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# A Study of Physical and Mechanical Properties: Durian Peel Starch-Sago Starch Biocomposite Bioplastic with Sorbitol Plasticizer Reinforced by Chitosan and Zinc Oxide

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***ABSTRACT**: Conventional plastics causes various problems, particularly related to the environment and health. Their impacts include air and soil pollution, blocked airways leading to flooding, and disruption to marine and terrestrial ecosystems. Furthermore, non-biodegradable plastic bags can release hazardous chemicals and microplastics, which pollute the environment. To solve these problems, many researchers are developing environmentally friendly plastics made from biomass by combining various additives according to the plastic's function, commonly referred to as bioplastic biocomposites. Biocomposite bioplastic can be made from biomass raw materials such as starch. Durian peel waste contains not only cellulose but also quite high starch content. However, starch-based biocomposites have problems, especially in their mechanical properties. The use of fillers as reinforcements such as chitosan and ZnO is needed to overcome this problem. This study aims to determine the effect of adding fillers (chitosan and ZnO) to starch-based biocomposite bioplastic (durian peel and sago). The method used in making plastic biocomposites is mixing process and solution casting. Sorbitol plasticizer of 25% and fillers of 4% each for chitosan and ZnO were added for variations in the total starch of durian peel and sago (1.25:3; 2.25:3; 3:3). Based on the results of the durian peel flour composition, it is proven that it has a fairly high starch content of 68.67%. The results of physical/mechanical tests of the best biocomposite bioplastic were obtained in sample A with a tensile strength of 18.816 MPa, elongation of 1.422% and young's modulus of 13.05%. The addition of ZnO filler only affects thickness, tensile strength, and elongation. These results indicate that the combination of materials can improve the mechanical properties of bioplastics based on durian peel waste starch and sago starch.*

***Keywords:** biocomposite bioplastic; chitosan; durian peel waste starch; sago starch; sorbitol*

## 1. INTRODUCTION

Conventional plastics, which are widely used in various industries and everyday life, are made from non-renewable petroleum raw materials and are difficult to decompose, thus causing negative impacts on the environment (Sharma et al., 2023). Biocomposite bioplastic have become a focus of research and development as an environmentally friendly alternative. Biocomposite bioplastic are plastic materials made from renewable sources such as plants, algae, and agricultural waste (Destiana et al., 2024). One attractive raw material for biocomposite bioplastic production is starch.

Durian peel is an abundant agricultural waste in many countries, including Indonesia. Durian peel contains crude fiber (62.46%), starch (36.8%), protein (19.9%), and lignin (10.53%) (Rahmatullah et al., 2024). Utilizing starch from durian peel as a raw material for biocomposite bioplastic can add value to this waste and reduce environmental impact.

Biocomposite bioplastic require plasticizers, and fillers to improve their quality characteristics. Plasticizers are used to increase the flexibility and durability of a material (Godwin, 2000). Fillers are needed to increase the tensile strength and reduce the brittleness of biocomposites bioplastic (Kong et al., 2023).

This research is a continuation of research conducted by Rahmatullah et al. (2024) with the same raw materials, namely a combination of starch (durian and sago peels), and sorbitol plasticizer, but only using one type of filler, namely chitosan. Chitosan, as a biopolymer, has the advantage of increasing tensile strength, making bioplastics stronger and more resistant to tearing. However, it has the disadvantage of slowing the rate of biocomposite bioplastic degradation and stiffening it (reducing the elasticity and flexibility) if used in excessive amounts. Therefore, further research is needed to explore other types of fillers (Syafri et al., 2021).

The addition of ZnO as a reinforcement in biocomposites has been proven to be able to improve mechanical properties, especially the tensile strength value of biocomposite bioplastic and percent elongation (Takribiah et al., 2022). Biocomposite bioplastic with Zinc Oxide fillers tend to have better morphology, increased thickness, and do not crack even though particle aggregation occurs (Hidayat et al., 2019).

Previous studies have reported the use of chitosan in starch-based biocomposite bioplastic. Therefore, the novelty of this study lies in the use of ZnO as a reinforcement in durian peel starch-sago starch-based biocomposite bioplastic with sorbitol plasticizer, which has not been reported in previous studies. This study aims to compare the effect of adding ZnO and chitosan as filler and sorbitol plasticizer on the physical-mechanical properties of biocomposite bioplastic with the ratio of durian peel starch to sago starch addition to the resulting biocomposite bioplastic.

## 2. MATERIALS AND METHODS

The materials used to make this biocomposite bioplastic are durian peel waste, tapioca starch, distilled water, sorbitol, chitosan, and ZnO. Weigh the required materials according to the specified composition. Table 1 shows the composition of bioplastic materials, with the main ingredients being durian peel starch and sago starch, sorbitol plasticizer, and variations in the type of filler (chitosan, and ZnO).

The durian peel starch production process follows the research method by Nurrohmah et al. (2021) and the biocomposite bioplastic production process by Melani et al. (2018), detail experiment can be seen in Figure 1.

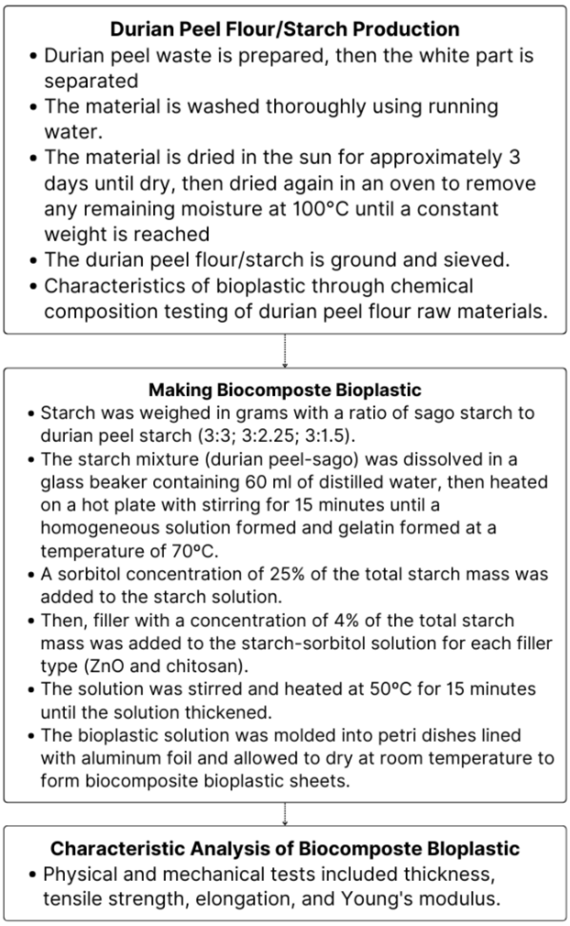



**Figure 1.** Block Diagram of Making Biocomposite Bioplastic.

**Table 1.** Research Matrix

| Sample | Sago starch (gr) | Durian peel starch (gr) | Plasticizier Sorbitol (gr) | Filler (gr) |
|---|---|---|---|---|
| A | 3 | 1.5 | 1.125 | Chitosan 0.18 |
| B | 3 | 2.25 | 1.3125 | Chitosan 0.21 |
| C | 3 | 3 | 1.5 | Chitosan 0.24 |
| D | 3 | 1.5 | 1.125 | ZnO 0.18 |
| E | 3 | 2.25 | 1.3125 | ZnO 0.21 |
| F | 3 | 3 | 1.5 | ZnO 0.24 |

## 3. RESULTS AND DISCUSSION

### 3.1. Analysis of the composition of durian peel flour

From the results of the analysis of the composition of durian peel flour in Table 2.

**Table 2.** Chemical component content of durian peel flour

| Component | Percent (%) |
|---|---|
| Protein | 13.03 |
| Starch | 68.67 |
| Amylose | 7.09 |
| Amylopectin | 11.21 |

From the composition test results above (Table 2), the most dominant composition is starch at 68.67%, with an amylose content of 7.09%, and amylopectin at 11.21%. Previous research has shown that starch content plays a crucial role, serving as one of the quality criteria for plastic-making materials. Starch consists of two fractions that can be separated with hot water. The soluble fraction is called amylose, and the insoluble fraction is called amylopectin (Nisah, 2018).

The higher the amylose content, the drier and less sticky the starch. Starch with a high amylose content produces flexible and strong biodegradable plastic, because the structure of amylose allows for the formation of hydrogen bonds between its constituent glucose molecules and, upon heating, forms a three-dimensional network that can trap water, resulting in a strong gel (Khamel, 2015).

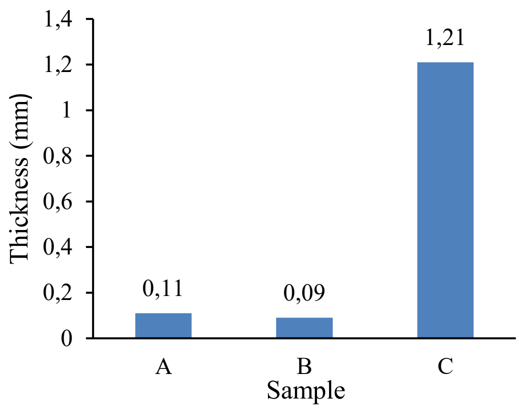
### 3.2. Thickness test results with variations in starch ratio and filler type (chitosan and ZnO)

Figure 2 shows that the thickness of biocomposite bioplastic with ZnO filler is higher than that with chitosan filler. The maximum value was obtained in sample D at 1.95 mm and the lowest in sample B at 0.09 mm.

ZnO has a density of 5.68 g/cm³ (Donia et al., 2021), higher than chitosan, which has a density of 1.21 g/cm³ (Wang & Roman, 2023). Furthermore, ZnO is insoluble in water, so when ZnO is added to a starch-plasticizer mixture, an inhomogeneous mixture is formed. This results in a greater thickness of biocomposite bioplastic with ZnO filler compared to those with chitosan.

The total starch concentration and volume of the biocomposite bioplastic mixture using both chitosan and glycerol showed similar results. The higher the total starch concentration and solution volume poured into the same-sized mold during biocomposite bioplastic production, the thicker the resulting biocomposite bioplastic (Rozikhin et al., 2020)

a)




b)

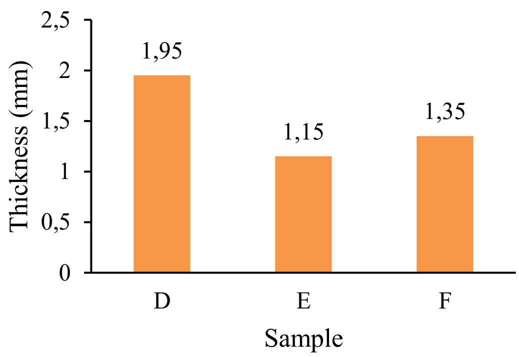



**Figure 2.** Effect of adding chitosan filler on the thickness of biocomposite bioplastic: a) chitosan; b) ZnO

**Description:**

Chitosan: A (0.18 g), B (0.21 g), C (0.24 g)
ZnO: D (0.18 g), E (0.21 g), F (0.24 g)
with a ratio of total starch variations (durian peel and sago).

### 3.3. Tensile Strength Test Results with Variations in Filler Starch Ratio (Chitosan and ZnO)

From the tensile strength test results in Figure 3, it can be seen that the type of filler has a different influence on the tensile strength value of the resulting biocomposite bioplastic. The highest value was obtained in sample A with a value of 18.816 MPa and the lowest value was obtained in sample F with a value of 1.344 MPa. In general, the use of chitosan filler has been shown to increase the tensile strength of biocomposite bioplastic when compared to ZnO for each variation of the ratio of durian peel starch addition.

The addition of chitosan causes interactions between amylose, amylopectin, and chitosan, forming hydrogen bonds within the biocomposite bioplastic. These hydrogen bonds between chains become stronger and more difficult to break (Setiani et al., 2013). However, excessive chitosan concentrations can have other effects. This is because chitosan has a linear polymer chain. This structure tends to form a crystalline phase due to its ability to organize polymer molecules in an orderly manner. This crystalline phase can make the biocomposite bioplastic strong, stiff, and hard, making it more easily broken (Sinaga, 2020).

Meanwhile, for ZnO, the tensile strength value fluctuates, with an optimum value in sample variation E. The bond formed between the polymer matrix and ZnO is not very strong, therefore there is a decrease in the tensile strength value. This is also because the ZnO is not well dispersed, making the biocomposite bioplastic mixture inhomogeneous. The less strong bond results in the ZnO particles as fillers being unable to bear/withstand the tensile load applied to the biocomposite bioplastic, so it does not contribute to increasing the tensile strength value of the biocomposite bioplastic (Fauziyah et al., 2024; Thipperudrappa et al., 2020).

The high tensile strength value is obtained with a more dominant sago starch content compared to durian peel starch. High amylose levels can increase the tensile strength of biocomposite bioplastic. This is in line with the results of Rozikhin et al., (2020) research which made biocomposite bioplastic using jackfruit seed starch and durian seed starch raw materials with different starch concentration ratio treatments. The higher the concentration of jackfruit seed starch, the higher the tensile strength of the biocomposite bioplastic. Treatment P1 (jackfruit seed starch 5%) obtained a higher tensile strength compared to treatment P5 (durian seed starch 5%). This is because jackfruit seed starch has a high amylose content, high amylose makes the number of polymers in the matrix formation increase, amylose bonds between polymers are stronger and the resulting tensile strength also increases.

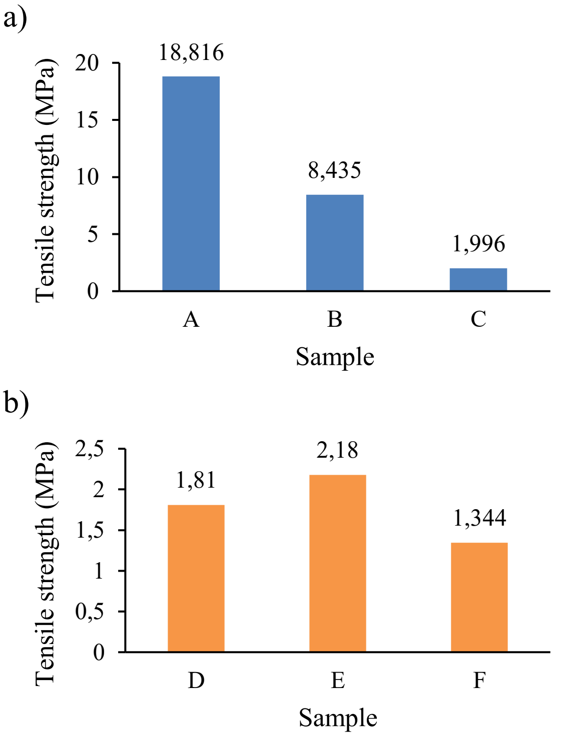



**Figure 3.** Effect of adding chitosan filler on the tensile strength of biocomposite bioplastic: a) chitosan; b) ZnO

**Description:**
Chitosan: A (0.18 g), B (0.21 g), C (0.24 g)
ZnO: D (0.18 g), E (0.21 g), F (0.24 g)
with a ratio of total starch variations (durian peel and sago).

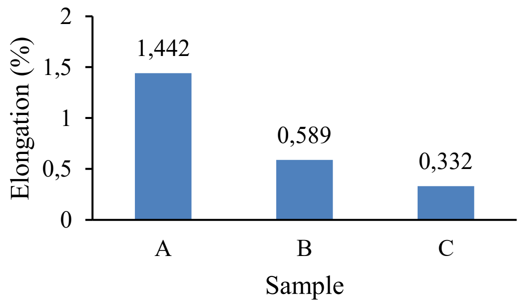
### 3.4. Elongation test results with variations in starch ratio and filler type (chitosan and ZnO)

Elongation, or flexibility, is a measure of a material's ability to resist deformation or fracture when subjected to bending forces. The highest value of the elongation test results was obtained in sample A 1.441%, in the sample with the addition of chitosan filler, and the lowest 0.209% in sample D, with the addition of ZnO filler.

The higher the chitosan concentration, the denser the biocomposite bioplastic structure, leading to a decrease in the material's elasticity or flexibility. This is likely due to chitosan's tendency to form strong hydrogen bonds and form a rigid network, which reduces the material's ability to undergo elastic deformation under load. In other words, higher chitosan concentrations tend to reduce the intermolecular space within the biocomposite bioplastic, making the material denser and less elastic (Haluti et al., 2025). The addition of ZnO can increase the flexural strength of biofilms, making them more resistant to bending or flexing (El Habbasha et al., 2025).

The high amylose content in starch results in high elongation properties. Starch with a high amylose content produces flexible and strong biocomposite bioplastic (Thirathumthavorn & Charoenrein, 2007), because the amylose structure allows for the formation of hydrogen bonds between its constituent glucose molecules and, upon heating, is able to form a three-dimensional network that can trap water, resulting in a strong gel (Nisah, 2018).

a)

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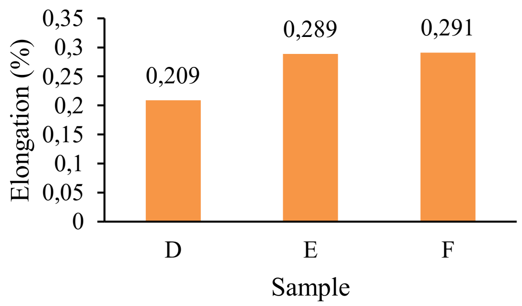



**Figure 4.** Effect of adding chitosan filler on biocomposite bioplastic elongation: a) chitosan; b) ZnO

**Description:**
Chitosan: A (0.18 g), B (0.21 g), C (0.24 g)
ZnO: D (0.18 g), E (0.21 g), F (0.24 g)
with a ratio of total starch variations (durian peel and sago).

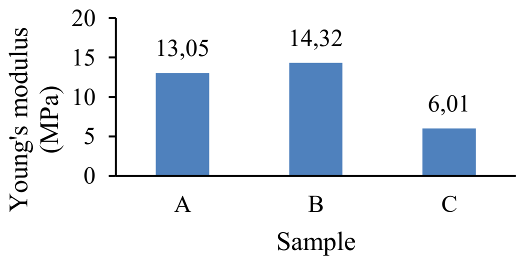
**3.5. Young's Modulus test results with variations in starch ratio and filler type (chitosan and ZnO)**

Based on Figure 5, it shows the results of the Young's modulus test of biocomposite bioplastic on each sample with varying values. For the addition of chitosan filler, the Young's modulus value tends to be greater when compared to the addition of ZnO filler. The optimum Young's modulus was obtained in sample B, with a value of 14.32 MPa, while the lowest value was in sample F at 4.62 MPa.

The young modulus of biocomposite bioplastic is good in sample B (tapioca 3 gr, durian peel starch 2.25 gr, and chitosan 0.21 gr) with a fairly dense structure. The addition of 1.3125 gr of sorbitol dispersed into the biocomposite bioplastic causes the distance between molecules in the biocomposite bioplastic to become dense with an optimum value of 14.32%. This is in line with the results of research by (Lazuardy & Cahyaningrum, 2013), that with a starch: chitosan ratio (2:1) with the addition of 20% plasticizer has an optimum young modulus value of 5%. The addition of starch in the mixture can cause the elongation value of chitosan-starch biocomposite bioplastic to decrease.

The addition of ZnO affects the interaction or bond formation process in the starch polymer matrix, resulting in a decrease in the stiffness of the biocomposite bioplastic matrix. The addition of ZnO can reduce the bonding during the plasticization process of the starch polymer matrix, resulting in a lower Young's modulus of the biocomposite bioplastic (Ahsan et al., 2022).

a)



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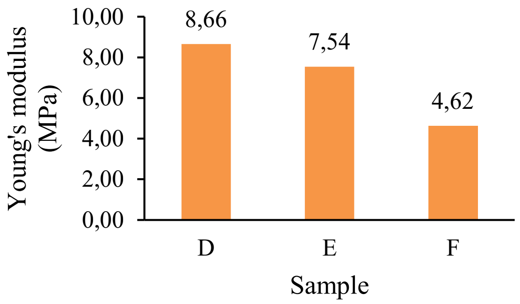


**Figure 5.** Effect of adding chitosan filler on biocomposite bioplastic Young's Modulus: a) chitosan; b) ZnO

**Description:**

Chitosan: A (0.18 g), B (0.21 g), C (0.24 g)
ZnO: D (0.18 g), E (0.21 g), F (0.24 g)
with a ratio of total starch variations (durian peel and sago).

## 4. CONCLUSIONS AND RECOMMENDATIONS

From the research and testing results of this biocomposite bioplastic, the following conclusions can be drawn: The biocomposite bioplastic was successfully produced using durian peel flour with a relatively high starch content of 68.67%. The addition of chitosan filler yielded superior results compared to ZnO, with the best values achieved in Sample A with a tensile strength of 18.816 MPa, an elongation of 1.442%, and a Young's modulus of 13.05 MPa. The addition of ZnO filler was shown to affect the tensile strength and elongation values, with increases occurring with each added starch ratio.

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## REFERENCES

Ahsan, S., Diniyah, R., & Firmana, M. F. (2022). Mechanical and Thermal Properties of PLA with $TiO_2$ and ZnO Fillers. *Jurnal Teknologi Dan Manajemen*. https://doi.org/10.52330/jtm.v20i1.43

Destiana, I. D., Salsabila, R. N., Aprilliani, F., & Suhartono, R. (2024). Biodegradability Analysis of Biodegradable foam Combination of Sugarcane Bagasse Fiber and Cassava Starch Based Pineapple Peel During Storage. *Agroindustrial Technology Journal*, *8*(2), 43–54. https://doi.org/10.21111/atj.v8i2.12839

Donia, D. T., Bauer, E. M., Missori, M., Roselli, L., Cecchetti, D., Tagliatesta, P., Gontrani, L., & Carbone, M. (2021). Room temperature syntheses of zno and their structures. *Symmetry*. https://doi.org/10.3390/sym13040733

El Habbasha, E. S., Abouzeid, R., Ibrahim, F. M., Youssef, A. M., Mahdy, S. Z. A., & El-Liethy, M. A. (2025). Developing a novel, low-cost, antimicrobial, and biodegradable pectin/HEC/ZnO biofilm for edible food packaging applications. *Biomass Conversion and Biorefinery*, *15*(4),6377–6388. https://doi.org/10.1007/s13399-024-05487-4

Fauziyah, Z., Sari, E., Melyna, E., & Wulansari, I. (2024). The Effect of Zinc Oxide (ZnO) Addition on Tensile Strength, Impact Strength, and Crystallinity of Recycled PP/Hemp Fiber Composites. *Journal of Polymer Chemical Engineering and Technology*, *2*(1),19–28. https://doi.org/10.52330/jpcet.v2i1.346

GODWIN, A. D. (2000). PLASTICIZERS. In *Applied Polymer Science: 21st Century* (pp. 157–175). Elsevier. https://doi.org/10.1016/B97800804341 7-9/50011-8

Haluti, I. J., Artiningsih, A., Syarif,. (2025). Effect of Chitosan Ratio on Degradable Bioplastic Characteristics of Tamarind Seed Starch (Tamarindicus Indica l) and

Tea Dregs. *Jurnal Kolaboratif Sains*, *8*(2),1100–1105. https://doi.org/10.56338/jks.v8i2.7079

Hidayat, S., Abdullah, A. H. D., Septiyanto, R. F., Muchtar, Y. R. D., & Affifah, I. (2019). Comparison of Mechanical Properties of Bioplastics with the Addition of Zinc Oxide (ZnO). *Gravity : Jurnal Ilmiah Penelitian Dan Pembelajaran Fisika*, *5*(2),8–12. https://doi.org/10.30870/gravity.v5i2.5939

Khamel, A. (2015). Edible Film Making (Study of Tapioca Suspension and Carrageenan Concentration on the Physical Properties of Edible Film). Laporan Tugas Akhir. Teknologi Industri Pertanian. Universitas Brawijaya.

Kong, U., Mohammad Rawi, N. F., & Tay, G. S. (2023). The Potential Applications of Reinforced Bioplastics in Various Industries: A Review. In *Polymers*. https://doi.org/10.3390/polym15102399

Lazuardy, G. P., & Cahyaningrum, S. E. (2013). Manufacture and Characterization of Bioplastics Based on Chitosan and Cassava Starch with Glycerol Plasticizer. *UNESA Journal of Chemistry*, *2*(3), 161–166.

Melani, A., Herawati, N., & Kurniawan, A. F. (2018). Taro Starch Bioplastic Through Melt Intercalation Process (Study of the Effect of Filler Type, Filler Concentration and Plasticizer Type). *Distilasi*, *2*(2), 53–67.

Nisah, K. (2018). Study of the Effect of Amylose and Amylopectin Content of Tubers on the Physical Characteristics of Biodegradable Plastics with Glycerol Plasticizer. *Biotik: Jurnal Ilmiah Biologi Teknologi Dan Kependidikan*. https://doi.org/10.22373/biotik.v5i2.3018

Nurrohmah, K., Sari, A. K., Riziani, D., & Kusumasari, S. (2021). Makudu (Makaroni Kulit Durian): A Potential Practical Processed Food to Reduce Durian Skin Waste. *JITIPARI (Jurnal Ilmiah Teknologi Dan Industri Pangan UNISRI)*. https://doi.org/10.33061/jitipari.v6i1.3960

Rahmatullah, R., Putri, R. W., Nurisman, E., Yandriyani, Y., Al Hadi, A., & Raihan, M. A. (2024). Manufacturing Biodegradable Bioplastics from A Mixture of Starch and Kapok Fibers with Variations of Chitosan and Glycerol. *Agroindustrial Technology Journal*, *8*(1), 60–76. https://doi.org/10.21111/atj.v8i1.11086

Rahmatullah, R., Putri, R. W., Waristian, H., Al Hadi, A., Handoko, K., & Gufron, M. F. (2024). The Effect of Plasticizer Type and Concentration on Cellulose Acetate-Based Bioplastic from Durian Skin. *Journal of Ecological Engineering*, *25*(11), 70–82. https://doi.org/10.12911/22998993/192677

Rozikhin, Z., Yelmira, H., & Farida, H. (2020). Making biodegradable plastic from durian seed starch and jackfruit seed starch. *Chempublish Journal*, *5*(2), 151–165. https://doi.org/https://doi.org/10.22437/chp.v5i2.7988

Setiani, W., Sudiarti, T., & Rahmidar, L. (2013). Preparation and Characterization of Edible Films from Breadfruit Starch-Chitosan Polyblend. *Jurnal Kimia VALENSI*, *3*(2). https://doi.org/10.15408/jkv.v3i2.506

Sharma, S., Sharma, V., & Chatterjee, S. (2023). Contribution of plastic and microplastic to global climate change and their conjoining impacts on the environment - A review. In *Science of the Total Environment*. https://doi.org/10.1016/j.scitotenv.2023.162627

Sinaga, A. S. (2020). Characteristics of Biodegradable Plastics from Starch and Fiber of Oil Palm Stems (Elaeis Guineensis Jacq). Laporan Tugas Akhir. Teknologi Hasil Hutan. Universitas Sumatera Utara.

Syafri, R., Andriani, Y., Irma, W., Veronika, D., Nuriana, S., Putri, P. Y., & Putri, A.

N. (2021). Synthesis and Characterization of Sago Starch-Chitosan-Based Bioplastic Containing Palm Fronds and Glycerol Plasticizer. *Photon: Jurnal Sain Dan Kesehatan*. https://doi.org/10.37859/jp.v12i1.3359

Takribiah, F., Harunsyah, H., Amalia, Z., Fauzan, R., & Sami, M. (2022). Making Bioplastic with ZnO Reinforcement and Adding Essential Oils as Antimicrobials. *Jurnal Teknologi*. https://doi.org/10.30811/teknologi.v22i1.2881

Thipperudrappa, S., Ullal Kini, A., & Hiremath, A. (2020). Influence of zinc oxide nanoparticles on the mechanical and thermal responses of glass fiber-reinforced epoxy nanocomposites. *Polymer Composites*, *41*(1), 174–181. https://doi.org/10.1002/pc.25357

Thirathumthavorn, D., & Charoenrein, S. (2007). Aging Effects on Sorbitol- and Non-Crystallizing Sorbitol-Plasticized Tapioca Starch Films. *Starch - Stärke*, *59*(10), 493–497. https://doi.org/10.1002/star.200700626

Wang, H., & Roman, M. (2023). Effects of Chitosan Molecular Weight and Degree of Deacetylation on Chitosan−Cellulose Nanocrystal Complexes and Their Formation. *Molecules*. https://doi.org/10.3390/molecules28031361