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Application of Bioplastic with Corn Cob Cellulose and Chitosan as Active Packaging for Pempek Products

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A B S T R A C T

Pempek is a fish-based food product that is highly susceptible to spoilage due to its elevated water and protein content, which fosters microbial growth. The reliance on conventional plastic packaging, such as polypropylene, raises environmental concerns, underscoring the need for alternative, more eco-friendly packaging solutions that enhance product safety. This study aimed to utilize bioplastics derived from corn cob cellulose and chitosan as active packaging to mitigate the deterioration of pempek during storage. The research involved extracting corn cob cellulose via the organosolv method, fabricating bioplastics via solution casting, packaging the pempek, and assessing Total Plate Count (TPC) and pH levels over 4 days of storage at room temperature. The findings revealed that the active bioplastic significantly inhibited microbial growth. The TPC of pempek packaged in bioplastic was 1–2 logs lower than that of the control on days 2-4. Additionally, the pH of the bioplastic-preserved pempek declined from 6.75 to 5.46, whereas the control increased from 7.77 to 8.17, indicating microbial spoilage. These results suggest that bioplastic incorporating corn cob cellulose and chitosan effectively slows deterioration, enhances microbiological safety, and presents a viable, environmentally friendly packaging alternative for food products.

Contribution to Sustainable Development Goals (SDGs):

SDG 12 – Responsible Consumption and Production
SDG 13 – Climate Action
SDG 14 – Life Below Water
SDG 15 – Life on Land

1. INTRODUCTION

1.1. Research Background

Pempek is a traditional dish typical of the Palembang region in South Sumatra. Pempek is usually made from ground fish meat mixed with sago or tapioca flour and other ingredients such as water, salt, and seasonings [1], and has a chewy,lastic texture [2]. The nutritional quality and food safety of pempek are highly influenced by the raw materials, processing methods, and sanitation during production [3]. Pempek contains animal protein and a high water content, making it easily perishable and a breeding ground for microbes [4]. Therefore, proper handling and storage of pempek products are necessary to avoid the risk of damage and extend their shelf life.

Packaging is one way to prevent the risk of damage to pempek products. Pempek packaging generally uses polypropylene (PP) plastic. However, the use of polypropylene plastic can pollute the environment and ecosystems. [5] reported that polypropylene is difficult to decompose naturally and has a very low recycling rate (about 1%). This plastic can persist in the environment for decades, leading to its accumulation in soil, water, and ecosystems. Additionally, polypropylene exposed to sunlight and weather can release toxic volatile organic compounds such as benzene and acrolein, which are harmful to human health [6]. It can also absorb and carry other pollutants (such as heavy metals and pesticides), increasing the risk of environmental toxicity[7].

Given the health and environmental risks associated with plastic packaging, bioplastics are an alternative. Bioplastics are plastics made from biological materials (biobased) such as starch, cellulose, or the fermentation products of microorganisms, and can be biodegradable (easily broken down by microorganisms) or derived from biomass [8]. One agricultural waste with potential as a raw material for bioplastic production is corn cobs. Corn cobs contain 15% lignin, 45% cellulose, and 35% hemicellulose [9]. The high cellulose content of corn cobs has the potential to serve as raw material for the production of biodegradable bioplastics [10].

Product protection can be enhanced by adding antimicrobial, antioxidant, and gas-regulating substances to bioplastic packaging, which is called active packaging. Active packaging that acts as an antimicrobial releases or activates antimicrobial compounds (such as antibiotics, pigments, toxins, enzymes, metal ions, or natural compounds) that can inhibit or kill microbes on the food surface or withinhe packaging [11]. The application of active packaging aims to improve the quality and safety of food products by preventing contamination, extending shelf life, and maintaining sensory quality [12]. Active packaging is a suitable choice for packaging pempek because it prevents microbial growth, extends shelf life, and is biodegradable.

Currently, there are already studies on bioplastics made from corn cob cellulose. The use of corn cob cellulose can improve the mechanical properties of bioplastics [10]. The addition of 10% corn cob cellulose to the biodegradable plastic formulation can increase the maximum elongation value to 28% [13]. Biodegradable plastic from corn cob cellulose with the addition of PVA and TiO2 produced a biodegradation value that met SNI standards, exceeding 60% within 1 week. Additionally, apples wrapped in biodegradable plastic are more durable and do not brown easily [14]. Generally, research on the use of corn cob cellulose in biodegradable plastics is still limited to testing physical and mechanical properties, but information on the effect of corn cob cellulose on microbial growth for active packaging is still limited. Therefore, applied research is needed to utilize cellulose from corn cobs as active packaging for pempek products.

1.2. Literature Review

Corn cobs are lignocellulosic waste produced during the corn shelling process, with approximately 30% of the plant composed of cobs. These cobs have a crude fiber content of 35.5%, a protein content of 2.5%, a calcium content of 0.12%, and a phosphorus content of 0.04% [15]; [16]. Their high cellulose content presents an opportunity for development as a raw material for biodegradable bioplastics [9]; [10]. To obtain pure cellulose, a delignification process is necessary to remove lignin, resulting in cellulose as the primary component [17]; [18]. Given that corn production in Lampung reached 1,107,739 tons in 2024 and continues to rise, the amount of corn cob waste generated is also increasing [19].

Chitosan is a polysaccharide derived from the deacetylation of chitin, which comes from the shells of crustaceans like shrimp and crabs. It possesses antimicrobial properties that can inhibit the growth of both Gram-positive and Gram-negative bacteria [20]; [21]. This antimicrobial action occurs as chitosan binds to peptidoglycan and cell proteins, damaging the microbial membrane and causing leakage of the cell's cytoplasm [22]; [23]. Furthermore, chitosan is considered safe for use in food products since it does not alter the color or aroma of the food and is soluble in weak acids, such as acetic acid [24]; [25]. Additionally, chitosan has the potential to enhance the mechanical properties and water resistance of bioplastics, as well as extend the shelf life of food products [26].

1.3. Research Objective

This study aimed to utilize bioplastics derived from corn cob cellulose and chitosan as active packaging to mitigate the deterioration of pempek during storage.

2. MATERIALS AND METHODS

The research on the application of bioplastics with the addition of corn cob cellulose as active packaging for pempek products was conducted at the Agro-Industry Laboratory of the Lampung State Polytechnic from July to October 2025. The materials, tools, and research procedures are described as follows:

2.1. Research Materials

The research materials were corn cobs, NaOH, ethanol, H_2O_2, cassava starch, chitosan, acetic acid, glycerol, distilled water, PCA media, NaCl, and pempek.

2.2. Research Tools

The tools used in this study included a disk mill, autoclave, incubator, pH meter, digital scale, analytical balance, 100-mesh sieve, hotplate, stirrer, beaker glass, measuring cylinder, volumetric flask, Erlenmeyer flask, graduated pipette, bulb, petri dish, and test tube.

2.3. Research Procedures

The research was designed to compare pempek without packaging (control) and those with bioplastic packaging. Three replications were conducted and analyzed using a T-test to determine differences between treatments. The research stages consist of extracting cellulose from corn cobs, producing bioplastic, applying bioplastic to pempek products, and conducting Total Plate Count (TPC) and pH tests.

2.3.1. Corn Cobs Cellulose Extraction

Cellulose extraction, based on research [27], used a modified organosolv method. Dried corncobs were ground using a disk mill and then sieved through a 40-mesh sieve. 100 grams of corncob powder was extracted using a 40% solvent mixed with 3.5% NaOH at a 1:5 (w/v) ratio. The mixture was heated at 70°C for 60 minutes. Afterward, it was cooled to room temperature for 30 minutes, rinsed with distilled water, and filtered until the pH was neutral. Then, it was bleached with 10% H_2O_2 and heated at 60°C for 60 minutes, followed by rinsing until the pH was neutral. The mixture was then dried in an oven at 50°C for 6 hours, ground to a powder in a blender, and sieved through a 100-mesh sieve to obtain cellulose powder.

2.3.2. Bioplastic Production

The bioplastic production technique uses solution casting [28]. The solution-casting technique involves moulding the bioplastic onto a glass plate and drying it at 55°C for 5-6 hours. The composition ratio used in bioplastic production is 50% cellulose and 50% chitosan. This composition is derived from the best formulation [29]. Additionally, 2% (w/v) glycerol is added to the bioplastic to increase its elasticity.

2.3.3. Application of Bioplastic in Pempek Products

Ten grams of pempek products were packaged in bioplastic and stored at room temperature, and observations were made from day 1 to day 4.

2.3.4. Total Plate Count (TPC)

The TPC test, as described by [30], complies with SNI 332.3:2015. A 5-gram sample, reduced in size, is added to 45 mL of sterile 0.85% NaCl solution and homogenised (10^{-1} dilution). The first dilution is then pipetted with a sterile pipette and transferred to a test tube containing 9 mL of NaCl solution, and the mixture is homogenised (10-2 dilution). The same procedure is then repeated for dilutions 10^{-4}, 10^{-5}, and so on, depending on the sample's condition. 1 mL of the sample from the last two dilutions is then pipetted into a sterile Petri dish, and 12-15 mL of Plate Count Agar (PCA) medium is added. The dish is then rotated back and forth and left and right to ensure complete mixing. The plates were then incubated upside down in an incubator at 35°C ± 1°C. The total microbial count was then recorded and calculated using the following formula:

$$N = \frac{\sum C}{[(1xn_1) + (0{,}1xn_2)]x\ (d)}$$

Description:

N = Number of sample colonies (colonies/gram)

∑C = Number of colonies counted in all plates

n_1 = Number of plates counted in the first dilution

n_2 = Number of plates counted in the second dilution

d = First dilution counted

2.3.5. pH

The pH test was based on hydrogen-ion activity, measured potentiometrically with a pH meter, as described in[31]. The pH test was conducted according to SNI 6989.11:2019, namely by weighing 1 gram of the pempek sample packaged in bioplastic, mashing it, and dissolving it in distilled water at a ratio of 1:10. Next, the solution was tested with a pH meter calibrated with a buffer solution.

3. RESULT AND DISCUSSION

Pempek is a fish-based food product with high water and protein content, making it highly susceptible to spoilage and microbial growth [32]. Unpackaged pempek shows a significant increase in total microbial counts over a short period, necessitating packaging technology that can slow spoilage. One widely developed innovation is bioplastic active packaging made from chitosan and corncob cellulose, which has antimicrobial properties and inhibits oxidation rates. Chitosan is a natural polymer with strong antimicrobial activity [33], while corncob cellulose serves as a biopolymer matrix that enhanc the mechanical strength of the plastic and supports the gradual release of active compounds [34]. Table 1 presents a comparison between pempek products packaged with bioplastic active packaging and those packaged without (control).

Table 1. Microbial development of pempek products

Treatment	Day-1	Day-2	Day-3	Day-4
Control (without packaging)				
Packaging with bioplastic				

Table 1 shows the development of microbial colonies in pempek during storage from day 1 to 4. In the control treatment (without packaging), the number of colonies increased significantly from day 1 to 4. On the first day, several creamy white colonies of varying sizes were observed, while on days 2 and 3, the colonies became denser and covered almost the entire surface of the medium. On day 4, the colonies appeared very numerous and large, covering nearly the entire plate. This evidence indicates uncontrolled microbial growth in pempek without packaging protection.

Meanwhile, samples packaged with bioplastic showed fewer colonies on each observation day. On days 1 to 3, the colonies appeared smaller, sparser, and less dense than the control. On day 4, the number of colonies increased, but their size and density remained much lower than in the control. This study demonstrates that the use of bioplastic with active packaging can suppress microbial growth during storage [35].

The colonies in the picture look like a group of spoilage bacteria that are often found in fish products. Creamy white colonies with smooth edges and a large, round shape likely represent Gram-negative bacteria such as Pseudomonas spp., which are very common causes of spoilage in fish and processed fish products [36]. Smaller, coccus-shaped, dense white, and shinier colonies may indicate Gram-positive bacteria such as Staphylococcus [37] or Micrococcus spp. [38]. Meanwhile, some larger colonies with uneven surfaces may be Bacillus spp., which are often found in high-protein foods [39]. Table 1 shows no dark or filamentous colonies, indicating that bacteria were dominant in this sample. Overall, colony morphology indicates that the active bioplastic can inhibit the growth of spoilage microbes in pempek.

3.1. Total Plate Count

The Total Plate Count (TPC) test was conducted according to SNI 332.3:2015. This test determines the safety and quality of pempek during storage under two treatments: unpackaged (control) and bioplastic active packaging. TPC test results can indicate the growth rate of spoilage microbes, thus demonstrating how quickly pempek deteriorates [40]. A significantly higher TPC value in the control indicates that pempek without protection quickly becomes contaminated, while a lower TPC value in bioplastic packaging demonstrates the effectiveness of active ingredients such as chitosan and cellulose in inhibiting microbial growth [41]. TPC serves as a quantitative indicator for assessing the safety, shelf life, and effectiveness of active bioplastic in slowing the deterioration of pempek. The TPC test results are shown in Table 2.

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Table 2. Total plate count result

Day	Average Colony Count (CFU/g)		p-value	Description
	Control (No Packaging)	Bioplastic Packaging		
1	4.3 x 10^7	2.0 x 10^7	0.145	Not significantly different
2	2.1 x 10^9	2.8 x 10^8	0.000	significantly different
3	2.3 x 10^9	6.8 x 10^8	0.000	significantly different
4	4.2 x 10^{11}	2.9 x 10^{10}	0.000	significantly different

Table 2 shows that the total microbial count test results on pempek showed a clear difference between the control sample (no packaging) and pempek packaged with bioplastic active packaging. On the first day, the total microbial counts for both treatments were relatively similar at 4.3×107 CFU/g and 2.0×107 CFU/g, respectively, and the T-test showed no significant difference. This indicates that the initial conditions of the pempek products remained similar. However, starting on days 2, 3, and 4, the control showed a much faster increase than the pempek packaged in bioplastic. This conclusion demonstrates the active role of the chitosan and cellulose components in suppressing microbial growth.

On day 2, microbial growth in the control reached 2.1×10^9 CFU/g, while in the bioplastic it was only 2.8×10^8 CFU/g. The difference increased significantly on day 3, reaching 2.3×10^9 CFU/g (control) and 6.8×10^8 CFU/g (bioplastic). The control count was 4.2×10^{11} CFU/g and the bioplastic count was 2.9×10^{10} CFU/g on day 4. A T-test showed a significant difference from day 2 to day 4, demonstrating the effectiveness of active packaging in slowing microbial contamination. Chitosan has a positive charge that can damage the cell walls of both Gram-negative and Gram-positive bacteria [42], while cellulose provides a stable structure that helps maintain low surface moisture in food, creating less-than-eal conditions for microbial growth [43].

SNI 01-3819-1995 says that the maximum total microbial count (TPC) for ready-to-eat processed fish products is between 1×10^5 and 1×10^6 CFU/g. The TPC test showed that both the control and the bioplastic went over this limit from day one. The only difference is the rate of microbial growth. On each observation day, bioplastics made from cellulose and chitosan slowed microbial growth by 1 to 2 logs compared to the control. Therefore, although active packaging did not completely stabilise the microbiological quality of pempekit, it still improved the quality and extended the product's shelf life [44].

These results align with various previous studies. Research by [45] showed that chitosan bioplasticreduced the total microbial load in processed fish by up to 2 logs during storage. Another study by [46] found thaadding agricultural waste cellulose improved the film's mechanical performance while controlling the release rate of the active antimicrobial components. Recent research on Cazon fish fillets by [47] showed that chitosareduced the total microbial load by 30-50% compared to the control. Thus, the results obtained in this study are consistent with research trends indicating that the combination of cellulose and chitosan is effective as an environmentally friendly active packaging material and canxtend the shelf life of high-protein food products [48].

3.2. pH

pH testing of pempek products is used to assess the product's freshness and safetyuring storage [41]. According to the Indonesian National Standard for Pempek (SNI 7661:2019), quality assessment places greater emphasis on organoleptic and microbiological aspects, but pH changes remain an important indicator in identifying deterioration processes or microbial activity during storage. Therefore, pH testing is necessary to understand the effectiveness of packaging on pempek quality stability. The results of the pH test on pempek products are shown in Figure 1.

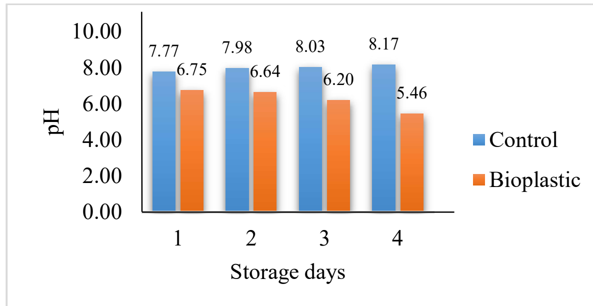

Fig 1. Results of the pH test on pempek products

Based on the test results, the control sample (without packaging) showed a pH increase from 7.77 on the first day to 8.17 on the fourth day. Conversely, pempek packaged in bioplastic with active packaging showed a decrease in pH from 6.75 to 5.46 during the same period. The T-test results indicated that the difference in pH between the two treatments was significant across all observation days. The increase in pH in the control samples reflects the activity of proteolytic bacteria, which break down proteins into basic compounds, such as amines, thus increasing the pH. This trend is common in fishery products stored without protective packaging [49].

In samples packaged using bioplastics, the decrease in pH indicates the influence of active packaging components, which suppress the activity of spoilage microorganisms. Some types of active bioplastics typically contain antimicrobial compounds, antioxidants, or organic acidthat can inhibit the growth of spoilage bacteria [50]. Also, the packaging conditions are relatively closed, which allows acid-forming microorganisms, such as lactic acid bacteria (LAB), to thrive. These microorganisms make acidic metabolites, which tend to lower the pH [51]. This conclusion is consistent with other studies reporting that the use of starch-, cellulose-, and chitosan-based bioplastics can slow the deterioration of fishery products and maintain chemical parameters, including pH, for longer periods [52].

From a food safety perspective, products with a pH near neutral to alkaline (pH > 6) are more likely to support bacterial growth that canpoil food [53]. Meanwhile, lower pH conditions (around 5–5.5) can slow the activity of certain microbes and help extend shelf life, although they do not necessarily guarantee safety without support from other parameters, such as total microbial counts and organoleptic quality [41]. The relatively lower pH in the bioplastic samples indicates the potential of active packaging to maintainhe quality of pempek during storage [54].

Overall, the results of this study are consistent with various studies reporting the effectiveness of bioplastics and active packaging in delaying the deterioration of fish-based products. The differences in pH change patterns between control and bioplastic samples indicate that the use of active packaging can inhibit protein degradation and the formation of alkaline compounds [55]. However, to ensure food safety, TVB-N analysis and organoleptic evaluation are necessary. These results reinforce the potential of active bioplastics as a safer, more effective packaging alternative to maintain the quality of pempek during storage.

4. CONCLUSION

Bioplastics, combined with corn cob cellulose and chitosan, can effectively serve as active packaging for pempek products. The results of the Total Plate Count (TPC) test showed that bioplastics significantly suppressed microbial growth rates from the 2nd to the 4th day of storage, with colony counts 1–2 logs lower than in the control without packaging. The antimicrobial activity of chitosan and the biopolymer matrix properties of cellulose help inhibit contamination and slow the deterioration of pempek. The pH test results showed that pempek packaged with bioplastic decreased from 6.75 to 5.46, indicating limited spoilage microbial activity, whereas pempek without packaging increased in pH due to protein decomposition. The use of active bioplastics derived from corn cob cellulose can extend shelf life, improve microbiological safety, and maintain the quality of pempek during storage, potentially making them an effective, environmentally friendly packaging alternative for high-protein food products.

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