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Synthesis of Biocomposite of Kappa Carrageenan and Polyvinyl Alcohol for Bioplastic

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Abstract: This research investigates the effect of incorporating kappa carrageenan and chitosan into biocomposites composed made from kappa carrageenan and polyvinyl alcohol, crosslinked with glutaraldehyde. The objective is to characterize the resulting biocomposites films and determine the optimal formulation based on mechanical properties and swelling behavior. The film were fabricated using the solution casting method, with varying concentrations of kappa carrageenan (3%, 4%, and 5% w/v) and chitosan (1.32%, 1.76%, and 2.2% w/v). Characterization was performed using Fourier Transform Infrared Spectroscopy (FTIR), water absorption testing, tensile strength analysis, and elongation measurements. The results showed that the addition of kappa carrageenan improved water resistance and tensile strength. Most biocomposite film samples met the National Standard for tensile strength in bioplastic applications, except for the formulations containing 3% kappa carrageenan with 1.76% chitosan and 5% kappa carrageenan with 2.2% chitosan, which did not meet the standard.

Keywords: Biocomposites, Kappa carrageenan, Solution casting, Chitosan

Introduction

Plastic is a synthetic material produced through the polymerization of various chemical compounds, typically derived from petroleum, natural gas, or other natural resources. Its widespread use is attributed to favorable properties such as strength, durability, formability, and relatively low production costs. Commonly used plastics include polyethylene, polypropylene (PP), polyvinyl chloride (PVC), polystyrene, and polyethylene terephthalate (PET). In Indonesia, the average annual plastic consumption per person is approximately 22.5 kg, which is lower compared to neighboring countries like Thailand, Malaysia, and Singapore, where consumption exceeds 60 kg per person. Most plastics are utilized in the packaging industry, particularly for food, beverages, and household products. According to the Directorate of Downstream Chemical and Pharmaceutical Industry, Indonesia produces 2.31 million tons of plastic annually, while national demand reaches 5.63 million tons (Ministry of Environment and Forestry, 2020).

Plastic waste, particularly from non-biodegradable materials, poses a significant environmental challenge. Some plastics take more than 400 years to decompose, breaking down into persistent microplastics. Indonesia generates an estimated 3.2 million tons of unmanaged plastic waste annually (Jambeck et al., 2015). This leads to soil and water contamination, with microplastics disrupting ecosystems and reducing soil fertility. One approach to managing this issue is through open-air waste processing facilities, such as the Integrated Waste Treatment Site (TPST) in Bantar Gebang, which processes up to 7,000 tons of waste per day. This samples from

this facility have been found to contain 6,061 microplastic particles per kilogram, underscoring the environmental urgency of reducing plastic pollution (Tun et al., 2022).

In response to these concerns, research has increasingly focused on developing biodegradable alternatives, such as bioplastics. Biocomposites—combinations of two or more natural materials—offer improved functional properties by leveraging the synergistic strengths of their components. In this study, PVA is used as the matrix polymer due to its thermoplastic behavior and hydrophilic characteristics resulting from a high content of hydroxyl groups. Kappa carrageenan is incorporated to enhance mechanical strength and water interaction properties. Chitosan is added as a natural filler with antimicrobial activity, while glutaraldehyde is used as a crosslinking agent to improve structural integrity by facilitating hydrogen bonding between the polymers. This combination aims to produce a biodegradable plastic film with balanced mechanical strength, water resistance, and environmental compatibility.

Methods

This research was conducted through several key stages, including the determination of kappa carrageenan and chitosan concentration variations, film preparation via solution casting, and comprehensive film characterization. The characterization involved Fourier Transform Infrared Spectroscopy (FTIR), swelling behavior analysis, mechanical strength testing (tensile strength and elongation), and a biodegradability assessment in soil.

Variations of Kappa Carrageenan and Chitosan Concentrations

The compositions of kappa carrageenan and chitosan used in the biocomposite films are listed in Table 1. Polyvinyl alcohol (PVA) was maintained at a constant concentration of 11% (w/v) across all samples, while the concentrations of kappa carrageenan and chitosan were varied. A 0.5% (w/v) glutaraldehyde solution was included as a crosslinking agent in selected formulations.

Table 1. Variation of concentration used in biocomposite film

Code	Kappa Carrageenan (%w/v)	PVA (%w/v)	Chitosan (%w/v)	Glutaraldehyde (%w/v)
A	-	11	1.32	
B	-	11	1.76	0.5
C	-	11	2.2	
D	3	11	1.32	
E	3	11	1.76	0.5
F	3	11	2.2	
G	4	11	1.32	
H	4	11	1.76	0.5
I	4	11	2.2	
J	5	11	1.32	
K	5	11	1.76	0.5
L	5	11	2.2	

Biocomposite Film Preparation via Solution Casting

To prepare the biocomposite film, 3 grams of PVA powder were dissolved in 27.3 mL of distilled water and stirred at 90°C for 1 hour. Chitosan (0.3 grams, 0.4 grams, and 0.5 grams) was separately dissolved in 22.7 mL of a 2% (v/v) acetic acid solution at room temperature for 2 hours. The PVA and chitosan solutions were then combined and stirred at 60°C for 1 hour. A 0.5% Glutaraldehyde (GA) solution was prepared by diluting 0.4 mL of a 25% (w/v) GA solution with 19.6 mL of distilled water and stirred at room temperature for 1 hour. This GA solution was added to the PVA-chitosan mixture and stirred at room temperature.

Kappa Carrageenan (KC) powder was sieved using a 100-mesh sieve. Weighed amounth (3 grams, 4 grams, and 5 grams) of KC powder were dissolved in 100 mL of distilled water at room temperature for 1 hour. Then, the KC solution was heated to 50°C to dissolve the KC completely dissolved. The KC solution was mixed with the

PVA/Chitosan/Glutaraldehyde solution at 50°C for 1.5 hour to obtain a homogeneous blend. The PVA/Chitosan/GA/KC solution (25 mL) was poured into petri dishes (100 mm diameter, 15 mm in height) and dried in an oven at 60°C for 12–24 hours to form biocomposite films.

FT-IR Characterization Test

The Fourier Transform Infrared (FTIR) technique is used as one of the characterizations for testing Kappa Carrageenan biocomposite samples with the aim of qualitatively identifying functional groups within the synthesized samples. FTIR measures the absorption of infrared radiation by each molecule in the sample, resulting in an infrared spectrum pattern that can be analysed based on the types of chemical bonds formed between atoms at unique vibrational frequencies. The FTIR instrument used for this testing is the Thermo Scientific Nicolet iS5 FTIR Spectrometer, employing the Attenuated Total Reflectance (ATR) method. A sample mass of 0.1 grams of the biocomposite film is prepared. This testing instrument is conducted using equipment located in the Integrated Chemistry Laboratory at the University of Pertamina.

Swelling Test

The swelling test on the biocomposite film samples is conducted using distilled water with a neutral pH of 7. Each film sample was cut into strips with dimensions of 3 cm × 1 cm. The initial dry mass (W_0) of each sample was measured prior to immersion. The samples were then placed in 25 mL of distilled water within sealed glass bottles and soaked for 7 hours. The swollen samples were removed at hourly intervals, blotted to remove surface water, and weighed to obtain the wet mass (W_s). The swelling degree was calculated using the following formula: (Costa-Júniora et al., 2009)

$$Swelling\ Degree\ (\%) = \frac{W_s - W_d}{W_d} \times 100\% \qquad (2.1)$$

Where:
Swelling Degree = Percentage of swelling film
Ws = mass of the sample at a specific time when it has swollen
Wd = mass of the sample in its dry or unswollen condition

Mechanical Strength Test

The Mechanical strength test is conducted to analyse the mechanical strength of the polymer biocomposite in response to external forces or loads applied. Tensile strength, strain at break, and Young's modulus are tested using the Universal Testing Machine AGS-G instrument, which is performed at the National Research and Innovation Agency (BRIN) for Plastics Tensile Test. The testing is carried out once and operates at a crosshead speed of 50 mm/min, a relative humidity of 54.40%, a temperature of 22.7 °C, and a gripped length of 25 mm. The film samples adhere to ASTM D882 standards. This testing method is used to determine how thin plastic sheets or films (with a thickness of less than 1.0 mm) can be stretched. The width should be at least 5.0 mm but not more than 25.4 mm, with a length that is 8 times longer than the width of the sample. Therefore, the sample size for this test is 8 cm in length and 1 cm in width (Markets, 2017).

Results and Discussion

Morphology

In this study, the polymers Polyvinyl Alcohol (PVA) and Kappa Carrageenan (KC) functioned as the primary matrices for biocomposite film synthesis using the solution casting method. Polyvinyl Alcohol (PVA) is a polymer material that acts as the continuous phase, or matrix, in the composite. PVA is hydrophilic, meaning it is water-absorbent, but it has good flexibility due to its high degree of hydrolysis, indicating a high content of O-H groups (Soeda, Yamagata, & Ishikawa, 2009). Kappa Carrageenan (KC) acts as a matrix to improve the hydrophilic properties of PVA and enhance the stiffness of the film (Ramadas, Rhim, & Roy, 2024). Chitosan was incorporated as a natural filler to improve antimicrobial properties and structural strength (Ke et al., 2021). Glutaraldehyde (GA) was employed as a crosslinking agent to strengthen intermolecular interactions between

PVA, KC, and chitosan (Migneault, Dartiguenave, Bertrand, & Waldron, 2004). Acetic acid (2% v/v) was used to dissolve chitosan, while distilled water served as the solvent for PVA, KC, and GA. The main experimental variables were the concentrations of Kappa Carageenan and chitosan.

The synthesis began with the mixing of 11% (w/v) solution of PVA with a 1.32% (w/v) chitosan solution, stirred at 60°C for 1 hour using a magnetic stirrer until a homogeneous mixture was obtained. Hydrogen bonding occurred between the hydroxyl groups of PVA and the functional groups of chitosan show in Fogure 1. The mixture was cast into petri dishes and dried in an oven at 60°C for 8 hours to form clear, elastic films with smooth surfaces.

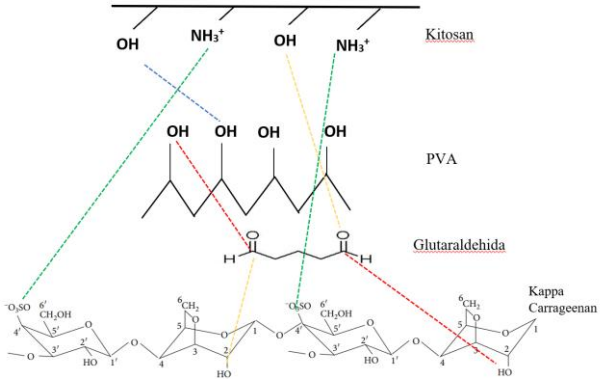

Figure 1. The functional group interactions between PVA kappa carrageenan, chitosan and GA

Subsequently, a 0.5% v/v glutaraldehyde (GA) solution was added to the PVA/chitosan mixture at room temperature and stirred for 1 hour. The GA served as a crosslinking agent to strengthen the bonds between the Kappa Carrageenan matrix and the PVA matrix, as well as the chitosan filler. A crosslinking agent is a chemical compound with two or more active functional groups that can crosslink two or more different chemical compounds, altering the chemical and physical properties of polymer networks. In this case, the hydroxyl groups in glutaraldehyde crosslink with the hydroxyl groups in PVA, Kappa Carrageenan, and chitosan, as depicted in Figure 1 below. The crosslinking agent GA forms a more complex polymer structure, thereby enhancing the mechanical properties of the film sample (Distantina, Noviyanti, Sutriyani, Fadilah, & Kaavessina, 2017; Li et al., 2020; Rojas, 2015). The drying process for the biocomposite film samples from the mixture of PVA/Chitosan/GA/KC is carried out at 60°C for a duration of 8-24 hours until the samples have a dry texture and can be peeled off. Based on observations, biocomposite film samples with an increased composition of Kappa Carrageenan exhibit a stiffer, harder, and yellowish-white appearance compared to control film samples with PVA and chitosan composition, which are flexible and clear in colour.

(a) (b)

Figure 2. The synthesis results of biocomposite film samples (a) PVA/chitosan (b) KC/PVA/chitosan/GA

Functional Groups Analysis

The kappa carrageenan biocomposite samples were analysed using FTIR spectra to determine the structural changes in the biocomposite film before and after the addition of the crosslinking agent. Figure 3 shows the FTIR spectra of the control film samples with the matrix composition of Polyvinyl Alcohol and the chitosan filler, compared to the film samples filled with Kappa Carrageenan matrix and the crosslinking agent

glutaraldehyde. The FTIR spectrum of the control sample containing PVA/Chitosan displays strong O-H stretch functional groups that broaden in the range between 3550-3200 cm^{-1} and N-H stretch functional groups for intramolecular and intermolecular structures of hydroxyl and primary amine groups in Polyvinyl Alcohol compounds. The FTIR spectrum of the PVA/Chitosan blend at a peak around 1640 cm^{-1} exhibits symmetric deformation of N-H bending functional groups as NH_3^+ groups, generated from the ionization of primary amino groups in an acidic medium. Furthermore, in the range of 1421-1440 cm^{-1}, O-H bend functional groups are identified, characteristic of carboxylic acid functional groups. Therefore, it can be concluded that Polyvinyl Alcohol reacts and combines with chitosan (Abdeen, 2011; Chopra et al., 2022; El-Hefian, Nasef, & Yahaya, 2010).

At peaks around 2850-3000 cm^{-1}, C-H stretch functional groups in aldehydes are shown, and the doublet absorption is identified to alkyl chains. At peaks around 1210-1260 cm cm^{-1}, sulphate S=O functional groups are present, and in the range of 1005-1080 cm^{-1}, glycosidic bonds are identified, which originate from the content of Kappa Carrageenan. The appearance of other peaks, specifically at 843-805 cm^{-1}, is characteristic of 3,6-anhydrogalactose-2-sulfate, a galactose unit bound by glycoside and a distinctive feature of Kappa Carrageenan. In Kappa Carrageenan, 3,6-anhydrogalactose-2-sulfate is a type of galactose unit that contains sulphate groups ($SO3^-$) and plays an essential role in forming a three-dimensional structure and a strong gel when this compound is hydrated (Hilliou et al., 2006; Mendoza et al., 2006; Pereira et al., 2009; Webber et al., 2012).

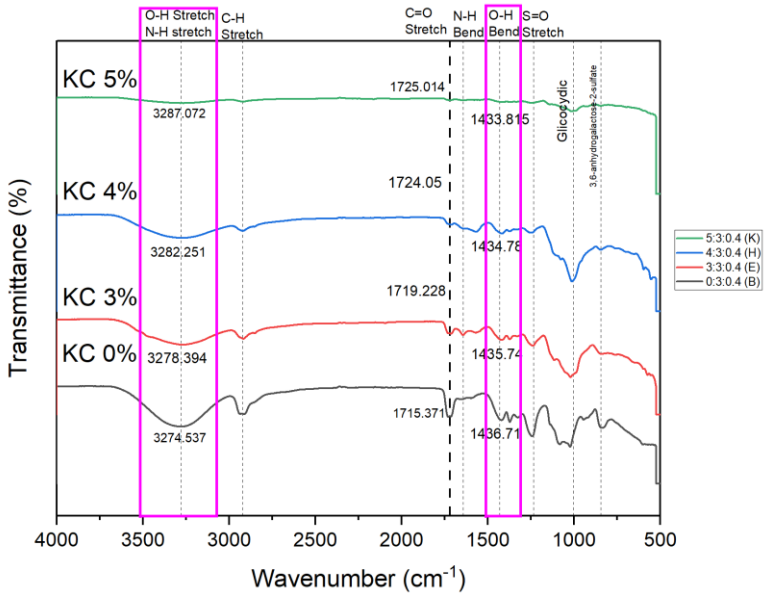

Figure 3. FTIR spectra of the kappa carrageenan addition in biocomposite PVA and chitosan

In the spectrum of samples containing Kappa Carrageenan (KC) at 3-5% w/v, structural changes in the biocomposite due to the addition of the crosslinking agent Glutaraldehyde (GA) are observed. Crosslinking reactions between glutaraldehyde, Kappa Carrageenan, and PVA occur through interactions of hydroxyl (OH) groups in each compound, as shown in Figure 3. Interactions between these compounds increase the intensity of O-H group absorption in the range of 3500-3200 cm^{-1}. However, based on the FTIR results, a reduction in the intensity of the O-H stretch peak is observed at compositions of Kappa Carrageenan 0%, 3%, 4%, and 5% in the absorption range of 3274.5 cm^{-1}, 3278.4 cm^{-1}, 3282.2 cm^{-1}, and 3287.1 cm^{-1}, respectively. On the other hand, in the fingerprint region for free hydroxyl (OH) groups, the intensity of the peak is reduced in compositions of Kappa Carrageenan 0%, 3%, 4%, and 5% in the absorption range of 1436.7 cm^{-1}, 1435.7 cm^{-1}, 1434.7 cm^{-1}, and 1433.7 cm^{-1}. Therefore, it can be concluded that the hydroxyl groups from Kappa Carrageenan, PVA, and chitosan are bound to the hydroxyl (OH) groups. This is also consistent with research conducted by (Tan et al., 2021), where the hydroxyl groups of PVA at 3251 cm^{-1} weaken after modification with Chitosan, Nanocrystalline cellulose, and tannic acid, which simultaneously interact with free hydroxyl (-OH) groups in the absorption range of 1411-1500 cm^{-1}, resulting in reduced peak intensity.

In the study by Distantina et al. (2017), Glutaraldehyde crosslinks OH groups from PVA with OH groups from Kappa Carrageenan through aldehyde groups (H-CH=O), leading to the appearance of peaks for new functional groups resulting from chemical crosslinking (CH_3CO^-). However, based on the FTIR results in Figure 3, the new functional groups formed due to the crosslinking agent glutaraldehyde cannot be identified. Therefore, the

addition of Kappa Carrageenan and chitosan to Polyvinyl Alcohol with the crosslinking agent glutaraldehyde results from physical mixing by combining functional groups from each component.

Swelling

Swelling Test in Kappa Carrageenan biocomposite film to analyse the interactions and absorption capacity between the film and a specific liquid or solvent. In this study, the film samples were immersed in distilled water at pH 7 for 7 hours, and the mass of the film samples was regularly checked every hour. Figure 4 and Figure 5 shows the results of water absorption tests on biocomposite film samples with variations in the addition of chitosan composition and Kappa Carrageenan composition.

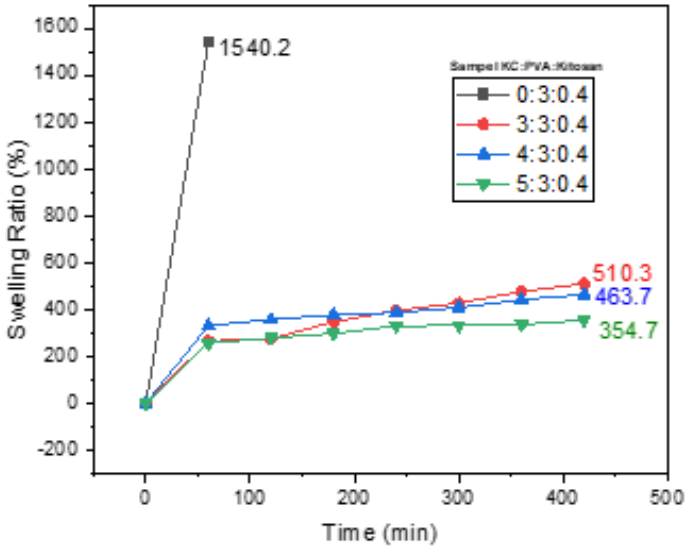

Figure 4. Swelling degree result after addition of kappa carrageenan in biocomposite film composition

Based on the graphs in Figure 4 the swelling degree of biocomposite films containing varying concentrations of kappa carrageenan. The control sample (PVA/chitosan, 0% KC) showed the highest swelling percentage, reaching 1540.2% within the first hour. All samples without KC fully disintegrated in water after 1 hour of immersion. This behavior is attributed to the hydrophilic nature of PVA, which possesses abundant free hydroxyl groups that readily form hydrogen bonds with water molecules. This is also consistent with FTIR results, where the control film exhibited a broad O–H peak between 3500–3200 cm^{-1}, indicating a high concentration of free hydroxyl groups.In contrast, films containing KC exhibited significantly lower swelling percentages and maintained their structural integrity throughout the test duration. This reduction in water absorption is due to the formation of hydrogen bonds between the hydroxyl groups of KC and PVA, which were further strengthened by glutaraldehyde crosslinking. The resulting crosslinked network limited water penetration and created a more compact film matrix.

Figure 5 shows the swelling behavior of samples with a constant KC concentration (5% w/v) and varying chitosan contents. The sample with 0.3% chitosan had the highest swelling among the three, while increasing chitosan to 0.4% and 0.5% reduced the swelling degree. This trend is explained by the additional hydrogen bonding introduced by chitosan, which further reinforces the network and restricts water diffusion. Furthermore, FTIR data support this conclusion, as the intensity of free O–H bending vibrations around 1430–1440 cm^{-1} decreased with the addition of KC and chitosan, indicating reduced availability of free hydroxyl groups and enhanced intermolecular bonding (Shahbazi et al., 2016). These findings suggest that both KC and chitosan play crucial roles in controlling water absorption. KC contributes to structural rigidity and reduced swelling, while chitosan enhances internal cohesion through hydrogen bonding, leading to improved film stability in aqueous environments

Furthermore, Kappa Carrageenan, as a matrix with hydroxyl groups, will interact more with the hydroxyl groups of PVA through crosslinking with glutaraldehyde, reducing the interaction between PVA polar groups and water molecules. The crosslinking between PVA and Kappa Carrageenan chains with the crosslinking agent glutaraldehyde results in a relatively rigid structure that restricts water's access to hydrophilic groups. This is also visually evident after 7 hours of swelling, samples with KC content swelled but still retained their film strip

shape. Additionally, the reduction in swelling percentage is also due to chitosan's role as a filler in the Kappa Carrageenan biocomposite, creating full hydrogen bonds within its constituent components, reducing the penetration of water molecules into the biocomposite film. This is also identified in the FTIR results with the addition of Kappa Carrageenan, resulting in a reduction in the peak intensity of free O-H groups in the range between 1430-1440 cm^{-1}, indicating the formation of bonds between the free hydroxyl (-OH) groups of PVA and the hydroxyl groups in Kappa Carrageenan and chitosan with the assistance of the aldehyde groups in glutaraldehyde as the crosslinker agent.

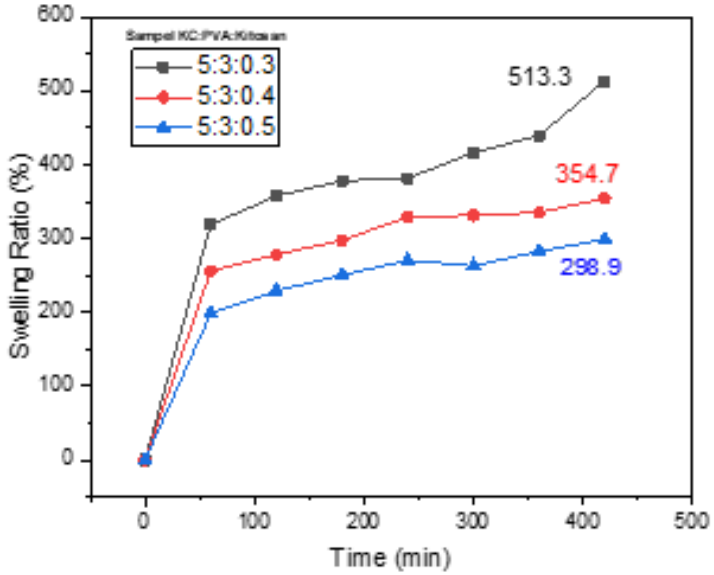

Figure 5. Swelling degree result after addition of chitosan in biocomposite film composition

Mechanical Strength

The mechanical strength test of Kappa Carrageenan biocomposite film samples includes tensile strength, elongation at break, and Young's modulus. Figure 6 and figure 7 shows the differences in material tensile strength and elongation values in samples with variations in chitosan composition and Kappa Carrageenan composition.

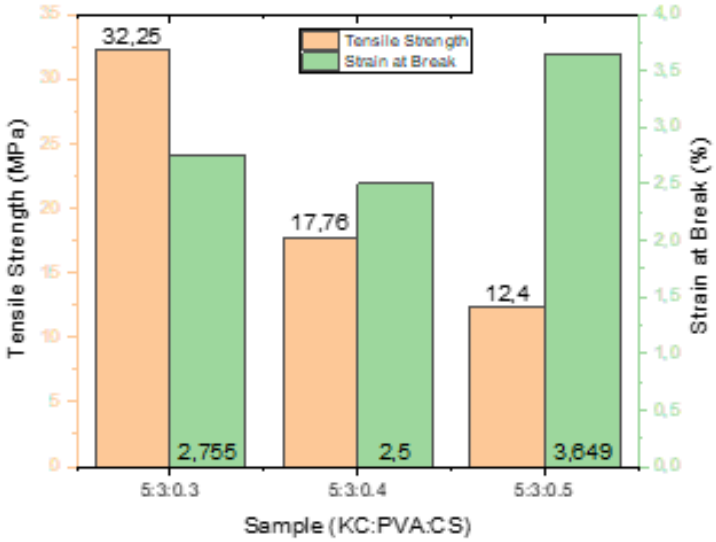

Figure 6. Tensile strength and elongation (strain at break) result after addition of chitosan in biocomposite film composition

Based on the graphs in Figure 6, the addition of chitosan composition to Kappa Carrageenan biocomposite film samples will increase the Strain at Break, which is the maximum length value of the film sample when subjected

to a load before breaking during the tensile test. The test results indicate that flexibility increases with the addition of chitosan. This is contrary to the intended purpose of adding chitosan to the biocomposite film as a filler to improve tensile strength and stiffness in the blending process of the Polyvinyl Alcohol matrix with the natural Kappa Carrageenan matrix. This is also consistent with the results of research conducted by (Shahbazi, Rajabzadeh, Rafe, Ettelaie, & Ahmadi, 2017), where the addition of Kappa Carrageenan and chitosan increased the stiffness of the blended film due to hydrogen bonding between the hydroxyl groups of PVA, Kappa Carrageenan, and chitosan. The inconsistency between tensile strength and elongation test results in this study is influenced by excessive crosslinking between the hydroxyl groups of each component. Excess chitosan molecules will localize in different phases than the polymer phase. Chitosan molecules that are not crosslinked between glutaraldehyde, Kappa Carrageenan, and PVA will inhibit the formation of intermolecular bonds in the polymer due to the steric hindrance of free hydroxyl groups of chitosan with the hydroxyl groups of PVA, Kappa Carrageenan, and interacting glutaraldehyde. This is the cause of decreased bond strength and increased elongation percentage (Alias & Ismail, 2020; Maghfiroh et al., 2013).

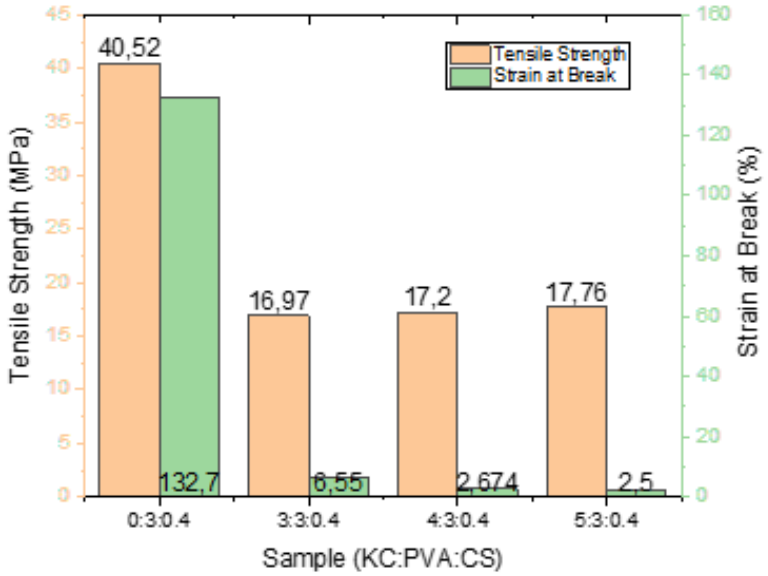

Figure 7. Tensile strength and elongation (strain at break) result after addition of kappa carageenan in biocomposite film composition

Based on figure 7, the effect of increasing KC concentrations in films with a fixed chitosan level (0.4% w/v). The addition of KC generally led to improved tensile strength, with a peak value of 40.52 MPa observed in the sample without KC (0% KC), followed by a moderate decrease in strength as the KC content increased to 5%. However, a notable decline in elongation at break was observed across all samples containing KC, with values falling below 10%. This trend suggests that the presence of KC contributes to the stiffness and rigidity of the films due to its ability to form dense hydrogen-bonded networks with PVA, enhanced further by crosslinking with glutaraldehyde. The reduced flexibility is attributed to a more compact and less mobile polymer structure. The PVA used in this study has a high degree of hydrolysis (88–89%), which provides more hydroxyl groups for hydrogen bonding. At elevated temperatures (60–80°C), the PVA-KC chains form a randomly entangled structure that transforms into a denser, coil-like configuration upon cooling, resulting in a stronger and stiffer film matrix. This is also identified in the FTIR results with the addition of Kappa Carrageenan, showing reduced peak intensity iin the O-H bending region (1430-1440 cm^{-1}), which indicates the formation between the free hydroxyl (-OH) groups of PVA reacting with the hydroxyl groups in chitosan and also Kappa Carrageenan crosslinked with the aldehyde groups in glutaraldehyde (Shahbazi et al., 2016; Tan et al., 2021). Based on the results of the mechanical strength test for biocomposites, the test results can be compared with the Indonesian National Standard (National; 2014) for bioplastic degradation category as follows:

Table 2. Indonesia national standard of biocomposite

SNI **No. 7818:2014**	Tensile Strength (Mpa)	Elongation (%)
Bioplastic	Min 13.7	400-1120%

However, the biocomposite film samples without the addition of kappa carrageenan exhibited the highest tensile strength compared to those containing kappa carrageenan. This observation is attributed to differences in the film formation process. Specifically, the extended drying time employed in the control sample preparation

ranging from 72-120 hours at 25°C and 24 hours at 40°C likely facilitated molecular rearrangement within the polymer matrix. This prolonged drying period promoted the development of a more ordered structure, increased crystallinity, and ultimately enhanced the film's mechanical strength (Costa-Júniora et al., 2009).

According to the Indonesian National Standard (SNI No. 7818:2014), bioplastic films must exhibit a minimum tensile strength of 13.7 MPa and an elongation percentage between 400–1120% to be classified under the degradable plastic category. Based on the mechanical test results (Table 3), most biocomposite films met the tensile strength requirement, except for the formulations containing 3% KC with 1.76% chitosan and 5% KC with 2.2% chitosan. However, none of the samples satisfied the elongation criteria, indicating that while the films are strong, they lack the flexibility required by the standard. All biocomposite film samples have not met the national standard for the elongation percentage of bioplastic.

Table 3. Results of the mechanical strength test for biocomposites

Sample (KC:PVA:CS)	Thickness (mm)	Tensile Strength (Mpa)	Elongation (%)
0:3:0:3	0.15	38.27	106.8
0:3:0:4	0.144	40.52	132.7
0:3:0.5	0.138	40.28	82.83
3:3:0.3	0.156	40.17	2.333
3:3:0.4	0.31	16.97	6.55
3:3:0.5	0.398	11.93	2.467
4:3:0.3	0.214	19.69	1.698
4:3:0.4	0.334	17.2	2.674
4:3:0.5	0.352	24.55	3.114
5:3:0.3	0.188	32.25	2.755
5:3:0.4	0.318	17.76	2.5
5:3:0.5	0.402	12.4	3.649

Conclusion

Based on the results of the research conducted, the synthesis of Kappa Carrageenan biocomposite was successfully carried out using the solution casting method. The addition of Kappa Carrageenan and chitosan concentrations to polyvinyl alcohol with the crosslinker agent glutaraldehyde resulted from physical mixing by combining the hydroxyl functional groups of each constituent component. This led to the formation of hydrogen bonds between the components of the Kappa Carrageenan, PVA, chitosan, and glutaraldehyde. In this process, new functional groups were not formed, but the intensity of absorption of free hydroxyl groups (-OH) in the fingerprint region of 1430-1440 cm^{-1} weakened due to bonding with hydroxyl groups among the biocomposite components. The characterization test results indicate that an increase in Kappa Carrageenan concentration improves the film's resistance to water absorption adn enhances tensile strength. Thus, the concentration of Kappa Carrageenan can be a crucial factor in enhancing the performance of the biocomposite film.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

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