability. Furthermore, FTIR analysis confirmed the presence of key functional groups, indicating strong polymer interactions and validating the structural potential of taro starch-based bioplastics. These findings reinforce the viability of starch-based bioplastics as an eco-friendly alternative for sustainable packaging applications, supporting efforts to reduce plastic pollution and promote biodegradable material innovations.

Abbreviations

SNI	Indonesian Standart National
MPa	Mega Pascal
PVA	Polivynil Alcohol
G	Glucomanan
K	Caragenan
P	Plasticizer
R1	Ratio 25:75
R2	Ratio 50:50
P1	Plasticizer castor oil
P2	Plasticizer stearic acid
P3	Plasticizer egg white
ASTM	American Standart Testing and Material
FTIR	Fourier Transform Infrared

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Author Contributions

Amna Hartiati: Conceptualization, Project administration, Writing – original draft

Dwi Widaningsih: Resources, Writing – review & editing

Bambang Admadi Harsojuwono: Supervision, Validation

I Wayan Arnata: Formal Analysis, Methodology, Software, Validation

Ardhinata Antares: Data curation, Formal Analysis, Methodology, Software, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest regarding financial, commercial, or other affiliations.

References

[1] Atere, J. O., O. Ogunmodede, and D. F. Adewumi. 2024. Investigating Functional Properties of Rice-Based Bioplastics. Pages 1–15.

[2] Badan Standarisasi Nasional. 2016. Kriteria ekolabel - Bagian 7: Kategori produk tas belanja plastik dan bioplastik mudah terurai (SNI 7188.7: 2016). Page Badan Standardisasi Nasional.

[3] Bidari, R., A. A. Abdillah, R. Alfredo, B. Ponce, and A. L. Charles. 2023. Characterization of Biodegradable Films Made from Taro Peel.

[4] Botha, E., T. Chuene, D. Mathobisa, and K. Harding. 2024. Production and Biodegradation Testing of Bioplastics. Pages 66–72 Production and Biodegradation Testing of Bioplastics.

[5] Botlhoko, O. J., R. C. Mphahlele, R. Lekalakala, and S. Muniyasamy. 2024. Blending Techniques for Preparing Cost-minimized Bioplastics and Biocomposites. Biodegradable Polymers, Blends and Biocomposites: 179–198.

[6] Chaudhary, S., M. Kour, and R. Kumar. 2024. Bioplastic films from starch of Colocasia esculenta and its waste: A smart template for sensing applications. International Journal of Biological Macromolecules 281.

[7] Dewi, N. K. A., A. Hartiati, and B. A. Harsojuwono. 2018. The Effect of Temperature and Acid Type on Hydrolysis of Taro Yam Starch (Colocasia Esculenta L. Schott) to The Characteristics of Glucose. Jurnal Rekayasa Dan Manajemen Agroindustri 6: 307.

[8] Fitriani, R. O., A. Hartiati, and L. Suhendra. 2018. Characteristics Of Liquid Sugar Made From Yam Gadung (Dioscorea hispida D.) In Variation Of Acid Types And Concentration. Jurnal Rekayasa Dan Manajemen Agroindustri 6: 203.

[9] Gibson, R. F. 1994. Principles of Composite Material Mechanics. Page Principles of Composite Material Mechanics.

[10] Harnis, R., and Y. Darni. 2011. Penentuan Kondisi Optimum Konsentrasi Plasticizer pada Sintesa Plastik Biodegradable Berbahan Dasar Pati Sorgum. Seminar Nasional Sains dan Teknologi-II.

[11] Hartiati, A., B. A. Harsojuwono, H. Suryanto, and I. W. Arnata. 2021. Synthesis of starch-carrageenan bio-thermoplastic composites on the type and concentration of thermoplastic forming materials as packaging materials. IOP Conference Series: Earth and Environmental Science 913.

[12] Hartiati, A., and I.. M. Tuningrat. 2020. Influence of Type and Concentration of Acids on Hydrolisis Starch of "Taro Tuber" Into Sugar Liquid. Agroindustrial Journal 6: 419.

[13] Jahangiri, F., A. K. Mohanty, and M. Misra. 2024. Sustainable biodegradable coatings for food packaging: challenges and opportunities. Green Chemistry 26: 4934–4974.

[14] Javaid, H., M. Khan, K. Mustafa, and S. Musaddiq. 2022. Biodegradable Plastics as a Solution to the Challenging Situation of Plastic Waste Management. Pages 1–22 Handbook of Biodegradable Materials.

[15] Kedir, W. M., A. K. Geletu, and G. S. Weldegirum. 2024. Spider web-reinforced chitosan/starch biopolymer for active biodegradable food packaging. Applied Food Research 4: 100526.

[16] Lounis, F. M., F. Benhacine, and A. S. Hadj-Hamou. 2024. Improving water barrier properties of starch based bioplastics by lignocellulosic biomass addition: Synthesis, characterization and antibacterial properties. International Journal of Biological Macromolecules 283.

[17] Mamauod, M. I., M. H. A. Hassan, and S. N. L. Mamauod. 2024. The Effect Of Glycerol Concentration On Starch-Based Bioplastics Derived From Banana Peels (Musa Acuminata). Malaysian Journal of Analytical Sciences 28: 1003–1011.

[18] Mayuri, T., R. N. Shukla, and J. Balaji. 2023. Biobased Food Packaging Materials: Sustainable Alternative to Conventional Petrochemical Packaging Materials: A Review. Asian Journal of Dairy and Food Research 42: 137–143.

[19] Muiruri, J. K., J. C. C. Yeo, H. Run, T. T. Lin, X. Hou, V. Raveenkumar, B. Y. Jian, W. Thitsartarn, C. He, and Z. Li. 2024. Plant oil fillers toughened poly (3-hydroxybutyrate) green biocomposites. European Polymer Journal 210.

[20] Permana, K. D. A., A. Hartiati, and B. Admadi. 2017. The Effect of Sodium Chloride (NaCl) Solution Concentration as a Soaking Agent on the Quality Characteristics of Taro Starch (Calocasia esculenta L. Schott). Jurnal Rekayasa dan Manajemen Agroindustri 5: 60–70.

[21] Rahmatullah, R. W. Putri, E. Nurisman, Yandriyani, A. Al Hadi, and M. A. Raihan. 2023. Manufacturing Biodegradable Bioplastics from A Mixture of Starch and Kapok Fibers with Variations of Chitosan and Glycerol. Agroindustrial Technology Journal 02: 91–97.

[22] Rastiyati, N. L. D., A. Hartiati, and B. Admadi. 2016. The Effect Of Nacl Concentration And Water To Ingredient Ratio On The Quality Characteristics Of Gadung Potato Starch (Dioscorea Hispida Dennst). J. Rekayasa Dan Manajemen Agroindustri 4: 116 – 125.

[23] Sanyang, M. L., S. M. Sapuan, M. Jawaid, M. R. Ishak, and J. Sahari. 2015. Effect of plasticizer type and concentration on tensile, thermal and barrier properties of biodegradable films based on sugar palm (Arenga pinnata) starch. Polymers 7: 1106–1124.

[24] Saputra, F., A. Hartiati, B. H. Admadi, M. Jurusan Teknologi Industri Pertanian, F. Teknologi Pertanian, and D. Jurusan Teknologi Industri Pertanian. 2016. Quality Characteristics Of Taro Starch (Colocasia Esculenta) In The Comparison Of Water With Taro Crushed And Sodium Concentration. Maret 4: 62–71.

[25] Saputri, C. A., F. A. Julyatmojo, Harmiansyah, M. Febrina, M. Mahardika, and S. Maulana. 2024. Characteristics of bioplastics prepared from cassava starch reinforced with banana bunch cellulose at various concentrations. IOP Conference Series: Earth and Environmental Science 1309.

[26] Saray, I. J., A. G. Fuentes, and L. Casinillo. 2023. Taro (Colocasia esculenta) and sea grapes (Caulerpa lentillifera) as potential materials for making bioplastic. EDUCATUM Journal of Science, Mathematics and Technology 10: 47–57.

[27] Shafqat, A., N. Al-zaqri, A. Tahir, and A. Alsalme. 2021. Saudi Journal of Biological Sciences Synthesis and characterization of starch based bioplatics using varying plant-based ingredients, plasticizers and natural fillers. Saudi Journal of Biological Sciences 28: 1739–1749.

[28] Sharma, S., T. Ghosh, N. Mulchandani, and V. Katiyar. 2024. Biodegradable Synthetic Poly (Lactic Acid) (PLA) for Food Packaging Application. Page Agro-Waste Derived Biopolymers and Biocomposites: Innovations and Sustainability in Food Packaging.

[29] Sultan, A., H. Sultan, W. Shahzad, A. Kareem, A. Liaqat, Z. Ashraf, A. Shahid, A. Rauf, S. Saeed, T. Mehmood, M. Zahra, A. Soto-Bubert, and R. Acevedo. 2024. Comparative analysis of physical and mechanical properties of starch based bioplastic derived from the pulp and peel of potatoes. Journal of the Indian Chemical Society 101.

[30] Suparwan, K. G. I., A. Hartiati, and L. Suhendra. 2021. The Effect of Filler Type and Concentration on The Characteristic Bioplastic Composites of Gadung Tuber Starch-Carrageenan. Jurnal Rekayasa Dan Manajemen Agroindustri 9: 312.

[31] Tiozon, R. J. N., A. P. Bonto, and N. Sreenivasulu. 2021. Enhancing the functional properties of rice starch through biopolymer blending for industrial applications: A review. International Journal of Biological Macromolecules 192: 100–117.

[32] Sundari, U. Y., A. Sandriya, E. D. P. Setyowati, O. Andanu and F. Fiardilla. 2024. Karakterisasi Fisik Film Berbasis Polivinil Alkohol (PVA) dengan Penambahan Nanoclay Sebagai Filler. Jurnal Penelitian UPR:Kaharati 4: 8-15.

[33] Wang, Z. L., and Z. C. Kang. 1996. FUNCTIONAL AND SMART MATERIALS -Structural evolution and structure analysis.

[34] Yulianti, N. L., B. A. Harsojuwono, I. B. P. Gunadnya, and I. W. Arnata. 2024. Optimization of Cellulose Nanofibers and Castor Oil in the Synthesis of Starch-carrageenan-polyvinyl Alcohol Bio-thermoplastic Film. Pakistan Journal of Analytical and Environmental Chemistry 25: 31–48.

[35] Averous, L. 2004. Biodegradable multiphase system based on plasticized starch: A review, J. Macromol. Sci. 44(3): 231-274.

[36] Khan, S., S. Nadir, Z. U. Shah, A. A. Shah, S. C. Karunathna, J. Xu, A. Khan, S. Munir and F. Hasan. 2017. Biodegradation of polyester polyurethane by Aspergillus tubingensis. Environmental Pollution. 225: 469-480. https://doi.org/10.1016/j.envpol.2017.03.012

[37] Nayiroh, N. 2013. Teknolologi Material Komposit. http://nurun.lecturer.uin-malang.ac.id/wp-content/uploads/sites/7/2013/03/Material-Komposit.pdf Accessed June 25, 2025

Biography

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