Journal of Bio & Geo Material and Energy (BiGME)
Volume 4 No. 2, September 2024
P-ISSN: 2808-1560 E-ISSN: 2808-1404

Study on Ratio of Jerbung Shrimp Waste Powder (*Fenneropenaeus Merguiensis de Man*) and Purple Yam Starch in the Production of Bioplastics

S. Widiyawati[1], Nazarudin[2,3], Ulyarti[1,3]

[1] Agricultural Product Technology Study Program, Faculty of Agriculture, Jambi University, Pondok Meja Campus Jl Tribrata Km 11, Jambi, Indonesia
[2] Chemical Engineering Study Program, Faculty of Science and Technology, Jambi University, Pondok Meja Campus Jl Tribrata Km 11, Jambi, Indonesia
3 Bio-Geo Material and Energy Centre of Excellence, Jambi University, Kampus Mendalo, Jl Raya Jambi-Ma.Bulian, Muaro Jambi, Jambi, Indonesia

E-mail : ulyarti@unja.ac.id

Article info :

Submitted : August 2024
Accepted : September 2024
Published : September 2024

Abstract :
Abstract – This research aims to determine to study the ratio of Jerbung shrimp waste powder and purple yam starch in the production of bioplastics. This research used a Completely Randomized Design (CRD) with 5 levels of ratio of jerbung shrimp waste powder and purple yam, namely 0:5; 0.5:4.5; 1:4; 1.5: 3.5 and 2:3. Each treatment was repeated 3 times to obtain 15 experimental units. The results showed that the ratio of Jerbung shrimp waste powder and starch had a significant effect on tensile strength, elongation, thickness, water resistance and WVTR. The best bioplastic characteristics was best produced using the ratio 0.5:4.5 with tensile strength of 18.17 N/mm2, elongation of 68.06%, thickness of 0.35 mm, water resistance of 75.15 %, WVTR 22.29 g/m2.hour and cumulative percentage of bioplastics ≤180 days according to SNI 7188 standards; 2022.

Keywords: Bioplastics, Ratio, Starch, Jerbung Shrimp Waste Powder

1. Introduction

One of the factors that causes environmental damage is plastic waste which is widely used in everyday life. The large use of plastic is caused by several factors, including economical price, not easily damaged, long lasting, light and easy to obtain. Therefore, the use of plastic is increasing every year, resulting in environmental pollution in the world. Bioplastic is an environmentally friendly plastic compared to plastic in general because it can be degraded naturally. In making bioplastics, the materials used are natural polymer compounds that can be used, namely polysaccharides, proteins and poly-lactic acid (PLA) which are found in the agricultural sector such as cassava, sago, soybeans and corn fiber (Pilla, 2011).

One source of raw material for bioplastics production is starch (Albar et al., 2021). Purple yam has great potential to be processed as a film-making material, because of its high starch content of 86.12% (Winarti & Saputro, 2017). However, starch is generally hydrophilic which can affect stability, heat resistant and mechanical properties the resulting starch and is unable to retain water and microorganisms. To correct the weaknesses of this starch-based bioplastic, it can be combined using materials that are strong and resistant to water and microorganisms.

One of the materials that can be added to improve the physical, mechanical and barrier properties of bioplastics is powder from shrimp waste. This is because shrimp waste powder contains 42.23% crude protein; crude fiber 19.87%; fat 2.89%; calcium 13.23%; phosphorus 2.08%; chitin content 9.56% (Mirzah & Filawati, 2013). Chitin and its derivative products can be used as raw materials for bioplastics (Najih, 2018). Chitin is a compound that is stable against chemical reactions, non-toxic and biodegradable. Chitin is not soluble in water (it is hydrophobic) (Pratiwi, 2014). Chitosan is a protein modification of chitin found in shrimp shells and is good for forming into films and has antimicrobacterial properties (Tripathi et al., 2009; Hartatik et al., 2014). Therefore the shrimp waste has the potency to be processed into powder for bioplastics material. For the shrimp wste powder can be used as a bioplastic material, it is necessary to convert shrimp waste consisting of shrimp heads and shells into chitin and chitosan while retaining some of the proteins and minerals that can be useful for bioplastics production. The conversion includes treatment using a weak acid such as acetic acid and a strong base such as NaOH (Puspitasari & Ekawandani, 2019; Purwanti & Yusuf, 2014). The application of waste shrimp shell powder resulting from processing using acids and bases as stated above has never been used in the manufacture of bioplastics. The research aims to apply several ratios of jerbung shrimp waste powder in bioplastic production using yam starch and to determine the physical, mechanical and barrier properties of the bioplastics.

2. Research Method

Materials and Tools

The materials used in this research were Jerbung shrimp waste (consist of shells only), purple yam, NaCl, $CaCl_2$, NaOH, $Mg(NO_3)_2$, CH_3COOH, and glycerol. The tools used in this research were screw micrometer, caliper, texture analyzer, ImageJ, 60 and 200 mesh sieve and 20 x 20 cm glass mold.

Research Design and Statistical Analysis

This research was carried out using a completely randomized design (CRD) with 5 different ratio treatments of Jerbung shrimp waste powder and cassava starch as listed in Table 1. The bioplastic was made by sticking 2 layers of bioplastics together using bioplastic film solution. Each treatment was repeated 3 times to obtain 15 experimental units.

Table 1. Composition ratio of bioplastic materials

Jerbung shrimp waste powder (g)	Purple yam starch (g)	Glycerol (g)	CH_3COOH (g)	Distilled water (g)	Total (g)
0	5	2	5	138	150
0.5	4.5	2	5	138	150
1	4	2	5	138	150
1.5	3.5	2	5	138	150
2	3	2	5	138	150

Shrimp Waste Powder Preparation (Astuti, 2023)

The Jerbung shrimp shells used were in good condition with the characteristics of normal smell, hard texture and fresh. The shrimp shells were washed using running water. The cleaned shrimp shells were then homogenized and dried in the oven at 100°C for 5 hours. After the drying process is complete, the size reduction process is carried out using a blender and sieved using a 60 mesh sieve.

The shrimp shell powder was weighed and soaked using a 10% acetic acid solution with a ratio of powder to acetic acid = 1:5, for 1 hour. The powder was filterred and washed using distilled water until the pH is neutral. The wet powder was soaked in 0.5 M NaOH solution and stirred at a temperature of 65˚C for 2 hours. After the mixture has cooled, it is filtered and washed with distilled water until the pH is neutral. The soaked shrimp shells were dried in the oven at 100°C for approximately 4 hours. After the drying process is complete, it is sieved using a 60 mesh sieve.

Yam Starch Extraction (Ulyarti et al., 2016)

Yam was cleaned, washed, sliced into 2 mm to 3 mm thick. The yam slices were then soaked in 15% table salt (NaCl) solution for 30 minutes and rinsed with water 3 times. The yam slices were ground in a blender with the addition of water in ratio 1:2 (yam: water). The pulp obtained was filtered using a 200 mesh sieve. After 6 hours, the sediment was separated and rinsed using distilled water until a clear supernatant was obtained. The starch precipitate was dried in an oven at 50°C for 6 hours. The dried starch is sieved using a 60 mesh sieve, packaged in a closed container and stored in the refrigerator.

Bioplastics Preparation (Albar et al., 2021 with modification)

Shrimp waste powder was previously soaked using 5% acetic acid for 1 hour. The powder and cassava starch were mixed with distilled water and heated on a hot plate until it reaches 80°C while continuing to stir. Then 2 g of glycerol was added from a total solution volume of 150 g. The starch solution was continuously heated at 80°C with stirring using a magnetic stirrer for 20 minutes. The homogenized film solution was then poured into a glass mold and dried using an oven at 50℃ for 24 hours.

A solution of 5 g starch was made, with 2 g glycerol and 50 g distilled water, heated to a temperature of 80℃ while stirring for 10 minutes. Then ± 15 g of this film solution were applied to the surface of the bioplastic before combining the 2 ply of sheets. Next, it was dried using an oven for 5 hours at 50°C. Bioplastics were equilibrated in a desiccator with RH 52% using a saturated $Mg(NO_3)_2$ solution for 48 hours before analysis. The film sheets are then tested for their characteristics which include tensile strength, elongation, thickness, water absorption capacity, water vapor transmission rate and degradation.

Analysis

The parameters observed were tensile strength, elongation (JIS, 2019), thickness (Warkoyo et al., 2014), water resistance (Lazuardi & Cahyaningrum, 2013), water vapor transmission rate (Piñeros-Hernandez et al., 2017), and cumulative degradation percentage (Fibriyani, 2017).

Data Analysis

The data obtained were analyzed statistically using analysis of variance at the 1% and 5% levels. If the difference is significant then the analysis was continued using Duncan's New Multiple Range Test (DMRT). The cumulative bioplastic percentage data was analyzed descriptively by displaying research data presented in the form of graphs and images.

3. Result and Discussion

Bioplastics are environmentally friendly plastics compared to plastics in general which are also called biodegradable which can be degraded naturally in the environment. Bioplastics are in the form of thin, elastic, transparent, slightly see-through sheets. The characteristics of bioplastics are influenced by the type and color of the raw materials used in making bioplastics (Setijawati, 2017). The following is a picture of the bioplastic product, the ratio of jerbung shrimp waste powder and starch in Figure 1.

(0 g : 5 g) (0.5 g : 4.5 g) (1 g : 4 g) (1.5 g : 3.5 g) (2 g : 3 g)

Figure 1. Bioplastic at different ratio of Jerbung shrimp waste powder and yam starch

The bioplastic made using several ratios of Jerbung shrimp waste powder and yam starch has a brownish yellow color. The more shrimp powder, the less transparent bioplastic and less elastic. The bioplastic has poor tensile strength when compared to commercial plastic. Bioplastic made of Jerbung shrimp waste powder and yam starch breaks more easily when stretched. The addition of shrimp waste powder decrease the tensile strength of bioplastics.

Table 2. Bioplastic test results for the ratio of Jerbung shrimp waste powder and yam starch

The Ratio Waste Powder : Yam Starch	Tensile Strength (N/mm^2)	Elongation (%)	Thickness (mm)	Water Resistence (%)	WVTR (g/m^2.hour)
0 : 5	11.91 ± 3.4^{ab}	69.63 ± 1.64^{a}	0.33 ± 0.04^{a}	74.90 ± 8.04^{a}	38.60 ± 0.97^{c}
0.5 : 4.5	18.17 ± 3.47^{c}	68.06 ± 3.45^{a}	0.35 ± 0.04^{a}	75.15 ± 2.18^{a}	22.29 ± 175^{ab}
1 : 4	13.47 ± 0.71^{b}	132.38 ± 36.40^{b}	0.38 ± 0.01^{a}	82.90 ± 4.26^{ab}	20.65 ± 0.79^{a}
1.5 : 3.5	12.78 ± 1.17^{b}	112.00 ± 3.89^{b}	0.40 ± 0.05^{a}	89.64 ± 9.21^{b}	19.98 ± 1.14^{a}
2 : 3	8.00 ± 1.38^{a}	108.03 ± 4.66^{b}	0.57 ± 0.07^{b}	87.55 ± 5.25^{ab}	24.77 ± 2.97^{b}

Note: Numbers followed by the same lowercase letters in the same column are not significantly different at the 5% level according to the DNMRT

Tensile Strength

The ratio of Jerbung shrimp waste powder and yam starch have a significant effect on the tensile strength of bioplastics (Table 2). Based on JIS Z 7127: 2019, this bioplastic is included in class 5, namely < 25 N/mm^2. The main component of shrimp waste residue is chitin together with protein and calcium carbonate (Guerrero et al., 2023). The higher the ratio of Jerbung shrimp waste powder, the smaller the amount of yam starch, which results in the film solution being less compact so that the resulting bioplastic is easily torn. The non-integrated mixture between the starch solution and shrimp waste powder results in the distribution of the molecules of the bioplastic components not being completely dispersed, so that the resulting material experiences a decrease in tensile strength (Nurrahmi et al., 2020). A solution that is less fused is indicated by the roughness of the bioplastic surface texture and unequal thickness (Simarmata et al., 2020). The decrease in the tensile strength value is related to the presence of empty spaces that occur due to the bonds between glycerol polysaccharides, causing the bonds between molecules in bioplastics to weaken.

The results of this research are in line with research previously reported by Dawam et al., (2020) on bioplastics made from cassava starch and glycerol plasticizers using the addition of 1-4% chitin which reduce tensile strength from 6.7 to 6.3 MPa. However, the other researcher (Nahir, 2017) reported the increase in the tensile strength of bioplastics with addition of chitosan. The tamarind seed starch bioplastic without the addition of chitosan had a tensile strength value of 4.61 MPa while bioplastic with the addition of chitosan was 16.15 - 27.62 Mpa (Nahir, 2017).

Elongation

As seen in Table 2, the highest elongation value are found in the ratio of Jerbung shrimp waste powder and yam starch 1:4 and the lowest value is found in the ratio of waste shrimp powder and yam starch 0:5. The bioplastic according to JIS Z 7127: 2019 standards is classified as class 4 bioplastics with elongation 20-200%. There seems to be an optimum ratio of jerbung shrimp waste powder and starch which produce the highest elongation. Increasing the ratio to 1: 4 increases the elongation of bioplastics, while further increase in the ratio of waste shrimp powder to starch, will decreasethe elongation.

Jerbung shrimp waste powder does not have elastic properties but is brittle and stiff. Jerbung shrimp waste powder does not dissolve completely, it is hydrophobic and has hydroxyl groups (-OH) which form intermolecular hydrogen bonds with the hydroxyl groups (-OH) in cassava starch which causes the bioplastic to become stiff. The addition of reinforcement results in a decrease in the elongation value due to the reduction in the intermolecular bond distance so that the plasticizer molecules are spaced apart (Ginting, 2016).

These results are in line with previous report by Dawam et al., (2020) on bioplastics made from cassava starch and glycerol. He reported that bioplastics with the addition of 1-4% chitin experience reduction in elongation from 55.5 to 40.8%. Similar to chitin, the addition of chitosan also decrease the elongation (Nahir, 2017).

Thickness

The thickness of the two layers of bioplastic produced is in between 0.33 - 0.57 mm (Table 2). The higher ratio of Jerbung shrimp waste powder in the film forming solution increases the total solids. Increasing the concentration of the polymer material in the film matrix will increase the total dissolved solids in the film solution, leading a thicker bioplastics. This is in line with other researchs on starch based-bioplastics (Syura, 2020). The addition of 2-3% chitin concentration increases film thickness (Zhou et al., 2022). The results of two-layer bioplastics in this study were higher than the results of single-layer bioplastics using tamarind seed starch and chitosan showing a thickness value of 0.12-0.32 mm (Nahir, 2017).

Water Resistance

The ratio of Jerbung shrimp waste powder and yam starch has a significant effect on the water resistance of the bioplastic (Table 2). The higher ratio of Jerbung shrimp waste powder in the film forming solution increases water resistance of bioplastics. This is because the Jerbung shrimp waste powder used has a lower solubility, namely 3.64% (Astuti, 2023). The powder contains chitin which cannot be dissolved in water or hydrophobic (Pratiwi, 2014). The results of this research are in line with previous research reported by Dawam et al. (2020) that increasing water resistance of bioplastics was observed upon addition of 1-4% chitin. The results of this two-layers bioplastics in this study were comparable to that of single-layer bioplastics (Nahir, 2017; Albar et al., 2021).

Water Vapor Transmission Rate (WVTR)

As seen in Table 2, the values of WVTR in the bioplastics are in the range 38.60 – 19.98 g/m².hour, which are still higher than many reported values such as Ariyani et al., (2019) using starch and CMC was 6.37 g/m2/day. Other study, Ardiansyah (2011) reported that bioplastics from arrowroot starch and glycerol plasticizer had a water vapor transmission rate of 8.43 g/m^2/day.

The WVTR value decreased along with the increase in ratio of shrimp waste powder in the film forming solution due to the hydrophobic nature of the powder. The decrease in the WVTR of the film is inversely proportional to its thickness. The thicker the film, the more difficult it is for water vapor to penetrate the film (Kusumawati & Putri, 2013).

The presence of chitin in starch-based bioplastics will inhibit the attractive force between the bioplastic and water, thereby preventing the release of water vapor from the bioplastic. The mass percentage of water vapor shows that the higher the chitin concentration, the lower the mass of water vapor that comes out through bioplastics (Dawam et al., 2020). The presence of chitin in the film forming solution may inhibit hydrogen interactions between starch molecules and water vapor. Other research reports on chitin bioplastics which experience a decrease in WVTR as the concentration of chitin increases (Zhou et al., 2022). The greater the concentration, the denser the chitin polymer network formed and the smaller the free volume, so that the amount of water vapor and oxygen that passes through the bioplastic per unit time also decreases (Li et al., 2019).

Cumulative Percentage of Bioplastics

The cumulative percentage of bioplastics is the process of decomposing organic material by microorganisms such as bacteria and fungi that live in the soil. Cumulative percentage rate of bioplastics in Figure 2.

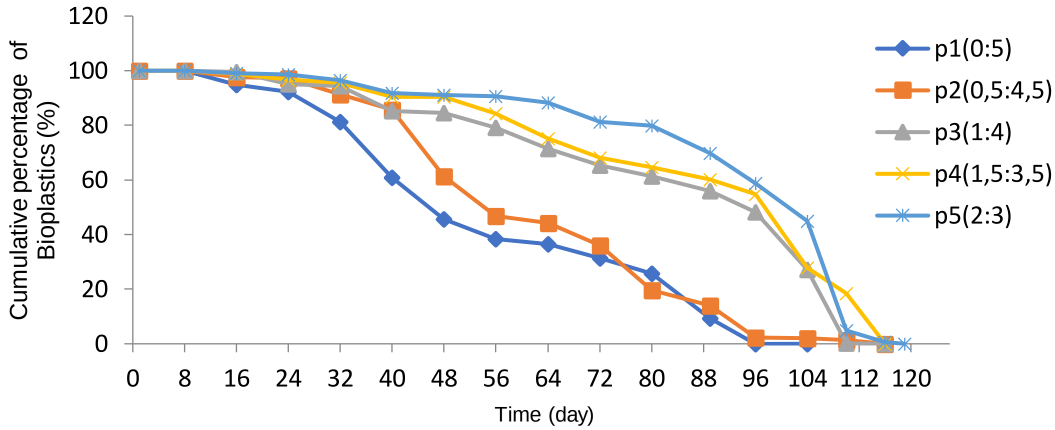

Figure 2. Graph of cumulative percentage of bioplastic

Figure 2 shows that the ratio of Jerbung shrimp waste powder and yam starch (0:5 and 1.5:4.5) decompose more quickly (96 days), whereas the higher the ratio of Jerbung shrimp waste powder, the longer bioplastics to decompose which is up to 119 days. According to European Union standards CEN 13432 and SNI 7188-7:2022, it can decompose 90% within 6 months or around 24 weeks (Suparyanto & Rosad, 2020). According to the bioplastic standard, the ratio of Jerbung shrimp waste powder and yam starch meets the CEN 13432 and SNI 7188-7:2022 standards, indicating that the bioplastic ratio of jerbung shrimp waste powder and yam starch is environmentally friendly because it degrades in less than 180 days.

The higher ratio of Jerbung shrimp waste powder in film forming solution, the longer it takes for bioplastics to decompose. The starch in bioplastics contains hydrophilic C-O ester and C=O carbonyl functional group bond structure which causes the binding of water molecules from the surrounding environment leading bioplastics easier to decompose. Furthermore, starch has hydrophilic bonds which can absorb water, making it easier for microorganisms to damage the matrix or starch (Simarmata et al., 2020). According to Murni (2016) in Qadri et al (2023), the process of decomposing biodegradable plastic polymers includes stages, starting from the stage of attachment of microorganisms to the surface of the polymer which is hydrophilic in nature, then the stage of growth of microorganisms using the polymer as a carbon source, then the stage of enzymatic erosion of the polymer using a hydrolysis process that produces carbon and energy, and finally mineralizes into H_2O and CO_2.

Meanwhile, the higher the ratio of jerbung shrimp waste powder used, the longer it will take for the bioplastic to decompose. This is in line with the increasing water resistance value of bioplastics. Because shrimp waste powder is hydrophobic, the more shrimp powder you add, the more bioplastic produced will be more resistant to soil water. This opinion is supported by Alam et al., (2018) in their research who concluded that adding a higher concentration of chitosan resulted in a longer decomposition time, because chitosan from shrimp shells which is hydrophobic and antimicrobial affects humidity and inhibits water absorption which is a requirement for the growth of microorganisms.

4. Conclusion

The ratio of Jerbung shrimp waste powder and yam starch has a significant effect on tensile strength, elongation, thickness, water resistance and water vapor transmission rate. The bioplastics made up of several ratios of Jerbung shrimp waste powder and yam starch are easily decomposed. The best bioplastic characteristics are found in the ratio of shrimp waste powder and starch (0.5:4.5) which produces a tensile strength of 18.17 N/mm^2, elongation of 68.06%, thickness of 0.35 mm, water resistance of 75.15%, and WVTR 22.29 g/m^2.hour.

References

Alam, Halid, T., & Illing, I. 2018. Efek Penambahan Kitosan Terhadap Karakteristik Fisika Kimia Bioplastik Pati Batang Kelapa Sawit. *Indonesian Journal of Fundamental Sciences*, *4*(1), 39. https://doi.org/10.26858/ijfs.v4i1.6013

Albar, A., Rahmaniah, R., & Ihsan, I. 2021. Pembuatan Dan Karakterisasi Bioplastik Berbahan Dasar Pati Umbi Uwi Ungu, Plasticizer Gliserol Dan Kitosan. *Teknosains: Media Informasi Sains Dan Teknologi*, *15*(3), 253. https://doi.org/10.24252/teknosains.v15i3.20183

Ardiansyah, R. 2011. Pemanfaatan Pati Umbi Garut untuk Pembuatan Plastik Biodegradable. *Fakultas Teknik. Universitas Indonesia. Skripsi*, 1–118.

Ariyani, D., Puryati Ningsih, E., & Sunardi, S. 2019. Pengaruh Penambahan Carboxymethyl Cellulose Terhadap Karakteristik Bioplastik Dari Pati Ubi Nagara (Ipomoea batatas L.). *Indo. J. Chem. Res.*, *7*(1), 77–85. https://doi.org/10.30598//ijcr.2020.7-sun

Astuti, F. D. 2023. Pengaruh Konsentrasi NaOH Terhadap Sifat Fisik dan Kimia Tepung Dari Kulit Udang Jerbung (Fenneropenaeus Merguiensis De Man). ., 1–8.

Dawam, A. H., Fikriyyah, A. K., & Furghoniyyah, U. 2020. Effect of chitin addition on water resistance properties of starch-based bioplastic properties. *IOP Conference Series: Earth and Environmental Science*, *483*(1). https://doi.org/10.1088/1755-1315/483/1/012002

Ghasemlou, M., Aliheidari, N., Fahmi, R., Shojaee-Aliabadi, S., Keshavarz, B., Cran, M. J., & Khaksar, R. 2013. Physical, mechanical and barrier properties of corn starch films incorporated with plant essential oils. *Carbohydrate Polymers*, *98*(1), 1117–1126. https://doi.org/10.1016/j.carbpol.2013.07.026

Ginting, M. H., Kristiani. M., Amelia. Y. & Hasibuan. R. 2016. The Effect of Chitosan, Sorbitol, andHeating Temperature BioplasticSolution on Mechanical Properties of Bioplastic from Durian Seed Starch (Durio Zibehinus). *Journal of Engineering Research and Applications*, *6*((1)), 33–38.

Hartatik, Y. D., Nuriyah, L., & Iswarin. 2014. Pengaruh Komposisi Kitosan Terhadap Sifat Mekanik dan Biodegradable Bioplastik. *Brawijaya Physics Student Journal*, 1–4.

JIS. 2019. *General rules of plastic films for food packaging* (JIS Z 1707 : 2019 (E); 2019th-01–21st ed.).

Kusumawati, D. H., & Putri, W. D. R. 2013. Karakteristik Fisik Dan Kimia Edible Film Pati Jagung Yang Diinkorporasi Dengan Perasan Temu Hitam. *Jurnal Pangan Dan Agroindustri*, *1*(1), 90–100. http://jpa.ub.ac.id/index.php/jpa/article/view/9

Lazuardi, G. P., & Cahyaningrum, S. E. 2013. Pembuatan dan karakterisasi Bioplastik berbahan Dasar Kitosan dan Pati Singkong Dengan Plasticizer Gliserol. *UNESA Journal of Chemistry*, *2*(3), 161–166.

Li, Y., Cao, C., Pei, Y., Liu, X., & Tang, K. 2019. Preparation and properties of microfibrillated chitin/gelatin composites. *International Journal of Biological Macromolecules*, *130*, 715–719. https://doi.org/10.1016/j.ijbiomac.2019.03.014

Mirzah, & Filawati. 2013. Pengolahan Limbah Udang untuk Memperoleh Bahan Pakan Sumber Protein Hewani Pengganti Tepung Ikan. *Jurnal Peternakan Indonesia (Indonesian Journal of Animal Science)*, *15*(1), 52. https://doi.org/10.25077/jpi.15.1.52-61.2013

Murni, & Harefa. 2016. *Biodegradasi Plastik (Low Density Polyethylene) Menggunakan Jamur Dari Tempat Pembuangan Akhir (Tpa)* [Universitas Sumatera Utara]. https://repositori.usu.ac.id/handle/123456789/72832

Nahir, N. 2017. Pengaruh penambahan kitosan terhadap karakteristik bioplastik dari pati biji asam. *Uin Alauddin Makasar*, 1–86. http://repositori.uin-alauddin.ac.id/1178/1/rezki.pdf?cv=1

Najih, I. 2018. *Sintesis Plastik Biodegradable Berbahan Kitosan, Arang Manggis dan Minyak Sereh*. Universitas Islam Negeri Walisongo.

Pilla, S. 2011. Handbook of Bioplastics and Biocomposites Engineering Applications. In S. P. Wisconsin (Ed.), *Handbook of Bioplastics and Biocomposites Engineering Applications*. https://doi.org/10.1002/9781119160182

Pratiwi, R. 2014. Manfaat Kitin dan Kitosan Bagi Kehidupan Manusia. *Oseana*, *XXXIX*, *No*(1), 35–43. http://oseanografi.lipi.go.id/dokumen/os_xxxix_1_2014-4.pdf

Purwanti, A., & Yusuf, M. 2014. Evaluasi Proses Pengolahan Limbah Kulit Udang Untuk Meningkatkan Mutu Kitosan Yang Dihasilkan. *Jurnal Teknologi*, *7*(1), 83–90.

Puspitasari, D., & Ekawandani, N. 2019. Pemanfaatan Limbah Kulit Udang Sebagai Pengawet Alami Makanan. *Jurnal TEDC*, *13*(3), 256–261. http://ejournal.poltektedc.ac.id/index.php/tedc/article/view/310

Qadri, O. R. J., Hamzah, F. H., & Ayu, D. F. 2023. Variasi konsentrasi kitosan dalam pembuatan bioplastik berbahan baku jerami nangka. *Agrointek : Jurnal Teknologi Industri Pertanian*, *17*(1), 106–113. https://doi.org/10.21107/agrointek.v17i1.14376

Simarmata, E. O., Hartiati, A., & Harsojuwono, B. A. 2020. Karakteristik Komposit Bioplastik Dalam Variasi Rasio Pati Umbi Talas (Xanthosoma sagittifolium)-Kitosan. *Jurnal Ilmiah Teknologi Pertanian Agrotechno*, *5*(2), 75. https://doi.org/10.24843/jitpa.2020.v05.i02.p05

Suparyanto & Rosad. 2020. Plastik Biobased dan Biodegradable. *Internationale Zusammenarbeit (GIZ) GmbH*, *5*(3), 248–253.

Tripathi, S., Mehrotra, G. K., & Dutta, P. K. 2009. Physicochemical and bioactivity of cross-linked chitosan-PVA film for food packaging applications. *International Journal of Biological Macromolecules*, *45*(4), 372–376. https://doi.org/10.1016/j.ijbiomac.2009.07.006

Ulyarti, Lavlinesia, Fortuna, D., & Surhaini. 2016. The study of physical properties of dioscorea alata's starch from jambi province. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(4), 456–459. https://doi.org/10.18517/ijaseit.6.4.735

Winarti, S., & Saputro, E. A. 2017. Karakteristik Tepung Prebiotik Umbi Uwi (Dioscorea spp). *Jurnal Teknik Kimia*, *8*(1), 17–21. https://doi.org/10.33005/JURNAL_TEKKIM.V8I1.709

Zhou, Y., He, Y., Lin, X., Feng, Y., & Liu, M. 2022. Sustainable, High-Performance, and Biodegradable Plastics Made from Chitin. *ACS Applied Materials and Interfaces*, *14*(41), 46980–46993. https://doi.org/10.1021/acsami.2c12764