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Original Article

New Product Development for Eco-Friendly Edible Film: Formulation Gelatin - Chitosan from Shrimp Shell Waste with Bacterial Cellulose Powder

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Abstract *- Indonesia produces 180,000 tons of shrimp shell waste annually, which has the potential to be processed into gelatin and chitosan for the manufacture of environmentally friendly edible films as a solution to the problem of plastic waste, namely 100 billion bags per year. However, gelatin and chitosan-based films tend to have low mechanical strength and poor water retention capabilities. To overcome this, reinforcement with bacterial cellulose obtained from nata de coco was carried out, due to its nanofiber structure and lignin-free content. This study used a Completely Randomized Design (CRD) method with one factor, namely the concentration of bacterial cellulose (0%, 2%, 4%, 6%, 8%, and 10%), with 4 replications each, to test its effect on thickness, fiber content, water solubility, and water content. The results showed that increasing the concentration of bacterial cellulose had a significant impact (based on ANOVA $p<0.05$ and Duncan's test $\alpha=0.05$) on all measured parameters. The film thickness increased from 0.04 mm (at 0% concentration) to 0.15 mm (at 10% concentration), the optimal fiber content was in the range of 73.95-74.08% (8-10% concentration), the water solubility decreased from 76.75% to 32.61%, and the water content decreased from 17.06% to 13.69% (in accordance with the SNI standard of a maximum of 16%). The formula with a concentration of 8-10% produced a denser matrix through the formation of hydrogen bonds, thereby increasing the stability of the film as a biodegradable packaging material for dry or semi-wet products. Thus, the addition of bacterial cellulose was effective in improving the physical and functional properties of gelatin-chitosan films, making them a sustainable alternative to replace the use of plastic.*

Keywords *- Edible film, Gelatin-chitosan, Bacterial cellulose, Thickness, Fiber content.*

1. Introduction

Plastic, as an example of a synthetic material, has become an essential part of today's life (Rafi & Perkasa, 2023). The advantages of plastic include its light weight, water resistance, strength, and relatively low price. However, plastic also has the disadvantage of being difficult to decompose naturally (Kumari et al., 2019). Due to the difficulty in decomposing plastic waste, the development of biodegradable food packaging is becoming increasingly crucial. Indonesia's consumption of plastic bags is estimated to reach 100 billion per year, or around 700 pieces per person, making Indonesia the second-largest producer of plastic waste in the world. Therefore, more environmentally friendly packaging options are needed (BRIN, 2024; Rasyid et al., 2023). Indonesia is not only grappling with packaging and plastic waste, but also with organic waste. The fishing industry, particularly seafood, is a major source of this organic waste. For example, waste from shrimp processing alone produces 180,000 tons annually (Anwari et al., 2018). One of the breakthroughs that has developed is the creation of edible films, namely thin layers that can be consumed and function to protect food from exposure to oxygen, moisture, and microorganisms, thereby extending the food's shelf life (Santoso, 2020; Putri et al., 2023). Gelatin and chitosan are natural polymers that are readily biodegradable and are often used in the manufacture of safe films for consumption. Gelatin is easy to process but tends to be brittle, while chitosan, obtained from shrimp shell residue, has antimicrobial properties and can increase film strength (Juwayriyah & Nugraha, 2020; Majekodunmi et al., 2017). Research by Isnaeni et al. (2022) shows that a combination of gelatin and chitosan from shrimp industry waste has the potential to be an environmentally friendly packaging alternative because it produces a biodegradable film with adequate functional characteristics. The combination of these two materials produces a more stable film, although it still exhibits weaknesses, particularly in terms of water resistance and mechanical properties, which affect thickness, water solubility, and water content (Ali et al., 2017; Erana et al., 2024).

Fig. 1 Edible Film

Bacterial cellulose obtained from nata de coco has the potential to be an effective solution due to its nanofiber structure, good mechanical strength, and ability to strengthen films without lignin (Harianingsih & Suwardiyono, 2017; Safiah, 2023). Previous research has shown that the addition of bacterial cellulose to edible films can increase thickness, tensile strength, and stretchability, while reducing water vapor permeability (Wang et al., 2018). Furthermore, the addition of bacterial cellulose has been shown to thicken films, compact polymer structures, and reduce solubility and water content (Liu et al., 2020; Yekta et al., 2020). Furthermore, bacterial cellulose also increases fiber content, which in turn improves the quality of gelatin- and chitosan-based edible films (Safira, 2025).

In light of these promising prospects, further studies are needed to assess the impact of different bacterial cellulose concentrations on the thickness, fiber content, water absorption capacity, and moisture content of edible gelatin-chitosan films. This study aims to create sustainable and edible films reinforced with bacterial cellulose, focusing on: (1) creating biodegradable and improved packaging materials for the food industry, (2) assessing how different bacterial cellulose concentrations (0%, 1%, 3%, 5%, 7%, and 9%) affect the physical and chemical properties of the films, and (3) determining the best formula to produce more water-resistant, stable, and environmentally friendly films. It is hoped that the findings of this study will trigger new developments in biodegradable food packaging suitable for dry and semi-wet products.

2. Materials and Methods

This research, conducted on gelatin-chitosan-based edible films reinforced with bacterial cellulose, used *Komagataeibacter. xylinus* starter media from BRIN Cibinong, sucrose, acetic acid with a concentration of 1%, ammonium sulfate (ZA) 0.5%, coconut water obtained from Pedurungan Market, Semarang City, as well as glycerol, powdered bacterial cellulose, fish skin gelatin, and shrimp shell chitosan brand Phy Edumedia.

2.1. Bacterial Cellulose Powder Manufacturing Process (Modified by Yanti et al., 2017)

The preparation of bacterial cellulose powder begins with filtration. 500 mL of coconut water is boiled until boiling, after which 5% sucrose (as a carbon source) and 0.5% ammonium sulfate (ZA) (as a nitrogen source) are added and mixed until completely dissolved. The coconut water solution is cooled before the addition of 1% acetic acid to stabilize the pH. Next, the solution is transferred to a 500 mL Erlenmeyer flask, covered with cotton, and sterilized using an autoclave at 121°C for 15 minutes. After sterilization, the solution is cooled to 30°C and transferred to a sterile plastic container. Inoculation is then carried out by adding 5% Komagataeibacter xylinus starter culture. The incubation process lasts for 7 days at 30°C, after which the bacterial cellulose can be harvested. The harvested bacterial cellulose is boiled at 100°C for 15 minutes to stop the growth of Komagataeibacter bacteria. After boiling, the cellulose is rinsed until the pH is neutral, which is between 6 and 7. The cellulose is then cut into small pieces and dried using a cabinet dryer at around 60°C for 20 hours. Once completely dry, the cellulose is ground into a powder and then sieved through a 100-mesh sieve to obtain a bacterial cellulose powder with a uniform particle size as the final product.

2.2. Edible Film Production (Modified by Agustin et al., 2021)

The production of edible films involves several steps. The edible film is prepared by dissolving 2.5% (w/w) gelatin in distilled water and heating the mixture at 60°C for 90 minutes with a magnetic stirrer. Prepare a 2.5% (w/w) chitosan solution from shrimp shells by dissolving it in 1% acetic acid, then heating at 70°C for 90 minutes. Next, mix the two solutions, add 20% glycerol, and heat again with a magnetic stirrer at 60°C for 90 minutes until thoroughly mixed. Then, add bacterial cellulose powder to the biopolymer solution, homogenize for 25 minutes, pour into molds, and dry at room temperature.

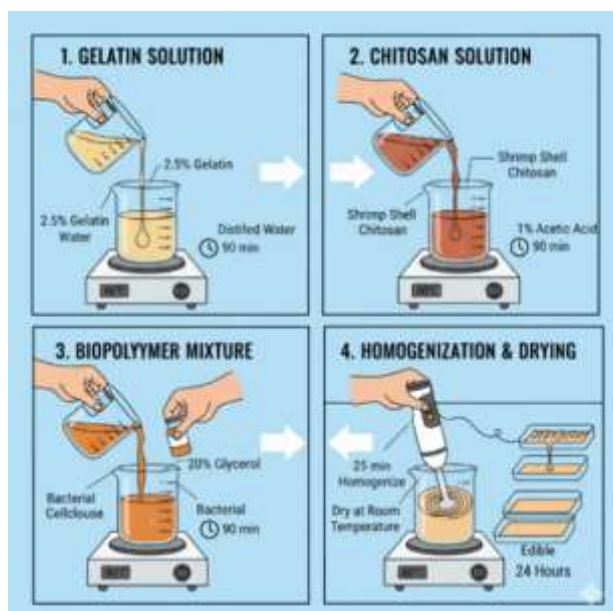

Fig. 2 Edible Film Making

2.3. Thickness Test (Ulyarti et al., 2024)

The thickness of an edible film is a critical factor affecting its mechanical properties and water vapor permeability. Thickness is measured using a Brookfield Texture Analyzer. Films that are too thin may reduce tensile strength, whereas films that are too thick may reduce transparency and flexibility (Sumiati et al., 2016).

2.4. Fiber Content Test (Amalia et al., 2021)

The fiber content analysis began with weighing 1 gram of the sample into an Erlenmeyer flask. Next, 50 mL of 0.3N H2SO4 was added, and the mixture was heated under a reverse condenser for 30 minutes. Subsequently, 25 mL of 1.5 M NaOH was added, and heating was continued for 30 minutes on a hot plate at medium heat. The solution was then filtered using a filter paper of known weight. The filtrate was then rinsed sequentially with 50 ml of 10% K2SO4 solution, 50 ml of hot water, and 25 ml of acetone. The filter paper and its remaining solids were transferred to a porcelain cup and dried in an oven at 105°C. After complete drying, the filter paper was cooled in a desiccator for 1 hour until its weight was stable, after which it was reweighed. The fiber percentage was calculated based on the following formula:

$$Fiber\ Content(\%) = \frac{a-b}{c} \times 100\%$$

Description:

a = weight of fiber residue in filter paper (g)
b = weight of dry filter paper (g)
c = weight of starting material (g)

2.5. Water Solubility Test (Modified by Ahmad et al., 2012)

The solubility test of edible films was carried out following the procedure established by Ahmad and colleagues (2012). Initially, the films were cut into 3x3 cm² pieces, and their initial weight (W1) was recorded. Then, the film pieces were immersed in 10 mL of distilled water at room temperature in a 50 mL centrifuge tube for approximately 24 hours. After the soaking process, the solution was filtered to separate the insoluble film portion. The insoluble portion was then dried in an oven at 105°C for approximately 3 hours. After drying, the samples were reweighed (W2) to determine the weight of the water-insoluble residue. The percentage of water solubility of the samples was then calculated using the following formula:

$$Water\ Solubility\ (\%) = \frac{w1-w2}{w1} \times 100\%$$

Description:

W1 = Weight of dry sample before immersion
W2 = Weight of dry sample after immersion

2.6. Water Content Test (AOAC, 2005)

Water content in edible films can be determined by oven drying. The initial stage involves drying an empty cup in an oven at 105°C for 15 minutes, then cooling it in a desiccator for 15 minutes, and weighing it (A). Then, approximately 1 gram of the sample is placed into the cup and reweighed (B). Next, the cup containing the sample is dried in an oven at 105°C for 6 hours, cooled in a desiccator for 15 minutes, and weighed to obtain the final weight (C).

$$Water\ Content(\%) = \frac{B-C}{B-A} \times 100\%$$

Description:

A = Weight of empty cup
B = Weight of cup + sample before oven-drying
C = Weight of cup + sample after oven-drying

2.6.1. Experimental Design

Water content in edible films was determined by oven drying. The initial stage involved drying an empty cup in an oven at 105°C for 15 minutes, then cooling it in a desiccator for 15 minutes, and weighing it (A). Then, approximately 1 gram of the sample is placed into the cup and reweighed (B). Next, the cup containing the sample is dried in an oven at 105°C for 6 hours, cooled in a desiccator for 15 minutes, and weighed to obtain the final weight (C).

3. Results and Discussion

3.1. Thickness

Thickness is a crucial aspect in edible film production, as it affects the mechanical strength, protective properties, and physical appearance of the film. Film durability can be enhanced by incorporating materials such as chitosan and bacterial cellulose, which contribute to a denser matrix (Yanti et al., 2021). Based on the measurements shown in Figure 3, the average thickness of the edible films ranged from 0.04 to 0.15 mm, which is still below the maximum limit set by the JIS standard of 0.25 mm. The thickest edible film, at 0.15 mm, was produced with the addition of 10% bacterial cellulose powder, while the lowest thickness (0.04 mm) was found in the control. Analysis of Variance (ANOVA) revealed that different doses of bacterial cellulose powder significantly affected edible film thickness ($P = 0.000$; $p < 0.05$), and Duncan's test at the 95% confidence level confirmed significant differences among treatments.

Table 1. Average Thickness of Edible Gelatin and Chitosan Films with Variations in the Addition of Bacterial Cellulose Powder

Treatment (Bacterial Cellulose Powder (%))	Thickness (mm) ± SD	Duncan Grouping
0	0.04 ± 0.00	a
2	0.06 ± 0.00	b
4	0.09 ± 0.00	c
6	0.12 ± 0.13	d
8	0.14 ± 0.00	e
10	0.15 ± 0.00	f

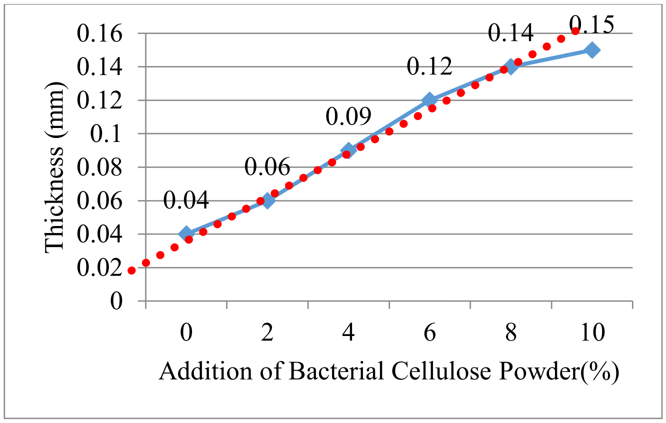

Fig. 3 Average Thickness of Edible Gelatin and Chitosan Films with Variations in the Addition of Bacterial Cellulose Powder

This study revealed that the addition of bacterial cellulose powder to edible films composed of shrimp gelatin and chitosan produced thicker films. Increasing the concentration of bacterial cellulose directly correlated with an increase in film thickness. These results are consistent with research by Ratna et al. (2022), which showed that the characteristics and composition of raw materials significantly determine the thickness of edible films. The combination of chitosan and bacterial cellulose can form a denser matrix, thereby producing films with greater thickness (Yanti et al., 2021).

In addition to material composition, edible film thickness is influenced by technical factors such as casting area size and suspension volume. Increasing the cellulose concentration increases the solution's viscosity, thereby increasing the amount of solids in the film matrix (Kusumawati & Putri, 2013). Consequently, solutions with higher solids content will yield thicker films after drying. This finding is supported by research by Santosa et al. (2024) and Deden et al. (2020), which reported that increasing polymer concentration increases solid density and, consequently, film thickness.

3.2. Fiber Content

Fiber in edible film packaging significantly increases mechanical strength, structural stability, and certain functions (Singh et al., 2021). Naturally sourced fibers, such as cellulose, strengthen the polymer structure by forming intermolecular hydrogen bonds, thereby increasing tensile strength and reducing water vapor permeability (Nuraini et al., 2024). Figure 4 presents the results of fiber content analysis in edible gelatin-chitosan films supplemented with bacterial cellulose powder.

Table 2. Average Fiber Content of Edible Gelatin and Chitosan Films with Variations in Bacterial Cellulose Powder Addition

Treatment (Bacterial Cellulose Powder (%)	Fiber Content (%) ± SD	Duncan Grouping
0	32.24 ± 0.68	a
2	44.20 ± 0.59	b
4	48.46 ± 2.50	c
6	67.68 ± 1.57	d
8	73.95 ± 1.18	e
10	74.08 ± 1.68	e

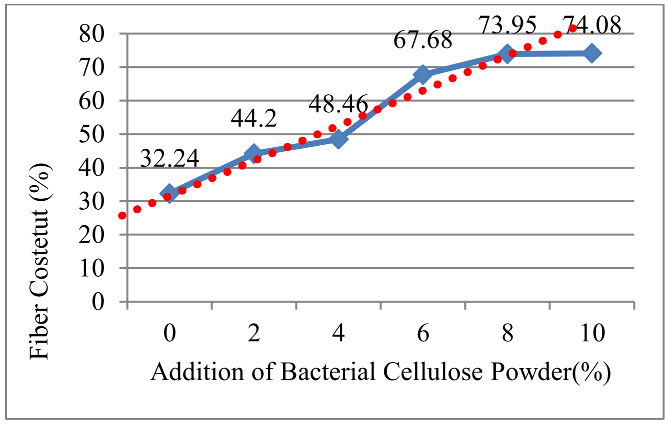

Fig. 4 Average Fiber Content of Edible Gelatin and Chitosan Films with Variations in Bacterial Cellulose Powder Addition

The fiber content in edible gelatin-chitosan films enriched with bacterial cellulose powder ranged from 32.24% to 74.08%. Analysis of Variance (ANOVA) demonstrated that differences in bacterial cellulose concentration significantly impacted fiber content ($p < 0.05$), as also demonstrated by a follow-up Duncan test. However, no significant differences were found between 8% and 10% concentrations, indicating that the addition of cellulose above 8% no longer increased fiber content.

The increased fiber content in this film is due to the characteristics of bacterial cellulose, a highly fibrous polysaccharide composed of β-1,4-glucose. The greater the amount of cellulose in the film, the more fibers are integrated into it. Furthermore, hydrogen bonds between the hydroxyl groups of cellulose and the functional groups in gelatin and chitosan strengthen the film's structure, which in turn enhances its ability to bind fibers. This process results in a denser, fiber-rich film matrix as the cellulose concentration increases.

The results of this study are consistent with several scientific studies indicating that the addition of cellulose to biopolymers can increase the solids and fiber content of films, while also enhancing their physical characteristics. Research by Braga et al. (2021) showed that chitosan films enriched with cellulose nanofibrils had better physical properties than films without such an addition. A study by Ding et al. (2025) also confirmed that the incorporation of cellulose into gelatin-based films can improve mechanical stability and structural compactness. However, the increase in fiber content is not always proportional; after reaching 8%, the addition of cellulose up to 10% does not provide a significant increase, possibly due to limited space in the matrix or the achievement of hydrogen bond saturation. Therefore, the addition of bacterial cellulose effectively increases the fiber content by approximately 8%, and further additions have no significant effect.

3.3. Water Solubility

The solubility test for edible films aims to determine how easily the film dissolves in water. According to Hutabarat et al. (2022), the nature of the packaged product plays a crucial role in determining the required level of film solubility. Food products with high water content require edible films with low solubility, while products with low water content are more suited to using edible films with high solubility (Lestari et al., 2022). The water solubility test data for edible gelatin-chitosan films formulated with the addition of bacterial cellulose powder are presented in Figure 5

Treatment (Bacterial Cellulose Powder (%))	Water Solubility (%) ± SD	Duncan Grouping
0	76.75 ± 1.18	a
2	66.02 ± 0.87	b
4	51.03 ± 2.85	c
6	46.00 ± 2.44	d
8	39.43 ± 4.83	e
10	32.61 ± 2.09	f

The solubility of edible gelatin-chitosan films with the addition of bacterial cellulose powder ranged from 32.61% to 76.75%. ANOVA analysis revealed that differences in bacterial cellulose concentration significantly affected the film's solubility ($p < 0.05$). Duncan's test confirmed this finding by showing significant differences in each treatment variation, indicating that bacterial cellulose concentration is a key factor determining film solubility.

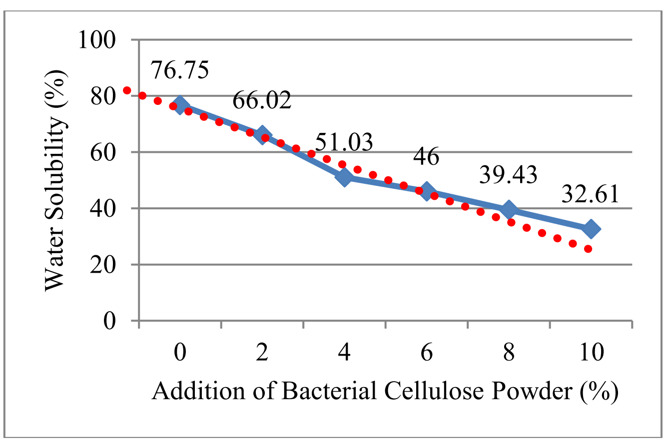

Fig. 5 Average Water Solubility of Edible Gelatin and Chitosan Films with Variations in Bacterial Cellulose Powder Addition

Solubility decreases with increasing bacterial cellulose content, due to its water-insoluble nature and high crystallinity. Liu and colleagues (2020) explained that this decrease in solubility occurs due to the formation of strong intermolecular bonds and a denser film structure. Furthermore, the spatial obstruction in the water-loving part of the film makes it increasingly difficult for water to enter and dissolve it.

The addition of bacterial cellulose did reduce the film's solubility, but the film remained quite soluble, particularly in the control without bacterial cellulose (0%), which showed a figure of 76.75%. This result is consistent with the study by Ali et al. (2017), which reported high solubility of gelatin-chitosan films, at 93.29%. However, this figure does not meet the maximum solubility standard of 14% for food packaging as stipulated by JIS (Ferdian & Farida, 2021). The decrease in solubility with increasing bacterial cellulose indicates the formation of a denser film structure, making it more water-resistant—an important characteristic for food packaging containing large amounts of water or in direct contact with water (Singh et al., 2015).

3.4. Water Content

The moisture level in edible film significantly affects the stability of the packaged product. Therefore, a low moisture content is desirable to minimize damage and increase product shelf life (Rusli et al., 2017). Data measuring the moisture content of an edible film made from shrimp shell gelatin and chitosan with the addition of bacterial cellulose powder are presented in Figure 6.

Treatment (Bacterial Cellulose Powder (%)	Water Content (%) ± SD	Duncan Grouping
0	17.06 ± 0.35	a
2	15.95 ± 0.25	b
4	14.96 ± 0.38	c
6	14.53 ± 0.36	d
8	13.86 ± 0.65	e
10	13.69 ± 0.36	e

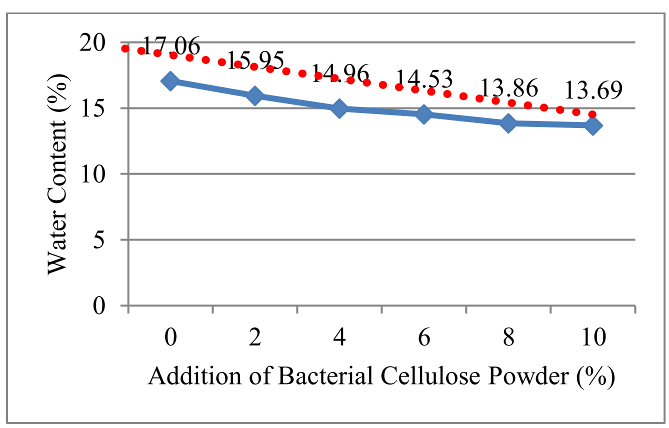

Fig. 6 Average water content of edible gelatin and chitosan films with variations in the addition of bacterial cellulose powder.

Water content analysis revealed that the gelatin-chitosan edible film enriched with bacterial cellulose powder had a water content ranging from 13.69% to 17.06%. Analysis of Variance (ANOVA) confirmed that different bacterial cellulose concentrations significantly affected the water content ($p < 0.05$). Furthermore, Duncan's test showed that the sample without bacterial cellulose (0%) showed a significant difference compared to all other samples, while samples with 8% and 10% bacterial cellulose did not differ significantly. In general, increasing the concentration of bacterial cellulose powder tended to decrease the water content, in line with the results of the water solubility test. This decrease is due to the high degree of crystallinity and strong intermolecular bonds in bacterial cellulose, which limit water absorption and retention in the film. Research by Liu et al. (2020) highlighted that the addition of nanocellulose can strengthen bonds within the material matrix, and Yekta et al. (2020) explained that reducing the number of free hydroxyl groups can reduce the film's water binding capacity.

Based on SNI 06-3735-1995, the maximum water content limit is 16%, but the edible films used as controls showed results below this standard (0%). In contrast, all edible films formulated with the addition of 2–10% bacterial cellulose powder successfully met the water content requirements. The lower water content of these films indicates good stability, thus potentially being used as primary food packaging, especially for products with moderate water content that require protection from moisture.

4. Conclusion

The characteristics of edible gelatin-chitosan films reinforced with bacterial cellulose powder at various concentrations (0–10%) were evaluated. The addition of bacterial cellulose significantly affected all measured parameters, including thickness, fiber content, water solubility, and water content. The highest film thickness (0.15 mm) was achieved at a cellulose concentration of 10%. Meanwhile, the highest fiber content (74.08%) was observed at 8%, indicating an optimal point beyond which further addition did not yield significant improvement. Increasing the cellulose content also consistently decreased the water solubility (up to 32.61%) and water content (up to 13.69%), indicating an increase in structural density and water resistance. The optimization results indicated that bacterial cellulose plays an effective role as an edible film reinforcement by densifying the matrix, increasing the solid content, and minimizing water absorption. In general, the best functional performance was achieved at a bacterial cellulose concentration of 8–10%, with characteristics of thickness, fiber content, solubility, and water content that meet the needs of biodegradable packaging. The conclusion of this study is that the addition of bacterial cellulose powder can improve the physical and functional properties of edible gelatin-chitosan films, making them a promising alternative for environmentally friendly and biodegradable food packaging applications.

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All Authors contributed equally to this work.

References

[1] S. Agustin et al., “Production and Characterization of Bacterial Cellulose-Alginate Biocomposites as Food Packaging Material,” *Food Research*, vol. 5, no. 6, pp. 204-210, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[2] Mehraj Ahmad et al., “Physico-Mechanical and Antimicrobial Properties of Gelatin Film from the Skin of a Unicorn Leather Jacket Incorporated with Essential Oils,” *Food Hydrocolloids*, vol. 28, no. 1, pp. 189-199, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[3] Haidir Ali, Ace Baehaki, and Shanti Dwita Lestari “Characteristics of Edible Gelatin-Chitosan Film with Added Genjer (Limnocharis Flava) Extract and Application in Pempek” *Journal of Fishery Product Technology*, vol. 6, no. 1, pp. 26-38, 2017. [Google Scholar] [Publisher Link]

[4] Nurur Rizqi Penta Amalia and Siti Aminah, “Fiber Content, Antioxidant Activity, Physical and Sensory Characteristics of Soybean Milk Yogurt with the Addition of Green Grass Jelly Extract,” *Journal of Food and Nutrition*, vol. 11, no. 11, pp. 50-59, 2021. [Google Scholar] [Publisher Link]

[5] *Official Methods of Analysis*, 18th Ed., Aoac International, 2005. [Google Scholar] [Publisher Link]

[6] D.G. Braga et al., “Chitosan-Based Films Reinforced with Cellulose Nanofibrils Isolated from Euterpe Oleraceae Mart,” *Polymers from Renewable Resources*, vol. 12, no. 1-2, pp. 46-59, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[7] Mohammad Deden, Abdul Rahim, and Asrawaty Asrawaty, “Physical and Chemical Properties of Edible Gadung Tuber Starch Film at Various Concentrations,” *Journal of Food Processing*, vol. 5, no. 1, pp. 26-33, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[8] Fuyuan Ding, and Lin Fu, “Recent Advances in Gelatin-Cellulose Composite Films for Food Packaging Applications,” *International Journal of Biological Macromolecules*, vol. 321, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[9] Don Hettiarachchige Udana Eranda et al., “Gelatin-Chitosan Interactions in Edible Films and Coatings Doped with Plant Extracts for Biopreservation of Fresh Tuna Fish Products: A Review,” *International Journal of Biological Macromolecules*, vol. 280, no. 2, pp. 1-34, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[10] Muh. Agus Ferdian Malang, and Siti Farida, “Characteristics of Edible Film from Modified Porang Flour as Instant Noodle Seasoning Packaging,” *Proceedings of the National Seminar on Industrial Technology, Environment, and Infrastructure*, vol. 4, no. A2.1- A2.8, pp. 1-8, 2021. [Google Scholar] [Publisher Link]

[11] Harianingsih Harianingsih, and Suwardiyono Suwardiyono, “Making Edible Film from Nata De Soya (Tofu Residue) as a Form of Waste to Product for tofu SMEs,” *Cendekia Exakta Scientific Journal*, vol. 2, no. 1, pp. 42-46, 2017. [Google Scholar] [Publisher Link]

[12] Juwayriyah, and I. Nugraha, Synthesis and Characterization of Edible Film Composites Made from Chicken Feet Gelatin and Montmorillonite, vol. 2, no. 2, pp. 382-392, 2020. [Publisher Link]

[13] Dyah Hayu Kusumawati, and Widya Dwi Rukmi Putri, “Physical and Chemical Characteristics of Edible Corn Starch Film Incorporated with Black Cucumu Juice,” *Journal of Food and Agroindustry*, vol. 1, no. 1, pp. 90-100, 2013. [Google Scholar] [Publisher Link]

[14] Briggita Rimba Artha Lestari, Nurul Wakhidhatur Rohmah, and Caecilia Pujiastuti, “Study of Edible Film Production from Yam Starch with the Addition of Chitosan and Glycerol,” *Chempro*, vol. 3, no. 1, pp. 38-44, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] Stephen Olaribigbe Majekodunmi et al., “Material Properties of Chitosan from Shells of Egeria Radiata: Drug Delivery Considerations,” *Journal of Coastal Life Medicine*, vol. 5, no. 7, pp. 321-324, 2017. [Google Scholar]

[16] Tindy Rahmadi Putri et al., “Effect of Different Starches on the Characteristics of Edible Film as Functional Packaging in Fresh Meat or Meat Products: A Review,” *Materials Today: Proceedings*, vol. 87, pp. 192-199, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[17] Zulmeliza Rasyid, Nurvi Susanti, and Nofri Hasrianto, “Analysis of Plastic Bag Waste Management Behavior in Pekanbaru City,” *JHMHS: Journal of Hospital Management and Health Science*, vol. 4, no. 1, pp. 1-13, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[18] Ratna Ratna, Maiful Hari, and Syafriandi Syafriandi., “Utilization of Kepok Banana Peel Pectin (Musa Paradisiaca L.) for Making Edible Film Packaging with the Addition of Glycerol as a Plasticizer,” *Agricultural Engineering*, vol. 15, no. 1, pp. 97-107, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[19] Arham Rusli, M. Metusalach, and Mulyati Muhammad Tahir, “Characterization of Carrageenan Edible Films Plasticized with Glycerol,” *Journal of Indonesian Fishery Product Processing*, vol. 20, no. 2, pp. 219-229, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[20] Safiah Safiah, “Biodegradable Plastic Made from Cassava Starch (Manihot esculenta) with a Mixture of Cellulose,” *Unida Scientific Engineering Journal*, vol. 4, no. 1, pp. 113-118, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[21] Zhe Liu et al., “Characterizations of Bacterial Cellulose Nanofibers Reinforced Edible Films Based on Konjac Glucomannan,” *International Journal of Biological Macromolecules*, vol. 145, pp. 634-645, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[22] Budi Santosa, Gatut Suliana, Mega Christin Yoweni, “Application of Na-CMC from Bacterial Cellulose as an Emulsifier in Instant Liquid Coconut Milk,” *Food Technology Scientific Information and Communication Media for Agricultural Technology*, vol. 15, no. 1, pp. 137-145, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[23] Budi Santoso, *Edible Film: Technology and Applications*, Noerfikri Palembang, 2020. [Google Scholar] [Publisher Link]

[24] Tarun Pal Singh, Manish Kumar Chatli, and Jhari Sahoo, “Development of Chitosan Based Edible Films: Process Optimization Using Response Surface Methodology,” *Journal of Food Science and Technology*, vol. 52, no. 5, pp. 2530-2543, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[25] Ulyarti et al., “Improving Edible Film Quality Using Modified Water Yam Starch (Dioscorea Alata L.),” *Journal of Food Technology*, vol. 7, no. 1, pp. 12-19, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[26] Nur Arfa Yanti et al., “The Effect of Sugar and Nitrogen Addition on Nata De Coco Production,” *BioWallacea: Journal of Biological Research*, vol. 4, no. 1, pp. 541-546, 2017. [Google Scholar] [Publisher Link]

[27] Reza Yekta et al., “Development and Characterization of a Novel Edible Film Based on Althaea Rosea Flower Gum: Investigating the Reinforcing Effect of Bacterial Nanocrystalline Cellulose,” *International Journal of Biological Macromolecules*, vol. 158, pp. 327-337, 2020. [CrossRef] [Google Scholar] [Publisher Link]