



Characteristics of Corn Cob Cellulose-Chitosan-Based Bioplastics as Antimicrobial Packaging for Pempek Products

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A B S T R A C T

The high level of corn production in Lampung Province has the potential to generate a large amount of corncob agricultural waste. Corncobs are lignocellulosic residues with a high cellulose content, making them a promising raw material for the production of biodegradable bioplastics. This study aimed to produce and characterize corncob cellulose-based bioplastics combined with chitosan as active packaging to extend the shelf life of food products, particularly pempek. Cellulose was extracted through acid hydrolysis, delignification, alkalization, and bleaching processes, and subsequently formulated into bioplastic films using the solution casting method with varying cellulose concentrations. The bioplastics were characterized in terms of thickness, tensile strength, elongation, biodegradability, and water vapor transmission rate (WVTR). The results showed that increasing cellulose content led to an increase in bioplastic thickness and tensile strength, while elongation and biodegradability decreased. Bioplastic thickness increased from 0.18 mm to 0.25 mm, and tensile strength increased from 0.96 MPa to 7.55 MPa with higher cellulose content. Meanwhile, elongation decreased from 98.6% to 45.21%, and biodegradability declined from 38.91% to 23.61%. In addition, the WVTR decreased to 0.021 g/m²·h at the highest cellulose concentration, indicating improved water vapor barrier properties. These findings suggest that corncob cellulose-based bioplastics with chitosan have strong potential to be developed as environmentally friendly active packaging for food products requiring mechanical protection and moisture control.

Contribution to Sustainable Development Goals (SDGs):

SDG 2: Zero Hunger

SDG 9: Industry, Innovation, and Infrastructure

SDG 12: Responsible Consumption and Production

SDG 15: Life on Land

1. INTRODUCTION

1.1. Research Background

Indonesia is an agricultural country, Corn production in Lampung Province in 2025, according to the Central Statistics Agency, is estimated at 1.26 million tons. This corn production is higher than in 2025, which was 1.11 million tons [1]. Corn production in Lampung in 2026 is projected to increase compared to the previous year. High corn production increases agricultural waste,

especially corn cobs. Corn cobs are a type of lignocellulosic waste [2], consisting of 23.3% lignin, 44.9% cellulose, and 31.8% hemicellulose [3]. The high cellulose content in corn cobs offers opportunities to convert it into products with higher economic value. The high cellulose potential of corn cobs can be used as a raw material for biodegradable bioplastics [4]. Bioplastics are made from compounds found in plants (starch and cellulose) or animals (chitosan) [5]. Starch, cellulose, and chitosan degrade naturally and quite quickly, giving bioplastics their biodegradability. According to [6], the higher the cellulose



content, the greater the effect on the characteristics of the bioplastic produced. One of the potential uses of cellulose is as a base material for bioplastics that can be easily biodegraded. Bioplastics are plastics composed of organic compounds and are biodegradable or easily decomposed by microorganisms. Bioplastics take 3-4 months to degrade, while conventional plastics take hundreds to thousands of years to degrade [7]. This shows that bioplastics degrade faster than conventional plastics, making them a solution to the problems caused by their use. The use of bioplastics continues to grow in several sectors, especially in food packaging. Bioplastics are used as a substitute for conventional plastics for disposable packaging, such as trays, films, and bottles [8], additional functions or as active packaging. Bioplastics also have the potential to be developed with additional functions as active packaging that can increase product shelf life.

Active packaging is a packaging technology equipped with additional materials such as antimicrobial agents, antioxidants, and gas regulators designed to interact with the packaged goods. The goal of active packaging is to improve the quality and safety of food products by preventing contamination, extending shelf life, and stabilizing sensory quality [9]. In the manufacture of corn cob bioplastics as active packaging, chitosan is added as an antimicrobial agent. Chitosan is antimicrobial, so it can suppress the growth and activity of microbes, such as pathogenic bacteria, fungi, and gram-positive and gram-negative bacteria [10]. The mechanism of chitosan as an antimicrobial is that chitosan acts as an active agent through electrostatic interactions of cationic groups that damage microbial cell membranes, thereby triggering fatal intracellular material leakage. Active chitosan binds essential metal ions and penetrates the cytoplasm to halt DNA replication and microbial protein synthesis [11]. Chitosan can also improve mechanical properties, water resistance, and extend the shelf life of food products through its antimicrobial effects [12].

One product that can be packaged using this active packaging is pempek. Pempek is a traditional food from Sumatra that has the potential for large-scale industrial development, as it has a distinctive taste and is quite popular among the public. Pempek also has economic value and is quite nutritious [13]. In the pempek industry itself, the main problems often encountered are the inconsistency of product quality and the shelf life of pempek [14]. Pempek contains 51.89% - 53.10% water, 7.0% - 8.2% protein, 37.05% - 40.40% carbohydrates, 0.42% - 0.54% fat, and 1.0% - 1.2% ash [15]. These elements make pempek susceptible to spoilage. Research conducted by [16] shows that pempek with a fish ratio of 39.7% stored at room temperature can only last for one day. Due to the susceptibility of pempek products to spoilage, it is necessary to design corn cob cellulose-based bioplastic packaging to extend the shelf life.

1.2. Literature Review

1.2.1. Bioplastic

Bioplastics are bio-based polymers (biopolymers) produced from biomass and capable of biodegrading [17]. According to [18] bioplastics are plastics made from natural materials that can be degraded by microorganisms into H₂O and CO₂ after use and disposal into the environment. Natural materials used for bioplastic production include starch, cellulose, and biopolymers such as chitosan and polylactic acid (PLA), which are biodegradable and thus more environmentally friendly because

they can degrade under certain conditions through microbial action [19].

The mechanical and functional properties of bioplastics depend on their constituent materials. Bioplastics made from starch-based raw materials tend to absorb water easily and are brittle unless reinforced with fillers or plasticizers [20]. PLA-based bioplastics are transparent and suitable for food packaging [21]. The addition of chitosan to bioplastic formulations increases hydrogen bonding, making the bioplastic stronger, antibacterial, and more water-resistant add that bioplastics with added cellulose improve elasticity, tensile strength, and transparency. To enhance the mechanical and functional properties of bioplastics, they are typically combined with nanofillers such as nano-cellulose or blended biopolymers to make them stronger, more flexible, and water-resistant [22].

In agriculture, bioplastics are used as mulch films that are buried in the soil and are biodegradable [23]. Additionally, in the healthcare sector, they are commonly used as wound dressings, drug delivery systems, and scaffolds for tissue engineering [24]. Even in the textile and automotive sectors, bioplastics are used for fibers and vehicle interior components [25].

1.2.2. Active Packaging

Active packaging is a packaging technology that incorporates additional materials such as antimicrobial agents, antioxidants, and gas regulators designed to interact with the packaged product. The goal of active packaging is to improve the quality and safety of food products by preventing contamination, extending shelf life, and maintaining sensory quality [9]. The active compounds added to active packaging are typically delivered in sachets or plastic films. The mechanism of action of active compounds in active packaging involves absorbing gases such as oxygen, carbon dioxide, and water vapor through reactions involving antimicrobial and antioxidant compounds. There are several types of active packaging commonly used in product packaging, such as essential oils, oxygen scavengers, ethanol emitters, and antimicrobial films [26]. The addition of essential oils in sachet form to active packaging can inhibit spoilage caused by microorganisms and oxygen, as essential oils contain antioxidants and antimicrobial compounds [27]. In addition to essential oils, antimicrobial chitosan also has potential as an additive in active packaging to prevent microbial growth and extend product shelf life [28]. Chitosan in active packaging offers several advantages, as demonstrated in research [12]: it can serve as a high-quality natural food packaging material that extends the shelf life of food, whether in the form of raw (fresh) ingredients or ready-to-eat meals. Furthermore, active packaging made from chitosan film exhibits good mechanical properties and a homogeneous microstructure, with no visible aggregates on the film layer [29].

1.2.3. Pempek

Pempek is a traditional dish native to Palembang, South Sumatra. Pempek is typically made from ground fish mixed with sago or tapioca flour and other ingredients such as water, salt, and flavor enhancers [22]. According to [30], pempek is one of the most popular types of processed fish products in Indonesia due to its distinctive flavor and chewy texture. Generally, pempek is served with a vinegar-based sauce made from palm sugar, chili peppers, and garlic, which provides a combination of sour, sweet, and spicy flavors. The primary raw material in pempek

production is fish meat with a chewy texture and a mild fishy aroma, such as mackerel (*Scomberomorus* spp.), snakehead (*Channa striata*), or belida (*Notopterus chitala*). According to [31], mackerel is widely used because it has a high protein content and an elastic meat texture, making it suitable for processing into products like pempek. In addition to fish, sago flour plays a crucial role in determining the chewiness and final texture of the product. Furthermore, snakehead fish is also widely used because it has a high protein content (17%) and low fat content (1%), as well as a white color, making it ideal for producing chewy, delicious, and white pempek. Fish meat with a low fat content produces a better fish gel compared to fish meat containing more fat [22]. Emppek-empek is high in animal protein because it is made from fish, carbohydrates from sago or tapioca flour, and various vitamins and minerals [32]. The nutritional quality and food safety of emppek-empek are greatly influenced by the raw materials, processing methods, and production sanitation [33]. Because it is made from fresh fish, pempek is prone to microbiological spoilage if not stored properly. Therefore, pempek is highly suitable as a test subject for bioplastic-based active packaging with antimicrobial properties to extend its shelf life.

1.3. Research Objective

The purpose of this study is to (1) determine the effect of corn cob cellulose concentration on the characteristics of bioplastics used as active packaging, (2) determine the characteristics of corn cob bioplastics used as active packaging for pempek products

2. MATERIALS AND METHODS

The research was carried out in July 2025 to January 2026 at Politeknik Negeri Lampung, Agroindustry Laboratory in the Integrated Smart Food Security Laboratory. The treatment was repeated four times, resulting in 20 experimental units.

2.1. Cellulose Production from Corn Cobs

Cellulose production refers to [34] which has been modified. Corn cobs are reduced in size using a grinding machine and a 80-100 mesh sieve. The corn cob powder is mixed with 3.5% (w/v) HNO₃ and heated at 90°C for two hours. The resulting pulp is filtered and washed until the filtrate is neutral, then delignified with 2% (w/v) technical NaOH and 2% (w/v) Na₂SO₃ at 50°C for one hour. The residue is filtered and washed again until the filtrate is neutral, then 17.5% NaOH (w/v) is added at 80°C for 30 minutes. After that, the residue is filtered and washed again until the filtrate is neutral, then purified by adding 10% H₂O₂ (v/v) and heated at 90°C for 90 minutes. The resulting cellulose is dried in an oven at 110°C for six hours.

2.2. Bioplastic Production

The bioplastic production process uses the solution casting method. Solution casting is carried out by placing the material on a glass plate and drying it at 55°C for 5-6 hours to remove the solvent. The ratio of materials in bioplastic production is 50% cellulose acetate and 50% chitosan. Polymer consisting of cassava starch and cellulose-chitosan with a ratio of (50:50). The cellulose-chitosan ratio is formulated as in Table 1. This

composition was obtained from the best results in the study [35]. In addition, 25% (w/v) glycerol was added to the material mixture to increase the bioplastic's flexibility.

Table 1. Cellulose-chitosan ratio in bioplastics

Cellulose concentration	Polymer		
	Cellulosa (g)	Chitosan (g)	Cassava starch (g)
25%	0.625	1.875	2.5
30%	0.75	1.75	2.5
35%	0.875	1.625	2.5
40%	1	1.5	2.5
50%	1.25	1.25	2.5

2.3. Characterization of Corn Cob Cellulose-Based Bioplastic

The characterization of this bioplastic consists of several tests, namely thickness, tensile strength, elongation, biodegradability, and Water Vapor Transmission Rate (WVTR).

2.4. Thickness Test

The thickness of the bioplastic was measured using a screw micrometer with a range of 0–25 mm. The test was conducted at five random points on the surface of the bioplastic, and the average value was taken from the test [36].

2.5. Tensile Strength Test

The tensile strength test was conducted in accordance with ASTM D-882 by cutting the bioplastic into 3 cm wide strips and lengths corresponding to the size of the bioplastic. The tensile strength test was measured using a tensile strain tester by placing the bioplastic piece on the cross-section, then the device pulled the bioplastic until it broke [37].

2.6. Elongation Test

The elongation percentage is the maximum increase in the bioplastic's length relative to its initial length when it is subjected to tensile force until it breaks. The measurement of the percentage of elongation is carried out simultaneously with the measurement of tensile strength. The elongation of bioplastic is calculated by dividing it by the initial length of the bioplastic before pulling [38].

2.7. Biodegradability Test

The biodegradability test follows [38], with a 3 x 3 cm sample placed in soil for 5 days. The first treatment is to weigh the initial mass before degradation and then weigh it again after degradation to determine the percentage change.

2.8. Water Vapor Permeability Rate Test (WVTR)

The water vapor transmission rate test refers to [39], where the bioplastic to be tested is cut into 10x10 mm pieces. Then, the silica gel in the desiccator is replaced with distilled water, and silica gel is placed in a plastic jar (the testing container for the

edible film) to $\frac{1}{4}$ of the jar's volume. Prior to this, the silica gel is dried at a temperature of 105 °C for at least 3 hours. The cut film specimens are then used as jar lids and stored in a desiccator containing distilled water. The jar containing silica gel and covered with film specimens is weighed at 0, 1, 2, 3, 4, and 5 hours. Water vapor transmission is calculated using the following formula:

$$WVTR = \frac{\Delta W}{t \times A}$$

W is the change in weight of silica gel after 5 hours (g), t is time (5 hours), and A is the surface area of the film (mm²)

3. RESULT AND DISCUSSION

3.1. Thickness Test

Thickness is one of the important characteristics in bioplastics because it acts as a barrier against water vapor. Thickness testing on starch-based bioplastics was carried out using the microcal messmer method (ASTM 1983) in a study using a screw micrometer [40]. This thickness measurement was carried out by measuring five different points on the bioplastic and then averaging the results.

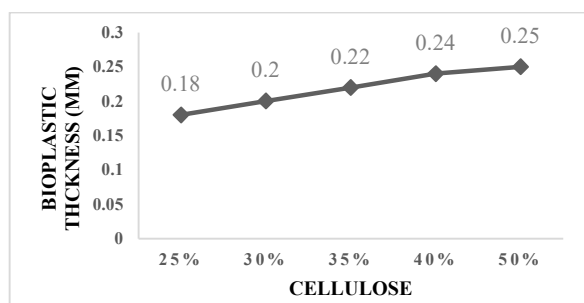


Fig. 1. Diagram of Thickness Test result

Based on Figure 1, it can be seen that the more cellulose added in the manufacture of bioplastics, the thicker the resulting bioplastics. The measurement of bioplastic thickness shows an increase with increasing cellulose content. Samples with a cellulose content of 25% had the lowest thickness, 0.18 mm, while at 50% cellulose content, the thickness increased to 0.25 mm. These bioplastic thickness results are in line with the research [41], where an increase in the concentration of microcrystalline cellulose in starch-based bioplastics is directly proportional to an increase in film thickness due to the increase in the amount of solids dispersed in the matrix. In addition, the addition of cellulose as a filler in cassava starch bioplastics causes a significant increase in film thickness. According to [42], the addition of cellulose from banana stems to starch bioplastics not only increases thickness but also increases film structural density, as evidenced by a more homogeneous surface morphology.

This increase in bioplastic thickness is caused by an increase in the amount of solids in the film-forming solution, where cellulose acts as a structural component that strengthens the matrix. Cellulose has hydroxyl groups (–OH) that are capable of forming hydrogen bonds, both between cellulose molecules and between cellulose and starch as the main components of bioplastics. These increasingly intensive intermolecular interactions cause the bioplastic matrix to become denser,

resulting in a film with greater thickness. This increase in thickness is also related to the characteristics of cellulose, which acts as a filler in the polymer matrix. The addition of cellulose increases the density and viscosity of the film-forming solution, resulting in a thicker bioplastic layer [43].

3.2. Tensile Strength Test

Tensile strength is the maximum pull that bioplastics can achieve before breaking. Tensile strength measurements aim to determine the elongation force at the maximum pull on a given area. Tensile strength can be calculated by dividing the tensile force produced by the area of the bioplastic being tested. The average tensile strength of bioplastics can be seen in Figure 2.

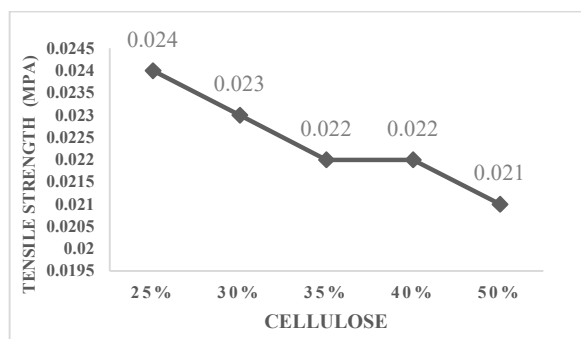


Fig. 2. Tensile strength test analysis results

Based on Figure 2, the more cellulose content is added during the manufacture of bioplastics, the higher the tensile strength of the resulting bioplastics. Samples with a cellulose content of 25% had the lowest tensile strength, 0.96 MPa, whereas at 50% cellulose content, the tensile strength increased to 7.55 MPa. The increase in tensile strength is directly proportional to the increase in cellulose content. This is due to cellulose's characteristics as a natural polymer with high structural strength. Cellulose contains many hydroxyl groups that can form strong hydrogen bonds among cellulose chains and between cellulose and starch or other film-forming polymers. More intensive intermolecular bonds produce a denser, stronger, and more stable film network, so tensile strength increases with increasing cellulose content. The decrease in elongation at high cellulose content occurs because the film matrix becomes stiffer, so that the film's ability to deform before breaking becomes smaller [44]. Corn cob cellulose-based bioplastics show that increasing the cellulose concentration significantly increases the tensile strength of the film due to increased density and intermolecular bonds, while elongation decreases due to reduced film flexibility [45].

3.3. Elongation Test

Elongation is a mechanical parameter that indicates a material's ability to undergo deformation or elongation before breaking or snapping. In the context of bioplastics, the elongation value reflects the material's flexibility and elasticity, making this parameter very important for assessing the suitability of bioplastics in applications that require stretchability, such as flexible packaging, food wrappers, or protective films. Bioplastics with high elongation values indicate that the material can withstand tensile forces with significant elongation, whereas

bioplastics with low elongation tend to be rigid and prone to breakage. The average elongation values for bioplastics are shown in Figure 3.

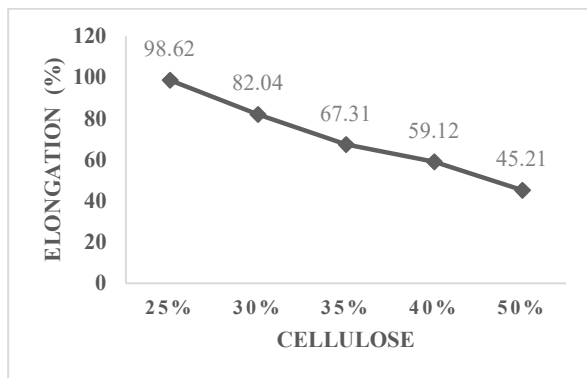


Fig. 3. Elongation test results

Based on Figure 3, it can be seen that the higher the cellulose content added during bioplastic manufacture, the lower the elongation of the resulting bioplastics. Samples with a cellulose content of 50% had the lowest elongation of 45.21%, while at a content of 25%, the elongation of bioplastics increased to 98.6%. Thus, the tensile strength and elongation data in this study are consistent with previous studies, namely that an increase in cellulose content increases the mechanical strength of the film but reduces its flexibility [46]. This confirms that corn cob cellulose has great potential as a reinforcing material in bioplastic formulations, especially for applications requiring high mechanical strength.

3.4. Biodegradability Test

Biodegradable bioplastics are plastic materials that can be broken down naturally by microorganisms, including bacteria and fungi, and by enzymes, producing end products such as water, carbon dioxide, methane, and biomass. This biodegradation process is greatly influenced by the chemical structure of the polymer, the degree of crystallinity, intermolecular interactions, and environmental conditions. Polymers that are amorphous, hydrophilic, and easily permeable to water generally degrade more quickly. Conversely, polymers with high crystallinity, such as cellulose, are more difficult to degrade because their dense structure impedes microbial access. Crystalline cellulose contains microfibrils bound by intramolecular and intermolecular hydrogen bonds and van der Waals forces, resulting in high orientation and small interchain spacing. The dense and regular microfibril structure reduces contact points and penetration, and tends to be inaccessible to microbial enzymes [47]. The average biodegradability of bioplastics can be seen in Figure 4.

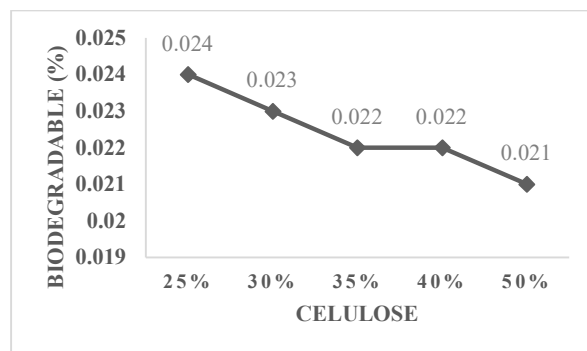


Fig. 4. Biodegradable bioplastics test analysis results

Based on Figure 4, the biodegradability test indicates a decrease in bioplastic degradability as the cellulose content increases. At a cellulose content of 25%, the degradability of bioplastics is 38.91%, whereas at 50% cellulose, it decreases to around 23.61%. This decrease in biodegradability is related to the crystalline nature of cellulose, which is difficult for microorganisms to break down. Strong hydrogen bonds between cellulose chains make the bioplastic structure denser and more resistant to enzymatic degradation [48]. Conversely, other components such as starch are more amorphous and easily hydrolyzed by microbes, thus contributing to higher biodegradability [49].

3.5. Water Vapor Permeability Rate Test (WVTR)

The water vapor transmission rate (WVTR) is an important parameter for assessing the ability of a bioplastic film to inhibit water vapor transfer through its surface. The lower the WVTR value, the better the film's barrier properties against water vapor, which means the film is more effective in protecting products from moisture loss or absorption. WVTR is a critical property in food packaging applications because excess moisture can accelerate chemical reactions, microbial growth, and deterioration of product quality during storage.

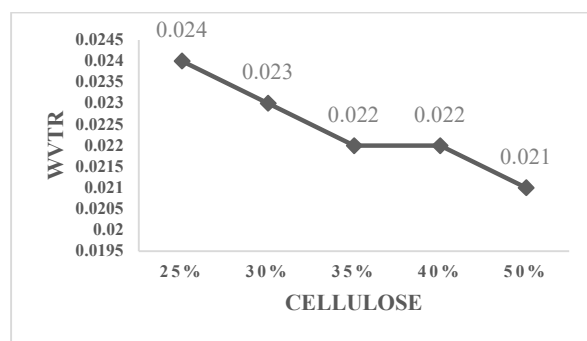


Fig. 5. WVTR test results

Based on the data in Figure 5, the WVTR of bioplastics shows a downward trend as the cellulose content increases. At a cellulose content of 25%, the WVTR was 0.024 g/m²·h, then decreased to 0.023 at 30%, to 0.022 at 35% and 40%, and reached the lowest value of 0.021 g/m²·h at 50%. The value of 0.021–0.024 g/m²·h when converted to approximately 0.50–0.58 g/m²·d, this value is better than the standard BOPP which is reported at

approximately 4–6 g/m²·d, and also better than the standard AlOx coated PET at 0.56 ± 0.03 g/m²·d; so the performance is already on par with some medium commercial barrier films [50]. This decrease in WVTR indicates that bioplastics with higher cellulose content have a denser and more compact structure, thereby reducing permeability to water vapor. Cellulose fills the intermolecular spaces in the polymer matrix, reducing the porosity of the film and slowing down water vapor diffusion [51]. This is in line with previous studies reporting that the addition of cellulose or cellulose nanofibers can improve the packaging properties of bioplastics by reducing permeability to gas and water vapor [52].

According to [53], increasing cellulose in biopolymer films significantly reduces water vapor transmission rates due to increased density and diffusion resistance. Other studies by [17] and [54] also support that increasing the cellulose fiber content in composite films improves barrier properties due to increased crystallinity and tortuosity in the water vapor migration pathway.

4. CONCLUSION

Corn cob cellulose has great potential for use as a raw material for biodegradable bioplastics and active packaging. Increasing the cellulose content significantly affects the characteristics of bioplastics, as evidenced by increases in thickness from 0.18 mm to 0.25 mm and tensile strength from 0.96 MPa to 7.55 MPa. Conversely, the elongation value decreased from 98.6% to 45.21% and biodegradability decreased from 38.91% to 23.61% as the cellulose content increased. In addition, the water vapor transmission rate (WVTR) decreased to 0.021 g/m²·h at the highest cellulose content, indicating an increase in water vapor barrier properties. With these characteristics, corn cob cellulose and chitosan-based bioplastics have the potential to be developed as environmentally friendly active packaging to improve the quality and shelf life of food products, especially pempek. Based on the balance between mechanical strength, flexibility, biodegradability, and water vapor barrier properties, the formulation containing 50% corn cob cellulose is recommended as the optimal formulation for active packaging applications, as it provides sufficient tensile strength while maintaining adequate elongation and biodegradation performance required for sustainable food packaging.

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