HYDROGEL FILMS DERIVED WATER HYACINTH STEMS and BANANA PEELS PECTIN: TENSILE PERFORMANCE AND SWELLING ABILITY

Retno Febriyanti[*], Muthia Elma[**], Iryanti Fatyasari Nata[*], Ni Kadek Devi Ananda Saraswati[***], Paskah Fransiska Afrida Simatupang[***]

[*]*Chemical Engineering Department, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia, 2120834320007@mhs.ulm.ac.id, ifnata@ulm.ac.id*

[**]*Doctoral Program of Environmental Science, Postgraduate Program, Lambung Mangkurat University, Kayutangi, Banjarmasin, South Kalimantan, Indonesia, melma@ulm.ac.id*

[***]*Materials and Membranes Research Group (M^2ReG). Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia, 1910814220015@mhs.ulm.ac.id, 1910814120013@mhs.ulm.ac.id*

Email Correspondence : melma@ulm.ac.id

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Abstract: Hydrogel films are sheet materials that form a 3D network structure and can be fabricated from one or more constituent materials. A combination of two natural polymers, namely carboxymethyl cellulose (CMC) derived from water hyacinth stems (WHS) and banana peel pectin, constructs these hydrogel films that are used as coating materials for food packaging. Citric acid replenishment to stabilize the cross-linking of the hydrogel films. This study is intended to determine the effect of WHSCMC, pectin, and citric acid on the swelling abilities and tensile performances of hydrogel films. CMC synthesis begins with harvesting water hyacinth stems obtained from the Gambut area waters in South Kalimantan, Indonesia. Then carried out the extraction and bleaching processes of cellulose. Cellulose extract powder was processed in two stages, videlicet alkalization and carboxymethylation, to obtain cellulose derivatives in the form of CMC. The results of WHSCMC were analyzed using FT-IR (*Fourier Transform Infra-Red*) and compared with commercial CMC. Giving results with significant similarity at the peaks of 998 cm^{-1} and 1015 cm^{-1}, specifically the ether glycosidic group. Fabrication of hydrogel films combines WHSCMC and banana peel pectin with various compositions (100:0, 90:10, 70:30, and 50:50 wt.%) with added citric acid as an aid for crosslinking at various concentrations (5, 10, and 15 wt.%). Hydrogel films sample 70:30, 5 wt.% (CPc-5) gave optimum results from the characterization of hydrogel films related to food packaging application coatings in the form of swelling ability of 6,647 g/g, tensile strength of 11,770 MPa, and elongation test of 11,896%. FT-IR analysis of CPc-5 indicates that there are carboxyl groups (COO-) and hydroxyl groups (-OH), which play a role in the formation of cross-links and hydrophilic properties.
Keywords: Hydrogel; Water Hyacinth; Carboxymethyl Cellulose (CMC); Banana Peels Pectin; Food Packaging; Swelling; Tensile Strength

Abstrak: Film hidrogel merupakan material lembaran yang membentuk struktur jaringan 3D dan dapat dibuat dari satu atau lebih bahan penyusun. Kombinasi dua polimer alami, yaitu karboksimetil selulosa (CMC) yang berasal dari batang eceng gondok (BEG) dan pektin kulit pisang membentuk film hidrogel yang digunakan sebagai bahan pelapis kemasan makanan. Penambahan asam sitrat untuk menstabilkan ikatan silang film hidrogel. Penelitian ini bertujuan untuk mengetahui pengaruh CMC BEG, pektin, dan asam sitrat terhadap kemampuan pembengkakan dan kinerja kekuatan tarik film hidrogel. Sintesis CMC diawali dengan pemanenan batang eceng gondok yang diperoleh dari perairan daerah Gambut, Kalimantan Selatan-Indonesia. Kemudian dilakukan proses ekstraksi dan pemutihan selulosa. Serbuk ekstrak selulosa diproses dalam dua tahap yaitu alkalisasi dan karboksimetilasi untuk mendapatkan turunan selulosa berupa CMC. Hasil CMC BEG dianalisis menggunakan FT-IR (*Fourier Transform Infra-Red*) dan dibandingkan dengan CMC komersial. Hasil yang diperoleh adalah adanya kemiripan pada puncak 998 cm^{-1} dan 1015 cm^{-1}, yaitu gugus eter glikosidik. Pembuatan film hidrogel mengkombinasikan CMC BEG dan pektin kulit pisang dengan berbagai komposisi (100:0, 90:10, 70:30, dan 50:50 % berat) dengan penambahan asam sitrat sebagai pengikat silang dengan berbagai konsentrasi (5, 10, dan 15 % berat). Sampel film hidrogel 70:30, 5% (CPc-5) memberikan hasil optimum dari karakterisasi film hidrogel terkait pelapis aplikasi kemasan makanan berupa uji kemampuan pembengkakan sebesar 6,647 g/g, kuat tarik 11,770 MPa, dan elongasi sebesar 11,896%. Analisis FT-IR terhadap CPc-5 menunjukkan adanya gugus karboksil (COO-) dan gugus hidroksil (-OH) yang berperan dalam pembentukan ikatan silang dan sifat hidrofilik.

Kata kunci: Hidrogel; Eceng Gondok; *Carboxymethyl Cellulose* (CMC); Pektin kulit Pisang; Kemasan Makanan; Pembengkakan; Kuat Tarik

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Introduction

Currently, the hydrogel has become a material that has many benefits. Hydrogel is a hydrophilic material that has cross-links to form a 3D network structure. The water absorbed by the hydrogel is retained in the tissue (Zainal et al., 2021). Hydrogels are widely used in the fields of food packaging, biomedical, agriculture, wastewater treatment, etc. In addition to its various uses, the hydrogel has a variety of forming materials.

Hydrogel-forming materials can be natural or synthetic materials. As a complement, it is not uncommon for hydrogels to be formed from hybrid materials with one or more additional materials (M. Dong & Chen, 2020). On an industrial scale, the use of synthetic-synthetic materials as a hybrid material from hydrogels. This is usually related to the mechanical properties of the hydrogel. But now, a combination of synthetic-natural materials has begun to be developed, even natural-natural ones (Kaczmarek, Nadolna, & Owczarek, 2020). Adapted to what the hydrogel will be used for.

In hydrogel application, which is intended for food packaging, it is expected to be natural in order that it is more biodegradable and made from natural polymers. Either one is the use of CMC that is synthesized from *Eichhornia* *crassipes*, famously as water hyacinth. Water hyacinth is considered an aquatic weed with extremely fast growth reaching 400-700 tons of biomass per hectare per day (Rakhmania, Khaeronnisa, Ismuyanto, Nanda, & Himma, 2017). Its height can reach 50-80 cm above the water surface (Ajithram, Jappes, & Brintha, 2021). It can disrupt the aquatic ecosystem because of its invasive habit (Yan, Song, & Guo, 2017). Water hyacinth as an ingredient for fabricating hydrogels can help the utilization of these weeds. Water hyacinth has a cellulose content of up to 60 wt. % (Sindhu et al., 2017) and low lignin content compared to other sources of cellulose, is less than 10 wt. % (Tanpichai, Biswas, Witayakran, & Yano, 2019). Water hyacinth stems (WHS) contain the most cellulose than the roots and leaves (Chonsakorn, Srivorradatpaisan, & Mongkholrattanasit, 2018). This cellulose can be modified into its derivative compound, namely carboxymethyl cellulose (CMC).

CMC as a hydrogel ingredient has been investigated in several studies. The problem with using CMC in the fabrication of hydrogels, especially in sheet form, is its mechanical properties (S. Dong et al., 2021). CMC-based hydrogels tend to be less stable so it is necessary to add natural ingredients that can increase their stability. Besides that, other materials such as pectin also used to improve the stability of hydrogel. The use of these two materials for food packaging materials by adding citric acid to help strengthen the cross-linking that occurs in the hydrogel. A previous study has been successful to improve membrane stability using pectin from apple and banana peels (Elma, Bilad, et al., 2022; Elma, Mustalifah, Suryani, Rampun, & Rahma, 2020; Pratiwi, Elma, Putra, et al., 2019; Pratiwi, Elma, Rahma, Rampun, & Saputro, 2019; Rahma et al., 2019; Rampun, Elma, Rahma, & Pratiwi, 2019; Syauqiyah et al., 2019). The membrane is an advanced technology which has a similar function to hydrogel films (Elma, Mujiyanti, et al., 2020; Elma, Pradana, Ul-haq, et al., 2022; Elma, Rampun, et al., 2020; Elma, Rezki, et al., 2020; Elma, Sari, et al., 2020; R. A. Lestari, Elma, Rahma, et al., 2020; R. A. Lestari, Elma, Rampun, et al., 2020; Rahma, Elma, Pratiwi, & Rampun, 2020; Sumardi et al., 2021; Waqas et al., 2021)

The fabrication of WHSCMC-pectin-based hydrogel films for food packaging must have suitable mechanical properties. In its application, hydrogel films are used as a packaging coating on sponge cakes. Hydrogel films are expected to prevent the sponge cake from spoiling longer than its normal shelf life (Batista et al., 2019). The rapid decay experienced by sponge cakes is due to the excessive free water content (Basiak, Lenart, & Debeaufort, 2017). While hydrogel film is a hydrophilic material that is able to absorb water up to more than twice its weight. It can maintain product moisture by absorbing excessive moisture content in sponge cake (Lu et al., 2020). This can be seen from its swelling ability, which affects the water absorption in the cake (Riaz et al., 2018). Swelling testing is very important in sponge cake packaging applications (Maroufi, Tabibiazar, Ghorbani, & Jahanban-Esfahlan, 2021). Likewise, the mechanic's properties of tensile strength and elongation need to be investigated to determine the properness of hydrogel films as food packaging materials (Yadav, Mehrotra, & Dutta, 2021). Intended as a determining factor for the flexibility or brittleness of the material (Bandyopadhyay, Saha, Brodnjak, & Sáha, 2019). This study aims to make a hydrogel film made from WHSCMC and banana peel pectin. Investigating the swelling ability, tensile strength, elongation, and functional groups based on variations in the addition of citric acid.

Research Methods

Chemicals and Materials

Materials. The material used in the fabrication of hydrogel films made by CMC from water hyacinth stems. Water hyacinth is harvested from Gambut area waters, South Kalimantan-Indonesia. Added banana peels pectin from Chemical Retail Shop Surabaya, and citric acid (1.00244.1000, Merck) as cross-linker.

Synthesis materials. The extracting cellulose process based water hyacinth stems uses 96% ethanol, toluene (99%, UPT BPPTK LIPI), 30% hydrogen peroxide (H_2O_2), demineralized water, NaOH, and CH_3COOH. Meanwhile, in the CMC synthesis process, the materials used are isopropyl alcohol, isobutyl alcohol (1.00984.0250, Merck), and sodium chloroacetate (Na-CA) (607-158-00-5, Merck).

Procedures

Synthesis of CMC Derived from WHS

Firstly, after the water hyacinth stems (WHS) are harvested and cleaned, they are cut into smaller sizes (± 10 cm). WHS was dried under the sun for 7 days and followed by oven drying at 100 ^{o}C for 2 h. It is ground into a powder and sieved to a size of 30/40 mesh.

To obtain cellulose, WHS powder was extracted by Soxhlet for 3 h at 115 ^{o}C using 96% ethanol and toluene (1:2) as solvents. The bleaching process is carried out by adding 30% H_2O_2, stirring and heating at 80 ^{o}C for 2 h. Succeed the bleaching process, cellulose will become whiter in color. Then washed with demineralized water. Added 17,5% NaOH solution, and stirred for 3 h. Afterwards, washed with demineralized water and dripped with CH_3COOH at the last until the PH 4. Dehydrated in the oven for 5 h at 60 ^{o}C and mashed.

Followed by the alkalization process and carboxymethylation process. The alkalization process begins by mixing cellulose and isopropyl-isobutyl 4:1 for 10 minutes. Added 10% NaOH, and stirred for 1 hour. In the carboxymethylation process, the mixture was added with Na-CA and stirred at a temperature of 55 ^{o}C for 3,5 h. After being filtered, washed with 96% ethanol and added with CH_3COOH to neutralize the pH. Then dried at 60 ^{o}C for 5 h, and mashed to produce CMC powder.

Fabrication of WHSCMC-pectin Hydrogel Films

WHSCMC-pectin as much as 5 wt% was mixed with 200 ml of demineralized water. Stirred until well-blended for 30 minutes. Added citric acid solution with concentrations of 5, 10, and 15 wt%. Variations in the composition ratio are shown in **Table 1** as follows:

Table 1. The composition ratio of WHSCMC-pectin hydrogel films

Sample	WHSCMC Concentration	Banana Peels Pectin Concentration	Citric Acid Concentration
CPa-5	100%	0%	5%
CPb-5	90%	10%	5%
CPc-5	70%	30%	5%
CPd-5	50%	50%	5%
CPa-10	100%	0%	10%
CPb-10	90%	10%	10%
CPc-10	70%	30%	10%
CPd-10	50%	50%	10%
CPa-15	100%	0%	15%
CPb-15	90%	10%	15%
CPc-15	70%	30%	15%
CPd-15	50%	50%	15%

The mixture was stirred and heated at 100 ^{o}C for 1 h. The WHSCMC-pectin hydrogel dough was cast on a silicon mold. The hydrogel was dried at 55 ^{o}C for 5 h. After the hydrogel is released from the mold, a hydrogel film sheet is formed.

WHSCMC-pectin hydrogel films were characterized for parameters such as swelling ability, tensile strength, elongation, and functional group analysis using FT-IR (*Fourier Transform Infra-Red*). Swelling ability was tested by preparing a hydrogel film sample cut with a size of 2 cm x 2 cm. The initial weight of the sample (w_0) was measured, then immersed in demineralized water for 1 h at room temperature (27 ^{o}C ± 2 ^{o}C). Before re-weighing, the water adhering to the surface of the hydrogel films was removed with a tissue. Weight after immersion was measured (w_t). The swelling ability of the hydrogel films sample is calculated by equation 1:

$$\text{Swelling Ability (SA)} = \frac{w_t - w_0}{w_0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Results and Discussion

Determines the functional group with Fourier Transform Infra-Red (FT-IR)

One of the most promising cellulose derivatives in its utilization is carboxymethyl cellulose (CMC). CMC is a water-soluble anionic polysaccharide. Each structure is linked by β-1,4-glycosidic bonds (Rahman et al., 2021). The carboxymethyl group (–CH_2-COOH) is inserted into the cellulose molecular chain and replaces the hydrogen atom from the hydroxyl group on the glucopyranose monomer (He, Li, Fei, & Peng, 2021). The synthesis of WHS cellulose into CMC was carried out by an important process, namely alkalization and carboxymethylation.

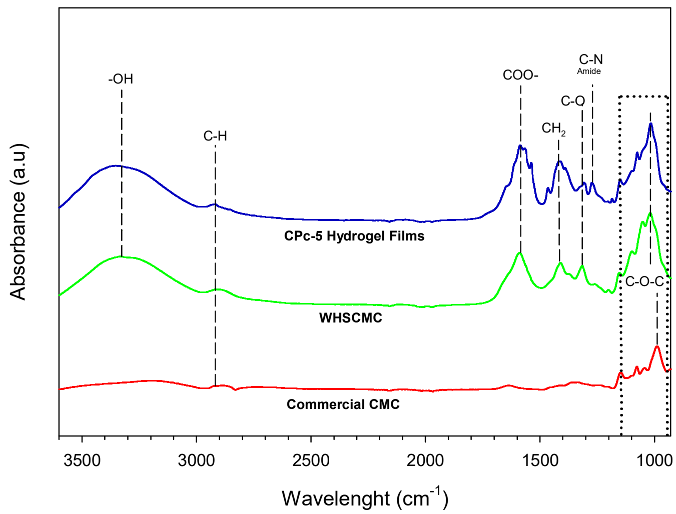

Figure 1. FT-IR analysis of WHSCMC, commercial CMC, and CPc-5 hydrogel films

The FT-IR spectrum shows the comparison between WHSCMC and commercial CMC in the wavelength region of 930 – 3600 cm^{-1} as shown in Figure 1. Between commercial CMC and WHSCMC, the peaks of the glycosidic ether group are similar at the wavelengths of 998 cm^{-1} and 1015 cm^{-1}. Followed by relatively smaller peaks at 1041 cm^{-1} and 1048 cm^{-1} indicating the C-O-C range. Another small peak that shows the similarity of the presence of C-H groups on both is at 2890 cm^{-1}. There is a difference in the presence of a peak at 3323 cm^{-1} which indicates stretching of the –OH group and a peak of 1589 cm^{-1} due to asymmetric stretching of COO- for WHSCMC. As for commercial CMC, at that point, there is no dominant peak formed. In WHSCMC there are also peaks of 1414 cm^{-1} and 1318 cm^{-1}, which show CH_2 and C-O groups, respectively. The results of FT-IR CMC in another study (Asnag, Oraby, & Abdelghany, 2019) informed similar signs, to wit having functional groups, successively C-O-C glycosidic ether, C-O bending vibration, CH_2 scissoring, C=O asymmetric stretching, C-H stretching vibration, and O-H stretching at the peak wavelength of 1063 cm^{-1}, 1325 cm^{-1}, 1417 cm^{-1}, 1602 cm^{-1}, 2920 cm^{-1}, and 3403 cm^{-1}.

Hydrogel film components consisting of WHSCMC, banana peels pectin, and citric acid form cross-links that can absorb water and try to maintain it. The hydrophilic nature is influenced by the hydroxyl group (-OH) and carboxyl group (COO-) (Elma, Ghani, Rahma, Alyanti, & Dony, 2022; Susanto, Elma, & Putra, 2022). To determine the functional groups that make up the hydrogel films, FT-IR

(*Fourier Transform Infra-Red*) analysis is needed. Figure 1 also shows whether these functional groups are visible in the CPc-5 hydrogel films.

The CPc-5 sample section in Figure 1 shows a peak at 3342 cm^{-1} which is the hydroxyl group (-OH) and 1594 cm^{-1} is the carboxyl group (COO-). In addition to affecting the hydrophilic trait, it is also one of the information regarding the presence of citric acid. At the peak of 1419 cm^{-1} is CH_2 scissoring, which is a carboxymethyl group which indicates the presence of CMC in the cross-linkage. Pectin in crosslinking also appears indicated by the amide group (C-N) which forms peaks at 1309 cm^{-1} and 1281 cm^{-1}. The co-formed amide bonds help to increase the stability of the hydrogel films and water absorption (Liu et al., 2022). There is a small peak at 2937 cm^{-1}, which is an aliphatic C-H group. There is also a peak at 1027 cm^{-1} indicating an ether group (C-O-C).

Figure 1 shows that most of the functional groups present in CPc-5 and WHSCMC have similarities. Even the similarity of the three samples is the presence of a dominant peak indicating a glycosidic ether C-O-C group, along with small peaks indicating the formation of a significant glycosidic bond with carboxyl and hydroxyl groups. Quite distinguishing is the presence of an amide group on CPc-5. Indicating that the hydrogel films bonded with the addition of banana peel pectin (Assyaifi et al., 2021; Elma, Nata, et al., 2022; Elma et al., 2021; Hidayah et al., 2021; Isnasyauqiah et al., 2022; Mat Nawi et al., 2022; Mustalifah, Rahma, Mahmud, Sunardi, & Elma, 2021; Rahma, Elma, Rampun, Sintungkir, & Hidayat, 2022). In addition, the presence of a carboxyl group in CPc-5 indicates the role of citric acid in forming cross-links, while the carboxyl group in WHSCMC acts together with CH_2 to form a carboxymethyl group which will be bound to a hydroxyl group in cellulose (Kanikireddy, Varaprasad, Jayaramudu, Karthikeyan, & Sadiku, 2020).

Fabrication of WHSCMC-Pectin Hydrogel Films and Swelling Properties

Hydrogel films have been fabricated from CMC derived from water hyacinth stems (WHS), varied with banana peel pectin and added citric acid as a cross-linker. Over the years, hydrogels have become a promising material for several fields of application due to their association with hydrophilic properties. Hydrogels are able to absorb water and store a certain amount of water in the network. One of them is for the application of sponge cake packaging coatings. Hydrogels are expected to be able to maintain storage by absorbing more water content and maintaining moisture. In addition, their use related to food packaging will be directed to the character of food grade and biodegradable. The basic materials used must be safe and natural.

CMC is good for use as an ingredient for fabricating hydrogel films. Even better when compared to other cellulose derivatives such as methylcellulose and hydroxyethyl cellulose in their swelling ability (Fekete, Borsa, Takács, & Wojnárovits, 2014). However, because CMC has excellent biodegradable properties, the longer the shelf life of CMC-based hydrogels, the weaker the bond structure (S. Dong et al., 2021). The addition of pectin will help increase its flexibility and stability (Khamsucharit, Laohaphatanalert, Gavinlertvatana, Sriroth, & Sangseethong, 2018). WHSCMC and banana peels pectin have the potential to become ingredients for hydrogel films for food packaging because they are relatively cheap, non-toxic, odorless and tasteless, transparent, and soluble in water (Panahirad et al., 2021). Some studies even show that CMC and pectin are resistant to fats and oils (Arnon-Rips & Poverenov, 2018; Lara-Espinoza, Carvajal-Millán, Balandrán-Quintana, López-Franco, & Rascón-Chu, 2018). Regarding its use in food packaging, the hydrogel is made to form sheets to facilitate the packaging process. Wrapping the sponge cake ensures that the hydrogel is in direct contact with the surface of the cake to minimize the air between them. This also makes it easier for the hydrogel to absorb excess water in the cake which can increase microbial activity.

Hydrogel formation cannot be separated from cross-linking. The use of natural materials as hydrogel-forming material has a strength that still tends to be brittle. So a cross-linker is needed, usually a carboxylic acid. One of them is citric acid. Citric acid has a single hydroxyl group (-OH) and three carboxylic groups (COO-) which helps to enhance hydrogen bonding interactions between polymers (Salihu et al., 2021).

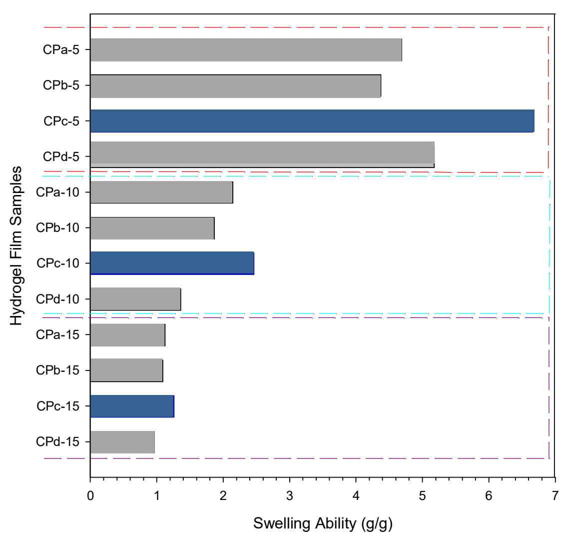

Figure 2. Effect of WHSCMC-pectin composition and citric acid concentration on the swelling ability of hydrogel films

Finding out the effectiveness of swelling ability on WHSCMC-pectin hydrogel films is needed for the characteristics of food packaging. Figure 2 informs that the pattern of swelling ability produced in the comparison of the concentrations of WHSCMC and pectin to variations in the addition of citric acid is the same. For each variation of the addition of citric acid (5, 10, and 15 wt%), the maximum swelling ability was shown in the WHSCMC : pectin ratio, which was 70:30 (wt%). That means a mixture with 30% banana peel pectin is optimum. At CPc-5, CPc-10, and CPc-15 each showed a value of 6,647 g/g; 2,4564 g/g; and 1,2521 g/g. The highest swelling ability value was added to 5% citric acid and the lowest was 15%. It indicated that the addition of citric acid resulted in a higher number of crosslinks and resulted in a denser network (Kowalski, Kijowska, Witczak, Kuterasiński, & Łukasiewicz, 2019). On the other hand, with a lower amount of citric acid addition (5 wt%), no more cross-links were formed and it provided a gap for water to be absorbed drastically.

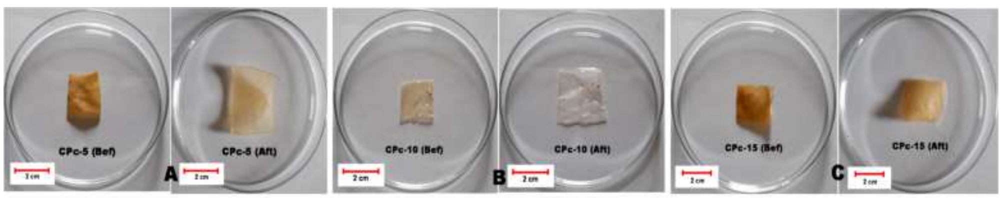

Figure 3. Hydrogel film before and after soaking in water for 1 hour with a concentration of citric acid (A) 5 wt%, (B) 10 wt%, (C) 15 wt%.

Figure 3 shows the comparison of hydrogel films before and after immersion for 1 hour. The swelling in the sample CPc-5 was more significant than that of CPc-10 and CPc-15. Scrutinized from the color change, CPc-5 initially looks brownish and tends not to be transparent becomes a more faded and transparent color. Whereas CPc-10 from the beginning of the hydrogel films was more transparent and had a clear light brown color, it became cleaner and more transparent. At CPc-15, the initial color is brown, but after that, it remains brown although it fades slightly to a lighter brown. The discoloration of the hydrogel films indicates the presence of swelling. The gaps between the crosslinks are occupied by the adsorbed and trapped water. This incident causes the hydrogel films to swell and increase the dimensions of the hydrogel. The larger or wider the size, it means that more water is absorbed. As CPc-5 has the highest swelling results from the test and seen from the change in size, the swelling almost doubled. While the CPc-10 increase in width is only half or less than the initial width. Moreover, the CPc-15 is not very significant. Related to the number and density of crosslinks formed by the combination of WHSCMC-pectin and citric acid as a crosslinker. The more citric acid is added, the more compact and dense the cross-links are. The amount of water that is absorbed will be less (Kowalski et al., 2019). That is why the trend of swelling ability results decreases with increasing citric acid concentration.

Tensile Properties

Measurement of tensile strength and elongation of three samples of hydrogel films with a composition of WHSCMC-pectin 70:30 wt% has been carried out. The tensile strength test aims to calculate the force (N) that occurs at the maximum stress per unit area (mm^2) of hydrogel films. This force is used for stretchability (Elma, Pradana, Sihombing, et al., 2022). The unit used for tensile strength is N/mm^2 or MPa. While elongation can show the flexibility of hydrogel films (El-Hadi, 2017). The results of measurements of the thickness of each sample obtained an average of 0.05 mm.

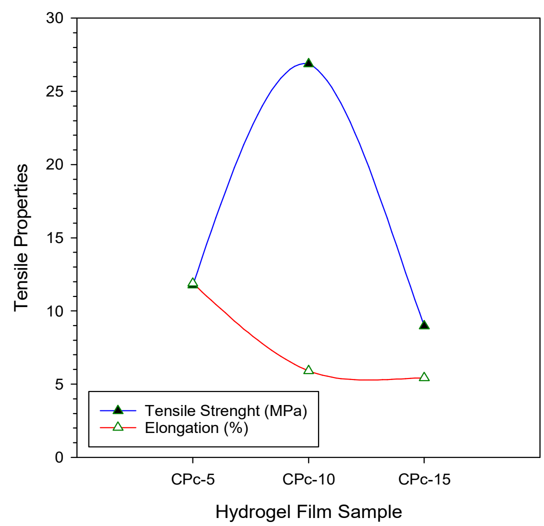

Figure 4. Results of tensile strength vs elongation

Figure 4 informs that the highest tensile strength test result is sample CPc-10, worth 26,879 MPa. Meanwhile, the tensile strength values of CPc-5 and CPc-15 are 11,770 MPa and 8,972 MPa, respectively. The data shows that as the concentration of citric acid as a cross-linker increases, the tensile strength performance also increases. However, Figure 4 shows when citric acid is added up to 15 wt. %, the tensile strength decreases significantly. The addition of excess citric acid can reduce the tensile strength of the hydrogel films. This can happen because the higher amount of citric acid will cause more cross-links to be formed so as to reduce the interaction between molecules (Dharmalingam & Anandalakshmi, 2019) between WHSCMC and banana peel pectin. Meanwhile, CPc-10 with significantly increased tensile strength indicated that the addition of 10 wt. % citric acid gave maximum results. The use of citric acid can also increase the tensile strength of the hydrogel film (Cazón, Velazquez, Ramírez, & Vázquez, 2017). The value of tensile strength will provide good performance for food packaging applications. Relating to the ability to withstand stress (Elma, Pradana, Sihombing, et al., 2022). But usually, when the tensile strength value increases it will be inversely proportional to the decreasing elongation value (Dharmalingam & Anandalakshmi, 2019).

In the elongation test, the results decreased for each addition of citric acid. The CPc-5, CPc-10, and CPc-15 samples were respectively 11,896%, 5,904%, and 5,432%. Here, the highest elongation value is by CPc-5. The decrease in elongation is because CA increases the intermolecular bonds with the polymer matrix so that the hydrogel properties of the films will be stiffer (Jantrawut, Chaiwarit, Jantanasakulwong, Brachais, & Chambin, 2017). At CPc-10 the ability to withstand pressure increases along with the strength and compactness of the crosslinks which causes a decrease in the flexibility of the hydrogel films. Information about tensile strength and elongation is important for the application of hydrogel films in food packaging. The mechanical properties of the three samples indicated that CPc-5 was suitable for sponge cake packaging. Aside from tensile strength that still in accordance with the *Japanese Industrial Standard* (JIS) at least 0.3 MPa (B. R. A. Lestari, Rohmah, & Pujiastuti, 2022), also the elongation is quite good when compared to the mixed hydrogel elongation results from CMC and gelatin of 4.41±0.23 % (Zafar, Khosa, Noor, Qayyum, & Saif, 2022).

Conclusion

Hydrogel films based on WHSCMC-pectin with the addition of citric acid as a cross-linker were successfully fabricated. In terms of swelling ability, the best composition was taken from the ratio of WHSCMC : pectin 70:30 wt. %. The addition of citric acid also affects the results of the swelling ability. From the three results of the highest swelling ability of each variation of citric acid, its tensile characteristics were tested through tensile strength and elongation tests. Hydrogel films with optimal characteristics testing in their application as a coating for food packaging sponge cakes are samples of WHSCMC : pectin 70:30 wt. % and the addition of 5% citric acid (CPc-5). The swelling ability is 6,647 g/g, the tensile strength is 11,770 MPa, and the elongation is 11,896%. As well as the results of the FT-IR analysis inform that the main group of hydrogel films is –OH which plays a role in the hydrophilic trait and COO- which designates the cross-linking process.

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