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Enhancing Biodegradable Plastics' Physical Properties Through the Incorporation of Talas Beneng Starch (*Xanthosoma undipes K. Koch*) and Glycerol as a Plasticizer

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ABSTRACT

The manufacture of biodegradable plastics with the main ingredients of talas beneng (*Xanthosoma Undipes K. Koch*) starch, chitosan, and glycerol as a plasticizer has been carried out by various additions of starch and reduction of chitosan. Initial assessment of talas beneng starch reveals: starch content - 20.51%, water content - 8.58%, fat content - 12.71%, and protein content - 3.51%. Physical testing of biodegradable plastic produces thickness values ranging from 0.166 mm to 0.234 mm, tends to meet JIS Z-1707: 2019 standards, density value is 1.674 g/cm^3, and the lowest water absorption value is 20.51%, both meet SNI 7188: 2016 standards, and there is a decrease in mass every week for 28 days in the biodegradation test.

Keywords: Biodegradable Plastic, Chitosan, Glycerol Plasticizer, Talas Beneng Starch

ABSTRAK

Pembuatan plastik *biodegradable* dengan bahan utama pati talas beneng, kitosan, dan gliserol sebagai *plasticizer* telah dilakukan dengan variasi penambahan pati dan pengurangan kitosan. Analisis awal pati talas beneng menunjukkan bahwa kadar pati talas beneng 20,51%, kadar air 8,58%, kadar lemak 12,71%, dan kadar protein 3,51%. Pengujian fisik plastik biodegradable menghasilkan nilai ketebalan berkisar antara 0,166 mm hingga 0,234 mm, cenderung memenuhi standar JIS Z-1707:2019, nilai densitas 1,674 g/cm^3 dan nilai serapan air terendah 20,51%, keduanya memenuhi SNI 7188:2016, dan terjadi penurunan massa setiap minggunya selama 28 hari pada uji biodegradasi.

Keywords: Chitosan, Plastik Biodegradable, Plasticizer Gliserol, Pati Talas Beneng

1. Introduction

Conventional oil-based plastics are difficult to decompose because plastic is a type of high-molecular compound polymerized by monomers with long chains of carbon molecules that are sturdy and not easily damaged [1]. Data shows that 34 million tons of plastic waste are disposed of annually worldwide, with 93% dumped into the sea and landfills [2]. Concerns about this petroleum-derived plastic's sustainability have arisen because of its poor degradability, making them the most dangerous environmental pollutant [3]. In December 2015, the European Commission adopted the European Union's Circular Economy Plan of Action in which plastic is considered a priority for addressing [4]. In January 2018, the European Plastics Strategy [5] was developed, in response to growing environmental concerns regarding the production, consumption, use and disposal of plastics in line with the European Union's approach. In March 2020, to lead the way towards a circular economy in the world and to use its influence, expertise and financial resources to implement the 2030 Sustainable Development Goals (SDGs), the European Commission launched a new Circular Economy Action Plan for a cleaner economy and more competitive Europe [6].

Biodegradable plastic is a new type of plastic that can be decomposed and lost in the natural environment [7]. Microorganisms and sunlight can help break down certain biodegradable compounds [8]. The principle of degradation is that it can be decomposed by microbes (bacteria, fungi, algae, etc.) that exist in nature into materials (CO_2, H_2O, CH_4 and biomass), which can be integrated into natural ecosystems without ecotoxic effects or residual by-products [9]. Biodegradable plastics are often made from plant sources. For example starch, a natural polymer found in some fruits and composed mostly of two types of polysaccharides: amylase and amylopectin [10].

One source of starch that has not been widely explored is Talas Beneng (*Xanthosoma Undipes K. Koch*). Talas Beneng is a local Indonesian plant with a fairly high starch content. In addition to its fast and easy growth, Talas Beneng is also rich in nutrients, including 6.73% protein, 81.81% carbohydrates, 0.17% fat and 56.29% starch [11]. Since starch is hydrophilic [12], glycerol is competent as a suitable plasticizer given its low hygroscopicity and volatility [13,14]. The presence of glycerol not only has a plasticizing effect but also enhances the cross-linking effect [15]. The efficiency of the plasticization process increases with the concentration of glycerol [16]. Chitosan, similar to starch, is a polysaccharide with non-toxicity, biodegradability, biocompatibility, and with film-forming properties [17,18]. Mixing starch with chitosan is a simple and cost-effective strategy to improve the mechanical and barrier properties of films produced by solvent casting [19,20].

Packaging is the largest application of Biodegradable plastics today [21]. Therefore, it is urgent to develop a facile method to manufacture the starch-based biodegradable plastic featuring high water resistance and physical testing [19] Utilization of talas beneng (*Xanthosoma Undipes K. Koch*) starch as a biodegradable plastic with the addition of chitosan and glycerol as a platicizer as well as physical characteristic test is expected to be able to provide plastic innovation with high economic value, environmentally friendly, and easily decomposed by microbes in the soil so that it can be useful in everyday life day.

2. Method

2.1. Preparation of Talas Beneng Corms into Starch

Talas beneng plant was obtained from the Village of Namotrasi Pasar 4 Sei Bingai District, Langkat Regency, North Sumatra. Talas beneng has a long and large stem, and each bud has a small corm on its roots. Talas beneng corm is large, and the flesh's color is yellow. The size of the talas plant can reach about 2.5 meters, with each stem having a maximum tuber size of 10-25 kg.

Talas beneng corms obtained are then washed thoroughly and peeled from the skin. Next, the corm is cut into chips. After talas beneng chips are cut, water is added, then mashed with a blender. Afterward, gauze was used to filter the result of talas beneng blending and allowed to settle for twenty-four hours. After that, the white precipitate that had settled at the bottom of the vessel was washed every five hours until the precipitate became purer. Within one day, the precipitate is left at room temperature. Then, the precipitate was dried in an oven at 60°C for one more day. After the starch dries, it is ground with a mortar and sifted through a 200-mesh sieve. Furthermore, the starch was analyzed to determine the water, protein, fat, and starch content levels.

2.2. Solution Preparation

2.2.1. Preparation of 2% CH3COOH Solution

Prepare a 1000 ml beaker. For dilution, 10 milliliters of acetic acid and distilled water are added to 1000 milliliters. The mixture was stirred at 25°C (room temperature) until it became homogeneous.

2.2.2. Preparation of Chitosan Solution

Prepare a 250 ml beaker. To dissolve in a 2% acetic acid (CH_3COOH) solution, chitosan is put into a beaker glass with a mass ratio of 1:50 (% w/v).

2.2.3. Preparation of Chitosan Solution

Prepare a 500 ml beaker. To dissolve the starch, distilled water was added to the beaker, and the mass of the starch was compared to the volume of the distilled water at 1:20 (% w/v).

3. Results and Discussion

3.1. Characteristics of Talas Beneng Starch

The characteristics of Talas Beneng are given in Table 1. As seen, the starch content is 20.51%, which was obtained by using SNI 3751:2018. The water content is 8.58% based on SNI 3751:2018; fat content of 12.71% based on SNI 2997:1996; and protein content of 3.51% (SNI 3751:2018).

Table 1. Characteristics of talas beneng starch.

Content Level	Unit	Total Result	Method
Talas Beneng Starch	%	20.51	SNI 3751:2018
Water	%	8.58	SNI 3751:2018
Fat	%	12.71	SNI 2997:1996
Protein	%	3.51	SNI 3751:2018

3.2. Analysis of Physical Testing for Biodegradable Plastic Characteristics

3.2.1. Thickness Test Analysis

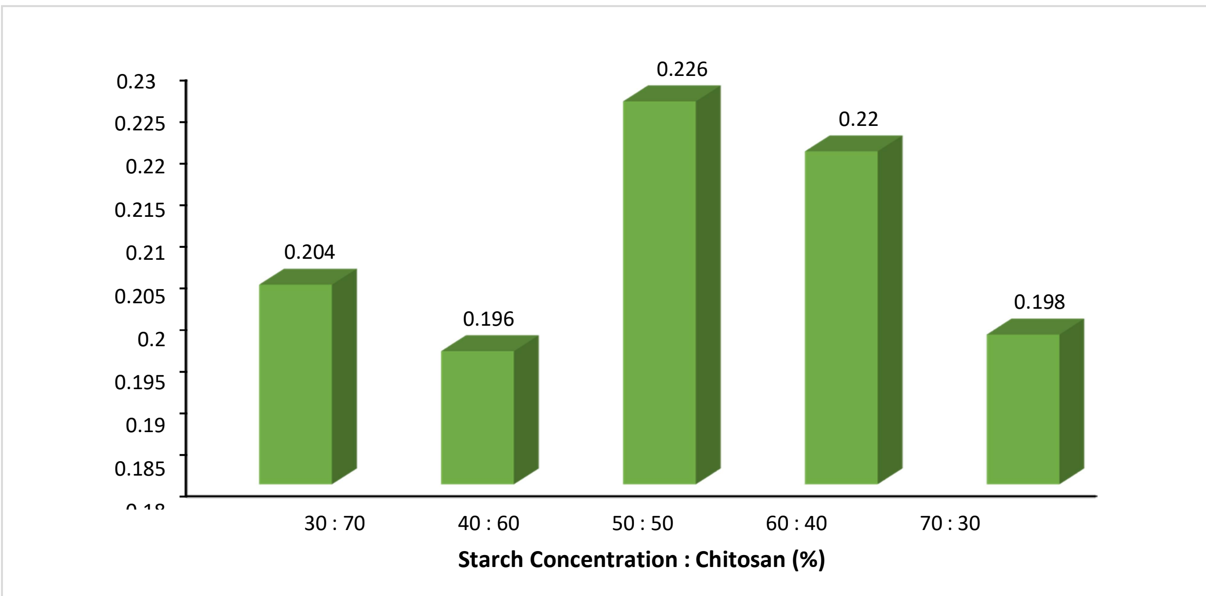

Figure 1. Graph depicting results from biodegradable plastic thickness testing.

Figure 1 shows the value of the thickness of the plastic in the variation of starch: chitosan. A composition of 50%:50% has the most dominant thickness compared to the other variations of starch: chitosan, which is 0.226 mm. This is because the thickness of biodegradable plastic is affected by the total amount of solids in the solution and the thickness of the mold [22]. Furthermore, noteworthy is the observation that the density value of the 50% starch: 50% chitosan blend variation appears comparatively lower when compared to other compositions. This trend reinforces the preeminence of biodegradable plastic thickness within the 50% starch: 50% chitosan blend. The density value of biodegradable plastic is derived by dividing its mass by volume.

Based on the food packaging industry standard (JIS Z-1707:2019), the maximum thickness allowed for biodegradable plastic is 0.25 mm. From the research results, the thickness of biodegradable plastic made from talas beneng starch ranged from 0.166 mm to 0.234 mm. Therefore, based on the JIS Z-1707:2019 standard, the thickness value of biodegradable plastic from talas beneng starch in this study tends to meet the standard.

3.2.2. Mass Density Analysis

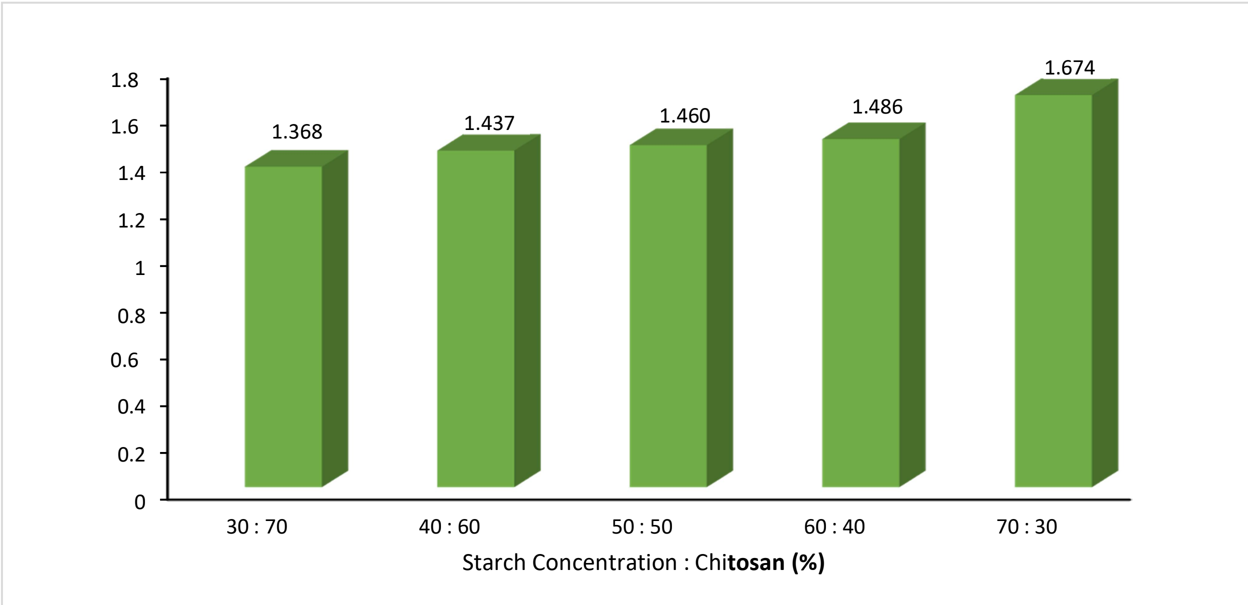

Figure 2. Graph depicting results from biodegradable plastic mass density.

Figure 2 shows that the effect of adding starch and reducing chitosan on density is in line. This means that the more starch added, the greater the density value. For the 30% starch variation, the density value was 1.368g/cm^3; for the 40% starch variation, the density value increased to 1.437 g/cm^3, then it rose again at the 50% starch variation to 1.460 g/cm^3 and continued to increase for the 60% and 70% starch variation, both are 1.486 g/cm^3 and 1.674 g/cm^3. This is because the more additives that have a higher density than HDPE are added to a polymer matrix, the higher the weight and density of the polymer so that the density becomes higher [23].

3.2.3. Water Absorption Analysis

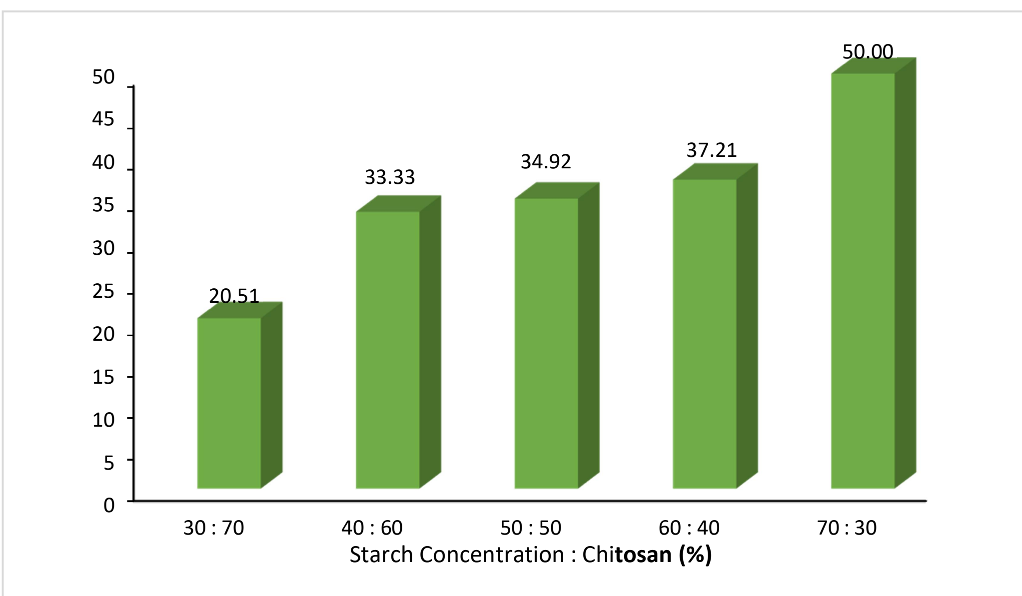

Figure 3. Graph depicting results from biodegradable plastic water absorption.

In Figure 3, it can be seen the effect of adding starch on water absorption. The percentage of water absorption in the addition of starch and reduction of chitosan increased from a starch composition of 30% to absorption of 20.51%; in a starch composition of 40%, the water absorption became 33.33%, in a starch composition of 50% the water absorption increased again to 34.92%, then there is an increase in absorption again at 60% starch composition, namely 37.21% until the 70% starch composition continued to increase to 50.00%. This shows that adding starch and reducing chitosan increases water absorption. The addition of chitosan additives with different concentrations has a significant effect on the water resistance properties of bioplastics. The water resistance of bioplastics increases as the concentration of chitosan increases, as evidenced by the lower water absorption capacity [24].

3.2.4. Biodegradation Analysis

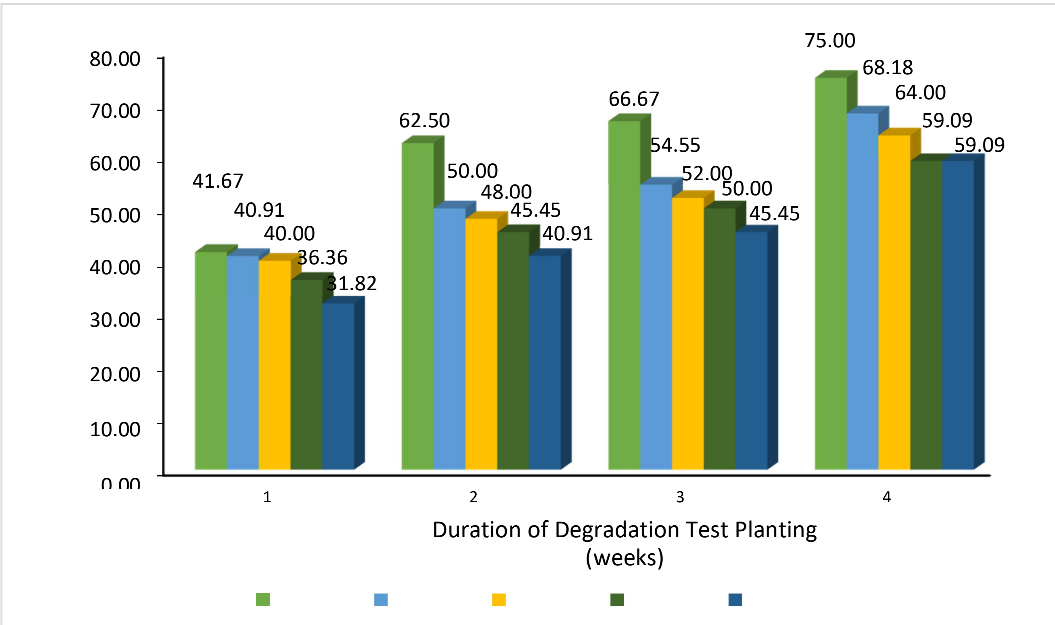

Figure 4. Graph of degradation results of the produced biodegradable plastics.

In Graph 4, it can be seen that the planting time affected the biodegradation of the samples, where there was a decrease in the mass of biodegradable plastic every week for 28 days of planting. According to the provisions of the non-ASTM Sea Water by Bioplastic Film PHBHx (11%HV) degradation percentage value with a planting time of 28 days, the percentage of biodegradable plastic degradation is 35% after planting. Compared with this study, with a planting time of 28 days, the highest biodegradable plastics biodegradation value is 75%. The degradation percentage value of biodegradable plastic from talas beneng starch in this study has above the standard. The results of this study are in line with the research conducted by Agung and Hidayati, more chitosan can accelerate the degradation process [25].

4. Conclusion

The results of the characterization of talas beneng starch obtained starch content of 20.51%, water content of 8.58%, fat content of 12.71%, and protein content of 3.51%. The results of the physical characterization of biodegradable plastic obtained the highest thickness value of 0.234 mm at a drying temperature of 90˚C with 100% glycerol plasticizer, the lowest water absorption value of 8.108% at a drying temperature of 90˚C with 60% glycerol plasticizer, and the highest density value of 2.032g/cm^3 at a drying temperature of 60˚C with 100% glycerol plasticizer and the highest biodegradation value of 38.095% at a drying temperature of 100˚C with 100% glycerol plasticizer for 28 days of planting.

References

[1] M. Shen *et al.*, "Are biodegradable plastics a promising solution to solve the global plastic pollution?," *Environmental Pollution*, vol. 263. Elsevier Ltd, Aug. 01, 2020.
[2] S. Pathak, C. Sneha, and B. B. Mathew, "Design of packed bed bioreactor for waste water treatment

View project Bioaccumulation of lead ions by bacterial strains isolated from industrial area ground water View project Blessy Baby Mathew Dayananda Sagar Institutions Bioplastics: Its Timeline Based Scenario & Challenges," *Journal of Polymer and Biopolymer Physics Chemistry*, vol. 2, no. 4, pp. 84–90, 2014,

[3] K. Kanagesan, R. Abdulla, E. Derman, M. K. Sabullah, N. Govindan, and J. A. Gansau, "A sustainable approach to green algal bioplastics production from brown seaweeds of sabah, malaysia," *J King Saud Univ Sci*, 2022.

[4] European Commission, "Closing the loop - An EU action plan for the Circular Economy," Brussels, Dec. 2015.

[5] European Commission, "A European Strategy for Plastics in a Circular Economy," Jan. 2018.

[6] European Commission, "A new Circular Economy Action Plan For a cleaner and more competitive Europe," Brussels, Mar. 2020. [Online]. Available: https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

[7] Y. Picó and D. Barceló, "Analysis and prevention of microplastics pollution in water: Current perspectives and future directions," *ACS Omega*, vol. 4, no. 4, pp. 6709–6719, Apr. 2019.

[8] L. M. Heidbreder, I. Bablok, S. Drews, and C. Menzel, "Tackling the plastic problem: A review on perceptions, behaviors, and interventions," *Science of the Total Environment*, vol. 668. Elsevier B.V., pp. 1077–1093, Jun. 10, 2019.

[9] G. Iannotti, N. Fair, M. S. Tempesta, H. Neibling, F.-H. Hsieh, and R. T. Mueller, "Studies on the Environmental Degradation of Starch-Based Plastics," 2018.

[10] R. M. Orenia, A. v Collado, M. G. Magno, and L. T. Cancino, "Fruit and Vegetable Wastes as Potential Component of Biodegradable Plastic," *Asian journal of multidisciplinary studies*, vol. 1, 2018.

[11] S. Kusumasari *et al.*, "Karakterisasi Sifat Fisikokimia Tepung Talas Beneng Sebagai Pangan Khas Kabupaten Pandeglang (Characterization of Physical and Chemical Properties of Flour from Talas Beneng (Xanthosoma undipesh K. Koch) as Indigenous Food from Pandeglang Regency)," 2019.

[12] M. Qamruzzaman, F. Ahmed, and M. I. H. Mondal, "An Overview on Starch-Based Sustainable Hydrogels: Potential Applications and Aspects," *Journal of Polymers and the Environment*, vol. 30, no. 1. Springer, pp. 19–50, Jan. 01, 2022.

[13] N. Suderman, M. I. N. Isa, and N. M. Sarbon, "The effect of plasticizers on the functional properties of biodegradable gelatin-based film: A review," *Food Biosci*, vol. 24, pp. 111– 119, 2018.

[14] G. Wypych, "Plasticizer Types," in *Handbook of Plasticizers (Third Edition)*, G. Wypych, Ed., Third Edition.ChemTec Publishing, 2017, pp. 7–84.

[15] R. M. D. Soares and V. Soldi, "The influence of different cross-linking reactions and glycerol addition on thermal and mechanical properties of biodegradable gliadin-based film," *Materials Science and Engineering C*, vol. 30, no. 5, pp. 691–698, Jun. 2010.

[16] Z. Y. Ben, H. Samsudin, and M. F. Yhaya, "Glycerol: Its properties, polymer synthesis, and applications in starch based films," *European Polymer Journal*, vol. 175. Elsevier Ltd,Jul. 15, 2022.

[17] H. Haghighi, F. Licciardello, P. Fava, H. W. Siesler, and A. Pulvirenti, "Recent advances on chitosan-based films for sustainable food packaging applications," *Food Packaging and Shelf Life*, vol. 26. Elsevier Ltd, Dec. 01, 2020

[18] W. Wang, C. Xue, and X. Mao, "Chitosan: Structural modification, biological activity and application," *International Journal of Biological Macromolecules*, vol. 164. Elsevier B.V., pp. 4532–4546, Dec. 01, 2020.

[19] L. Ren, X. Yan, J. Zhou, J. Tong, and X. Su, "Influence of chitosan concentration on mechanical and barrier properties of corn starch/chitosan films," *Int J Biol Macromol*, vol. 105, pp. 1636–1643, 2017

[20] K. Zheng *et al.*, "Chitosan-acorn starch-eugenol edible film: Physico-chemical, barrier, antimicrobial, antioxidant and structural properties," *Int J Biol Macromol*, vol. 135, pp. 344–352, 2019.

[21] European Bioplastics, "Global Production Capacities of Bioplastics 2019-2024," 2019. [Online]. Available: http://www.european-bioplastics.org/news/publications/

[22] S. Jafarzadeh, A. Karim, A. Fazilah, and S. Mahmud, "Physico-mechanical and microstructural properties of semolina flour films as influenced by different sorbitol/glycerol concentrations," *Int J Food Prop*, vol. 21, May 2018.

[23] D. W. Nurhajati, I. N. Indrajati, H. E. Mayasari, and M. Sholeh, "Pengaruh penambahan pati tapioka terhadap sifat mekanis dan struktur komposit high density polyethylene," *Majalah Kulit, Karet, dan Plastik*, vol. 34, no. 2, p. 77, Jan. 2019.

[24] M. N. Alam *et al.*, "Efek Penambahan Kitosan Terhadap Karakteristik Fisika Kimia Bioplastik Pati

Batang Kelapa Sawit Indonesian Journal Of Fundamental Sciences (Ijfs)," 2018.
[25] K. I. Agung and N. Hidayati, *Pembuatan Bioplastik Dari Pati Onggok Dan Kitosan:Efek Massa Kitosan*. 2021.