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Carrageenan-based Film Utilization for Eco-friendly Tea Bag

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ABSTRACT

This study addresses concerns related to potential health risks associated with chlorine residues in traditional tea bags, which exhibit resistance to decomposition in soil. Consequently, the study utilized carrageenan, derived from *Eucheuma cottonii* seaweed, as a coating material for edible film. This research explores the impact of carrageenan concentration and drying temperature on the performance of tea bags. This study applied the randomized complete block design to analyze the impact of three carrageenan concentrations (1%, 3%, and 5%) at three different drying temperatures (80ºC, 85ºC, and 90ºC) on carrageenan-based film. The investigation comprehensively evaluates the compliance of the carrageenan-based film with commercial-grade quality standards through critical factors such as thickness, solubility, mechanical strength and hedonic analysis. The findings indicate that the most effective carrageenan-based edible film can be produced at a concentration of 3% and a drying temperature of 90°C, highlighting its potential as an eco-friendly alternative in tea bag production.

Keywords: Carrageenan concentration, carrageenan-based edible film, drying temperature, *Eucheuma cottonii*, tea bag

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INTRODUCTION

Indonesia has many traditions that make it a country full of diversity and beauty. Each corner has special, interesting characteristics and cannot be replaced easily. Among the myriad fascinating traditions, one that stands out is the ritual of drinking tea, locally referred to as "Ngeteh" in the Javanese dialect (Fernandes & Kurniawan, 2014).

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Tea is a frequently enjoyed beverage known for both its affordability and positive impact on health, owing to the beneficial compounds found within it. Over time, there has been a growing preference for tea bags due to their convenience and practicality. An emerging habit involves leaving the tea steeping for an extended duration to extract more of its benefits. However, it is important to note that prolonged steeping can dissolve chlorine, a paper-bleaching agent in the tea bag, without the consumer's awareness. (Wansi & Wael, 2014).

Apart from the chlorine content in tea bags, the POM Agency (2016) conveys several things related to the content of tea bags, namely, "Tea bags are generally made of paper and plastic." Polyethylene plastic in tea bags serves the purpose of heat sealing, and its notable characteristic is that it does not melt at the boiling point of water, which is evident when tea bags remain unopened. Including microplastics in tea bags raises concerns for health and the environment, as these particles are challenging to decompose. Furthermore, the persistence of microplastics in the environment can lead to potential ecological repercussions, emphasizing the need for sustainable alternatives in tea bag production (Afrin et al., 2022).

In this context, edible film packaging emerges as an alternative material with the potential to maintain the quality of food ingredients while being environmentally friendly. According to Siah et al. (2015), applying edible film packaging using seaweed as a viable raw material provides a novel approach to tea bag production. Through initial processing to obtain carrageenan flour derived from seaweed, this flour becomes a pivotal component in producing edible films for crafting tea bags.

Carrageenan is the sap of the seaweed *Eucheuma cottonii*, and this type belongs to the class of red algae *(Rhodophyceae*). Carrageenan can be obtained by extracting seaweed with water or alkaline solvents. Carrageenan is a linear polysaccharide with a large molecule consisting of more than 1000 galactose residues consisting of ester, potassium, sodium, and potassium sulfate with galactose and 3,6 anhydrogalactopolymer (Rusli et al., 2017). Based on cell bonds and gel properties, carrageenan can be divided into three types, namely kappa, iota, and lambda. Kappa carrageenan produces the strongest gel properties, while lambda carrageenan does not form a gel in water. Still, lambda carrageenan interacts well with protein, so this type is suitable for food production. *E. cottonii* produces kappa carrageenan that dissolves in hot water and forms a gel in water (Fardhyanti & Julianur, 2015).

Carrageenan derived from seaweed can be used as a thickener, superstitious, stabilizer, and emulsifier. Apart from that, carrageenan is also widely used in the industrial world, both in the food, cosmetics, and pharmaceutical industries. This research uses carrageenan as a food coating in edible film. Nonetheless, there is a significant gap in research on the factors that influence the production of biodegradable tea bags using edible seaweed films. This study aims to fill this gap by investigating crucial factors such as the ideal proportion of carrageenan flour and an appropriate drying temperature. This sustainable approach not only introduces an eco-friendly packaging solution but also harnesses the natural properties of seaweed, potentially enhancing the overall health benefits of tea consumption.-

MATERIALS AND METHODS

This research used carrageenan flour from seaweed (*E. cottonii*) from Maluku's coastal area. Food-grade glycerin and distilled water were purchased from the chemical center shop. The Indonesian black tea (Poci brang) was purchased from the Maguwoharjo traditional market.

Production of Carrageenan Based Film (Rani & Kalsum, 2016)

According to Figure 1, the production of the edible film involved several key steps. A carrageenan solution was initially prepared at three concentration levels: 1%, 3%, and 5% (w/v). For each concentration, 1, 3, and 5 grams of carrageenan flour were placed into a 100 mL measuring cup, and distilled water was added to reach a volume of 100 mL. The mixture was then stirred using a magnetic stirrer and heated until it reached a temperature of 60°C. Once this temperature was attained, 10% (v/v) glycerol was introduced to the solution as a plasticizer, with continuous stirring and further heating to reach 80°C. The

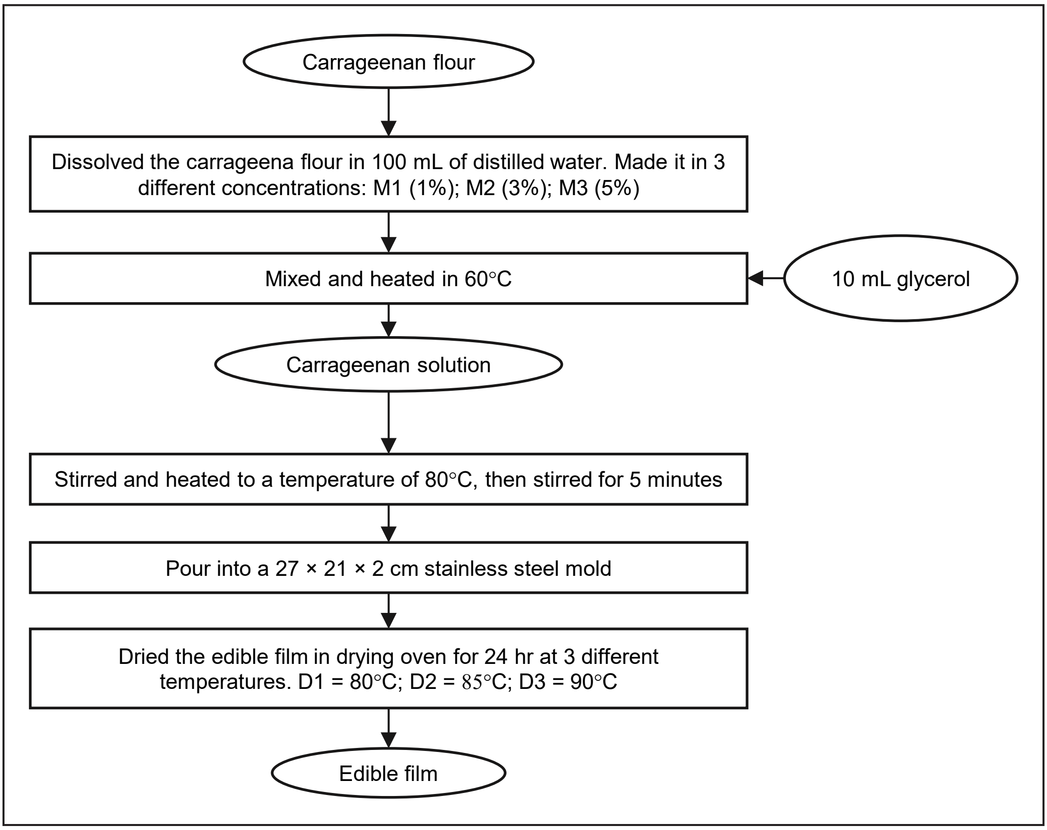

Figure 1. Carrageenan based edible film preparation

still-warm carrageenan solution was poured into a plastic mold or tray and left to stand for 10 minutes at room temperature. The sample was oven-dried for 10 hours at different temperatures (factor D parameters).

Production of Pouch

The pouch (tea bag) was produced according to Figure 2. The film sample was then cut into a 6 × 10 cm rectangular shape. It was started by folding the 10 cm edge to 1 cm and then folding the edible film in half until the bag was 5 cm long. The pocket was sealed on both the right and left sides. The bag was filled with ¾ of a tea bag's worth of tea powder, then sealed the top to ensure no part of the bag was open. Finally, a hole was made in the bag with a needle to allow proper tea extraction.

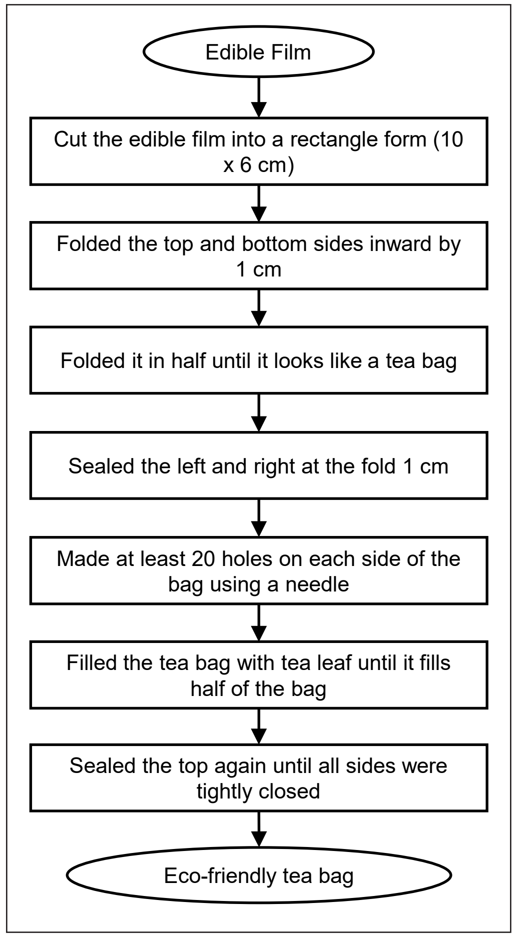

Figure 2. Eco-friendly tea bag preparation

Water Content and Solubility Analysis

The squares (2 × 2 cm) were cut from the films and weighed (W1), then the films were put in the Ecocell 55 (105°C) oven for 2 h and then weighed again (W2). The squares were put in the beaker containing 25 mL of distilled water, and after 24 h at laboratory temperature, the films were dried and weighed (W3). Water content and solubility were calculated according to Equations 1 and 2:

$$\text{Water content (\%)} = [(W1-W2)/W1] \times 100 \quad [1]$$

$$\text{Solubility (\%)} = [(W2-W3)/W2] \times 100 \quad [2]$$

Ash Content Analysis

TAPPI standard method, T211 om-85, was used to determine the ash content. The oven-dried sample (2 g) was burned (dry oxidation) in a muffle furnace model at 575 ± 25°C for 4 h. This standard test method was used to determine the volume of ash remaining after dry oxidation of the sample. The percentage of ash was calculated by Equation 3:

$$\text{Ash (\%)} = \frac{\text{Weight of solids remaining (g)}}{\text{Original weight of carbon (g)}} \times 100 \qquad [3]$$

Tensile Strength and Elongation Analysis

Tensile strength and elongation were measured using a UTM (*Universal Testing Machine*). The squares (5 × 10 cm) were cut from the films and placed under the top plate. The working principle of UTM is that the plate will apply a pulling force to the object until it breaks. Later, the parameters in UTM will show the maximum value or data on the strength of the material (Tensile Strength). The elongation data was also shown by comparing the object's length before and after being tested.

Organoleptic Test

An organoleptic test was performed on 20 untrained panelists with two parameters (color and aroma). Seven sequential scales were used, starting from 1 (dislike very much), 2 (dislike), 3 (dislike slightly), 4 (neither like nor dislike), 5 (like slightly), 6 (like), and 7 (like very much).

Statistical Analysis

This research used a Completed Block Design (CBD) with two treatment factors and two repetitions. Factor I was the Percentage of Carrageenan Addition (M), with three concentrations, M1 (1%), M2 (3%), and M3 (5%), and Factor II was the Effect of Drying Temperature (D), with temperature variations D1 (80°C), D2 (85°C) D3 (90°C). The process was replicated twice to yield 18 experimental units (3 x 3 x 2 repetitions). The data obtained was analyzed with analysis of variance (ANOVA) at a 95% confidence level ($p \leq 0.05$).-

RESULTS AND DISCUSSION

The test results showed that carrageenan flour had an average water content of 5.3 ± 0.8 % and an ash content of 13.2 ± 0.9 %. The results indicated that the novel tea bag preparation method complied with commercial-grade quality standards, according to the Standard National Indonesia (SNI) specifications, which specified a maximum water content of 14% and an ash content of 18% for commercial carrageenan flour.

Figure 3 illustrates the thickness analysis, wherein measurements were taken from three sides. The depicted results represent the average value obtained from the thickness analysis.

As illustrated in Figure 3, it is evident that elevating the temperature results in a thinner formation of the edible film due to increased water evaporation, thereby reducing its thickness. Conversely, a higher percentage of carrageenan leads to a thicker edible film. It was attributed to the increased total solid content in the higher percentage of edible films. This observation aligns with findings from Supeni (2012). Notably, the Japanese

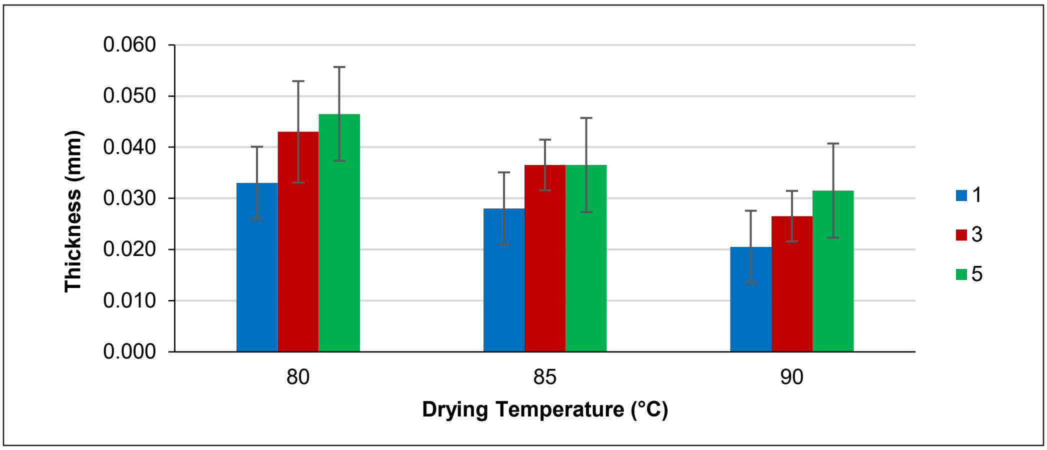

Figure 3. Effect of different percentages of carrageenan (1%, 3% and 5%) and drying temperature (80°C, 85°C and 90°C) against edible film thickness (mm).
Note. Values given are mean (SD)

Industry Standard stipulates a maximum allowable thickness for the edible film at 0.25 mm, confirming that the formed edible film complies with the standard (Dwimayasanti & Kumayanjati, 2019). Furthermore, the analysis of variance revealed no significant difference in the drying temperature and thickness factor, showing the stability and consistency of the results under varying conditions.

The data of solubility analysis in hot water can be obtained in Figure 4, which shows that the higher the percentage of carrageenan, the higher the solubility. This outcome is attributed to the increase in the dissolved solids content originating from the basic ingredients for making edible films as well as an increase in the number of intermolecular bonds in the edible film-making solution and the nature of carrageenan which is hydrophilic and can only dissolve in hot water solvents (Rusli et al., 2017). Examining Figure 4 reveals

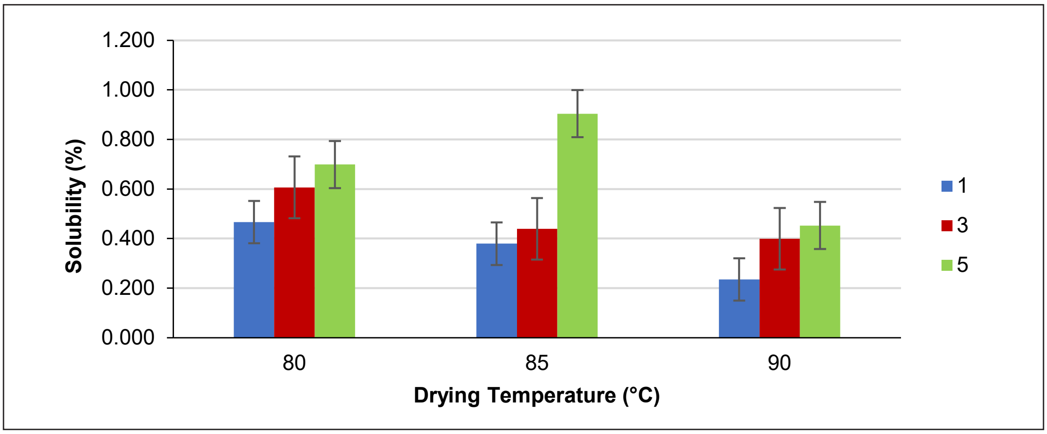

Figure 4. Effect of different percentages of carrageenan (1%, 3%, 5%) and drying temperature (80°C, 85°C and 90°C) against the solubility of edible film in hot water (%)

a direct proportionality between the percentage of carrageenan and solubility in each drying temperature treatment. This correlation may be influenced by the solvent temperature, causing a substantial dissolution of the edible film's solids in water, resulting in higher solubility for a higher percentage of carrageenan. Conversely, the drying temperature exhibits an inverse relationship, with higher temperatures leading to lower solubility of the edible film. Higher drying temperature reduces the water content of the film. Low water content would form a denser film structure (Sutharsan et al., 2023). The film would be less accessible to the water. The analysis of variance showed that there was no significant difference in drying temperature and solubility factor.

Consequently, the film prepared under elevated temperatures is preferable, as it would exhibit reduced susceptibility to water penetration. This feature emphasizes their improved water resistance and signifies their overall advantageous quality in terms of durability and potential for extended use in hot beverages.

Tensile strength is a crucial mechanical property of edible film, as it directly correlates with the film's capability to shield or encapsulate food ingredients and prevent the food products from experiencing physical or chemical changes (Rusli et al., 2017).

In Figure 5, it was seen that there was an increase in tensile strength for a higher percentage of carrageenan. In general, the higher the concentration of carrageenan given, the tensile strength or elongation of the edible itself increased. A higher percentage of carrageenan enhances the edible film's water-binding ability due to the inherent hygroscopic nature of carrageenan. This forms a gel matrix, increasing the bonds between constituent molecules and yielding a more compact edible film. Consequently, this leads to higher elongation percentages and tensile strength in the edible film. (Handito, 2011). However, the study results did not exhibit this phenomenon, which was potentially influenced by the higher drying temperature. The elevated temperature increased water evaporation,

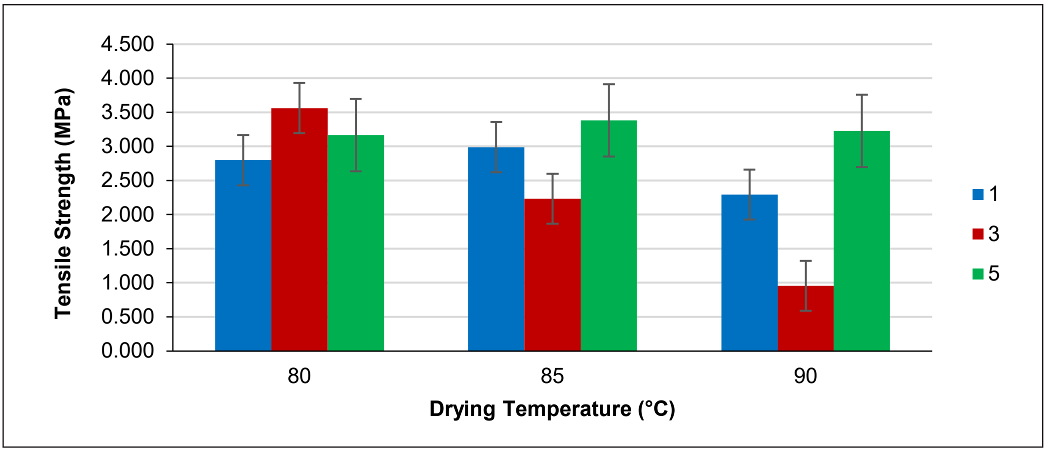

Figure 5. Effect of different percentages of carrageenan (1%, 3% and 5%) and drying temperature (80°C, 85°C and 90°C) on tensile strength of edible film (MPa)

diminishing carrageenan's gelling properties and reducing the edible film's tensile strength (Handito, 2011). In accordance with the Japanese Industrial Standard (1975), the edible film's tensile strength should be at least 0.39 MPa. This requirement is achieved by all edible films produced in this study via the novel process.

Based on Figure 6, it was observed that increasing the percentage of carrageenan increased the elongation of the edible film. Likewise, with tensile strength, a higher percentage of carrageenan made the carrageenan molecules that formed the film matrix stronger so that the film became more inelastic or brittle. Increasing the concentration of carrageenan could increase the bonding between polymeric materials (Rahmawati et al., 2019). As a result, the percentage of elongation decreased. The edible film with the smallest elongation value resulting from this research was at a carrageenan concentration of 3% at a drying temperature of 90ºC, which could be categorized as having the highest mechanical strength. Darawati and Pranoto (2010) supported this opinion that the stronger the film formed, the more difficult it was to elongate, thus reducing the extension percentage value.

From Figure 7, the organoleptic score of aromas was between 4–5 (neither like nor dislike to like slightly). The higher the drying temperature, the lower the favorability value of the aroma. The aroma was a volatile compound that was easy to evaporate during drying (Qu et al., 2019; Chen et al., 2020). Additionally, the analysis of variance indicated no significant difference in the organoleptic score of aromas based on varying carrageenan percentages. Considering the economic benefits, applying lower carrageenan concentrations as the edible film is preferable.

From Figure 8, it was observed that the higher the drying temperature and the increased percentage of carrageenan, the value of the color preference decreased because,

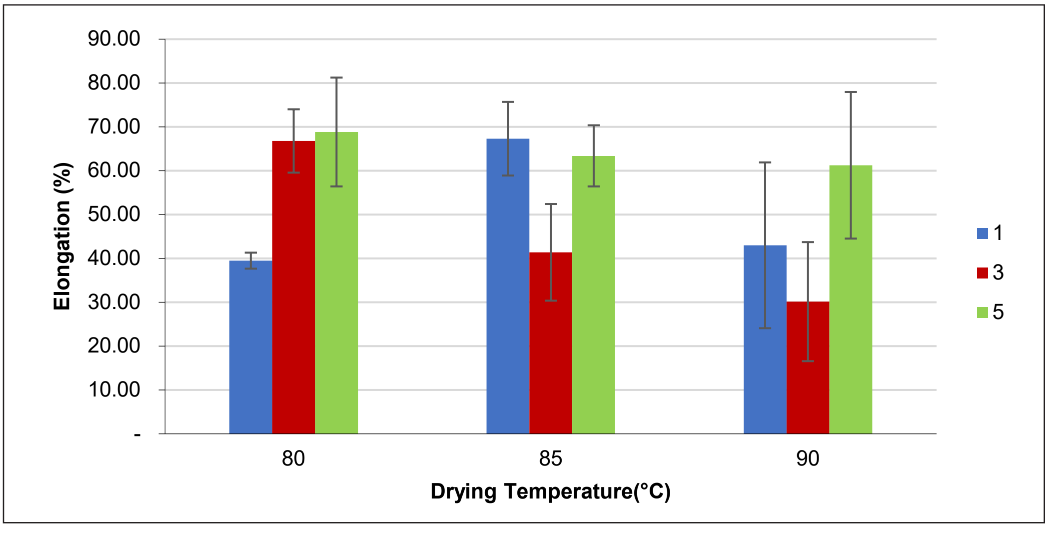

Figure 6. Effect of different percentages of carrageenan (1%, 3% and 5%) and drying temperature (80°C, 85°C and 90°C) against elongation of edible film (%)

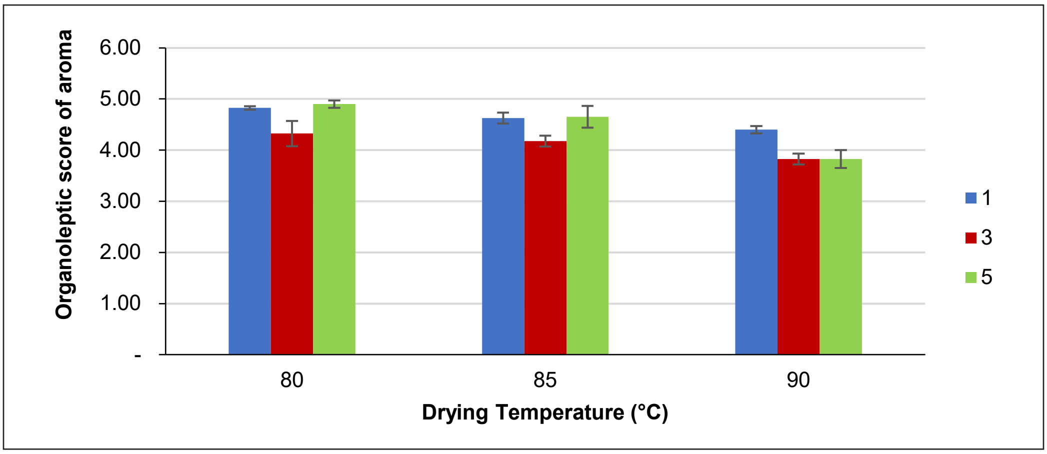

Figure 7. Effect of different percentages of carrageenan (1%, 3% and 5%) and drying temperatures (80°C, 85°C and 90°C) regarding the aroma of tea brewing

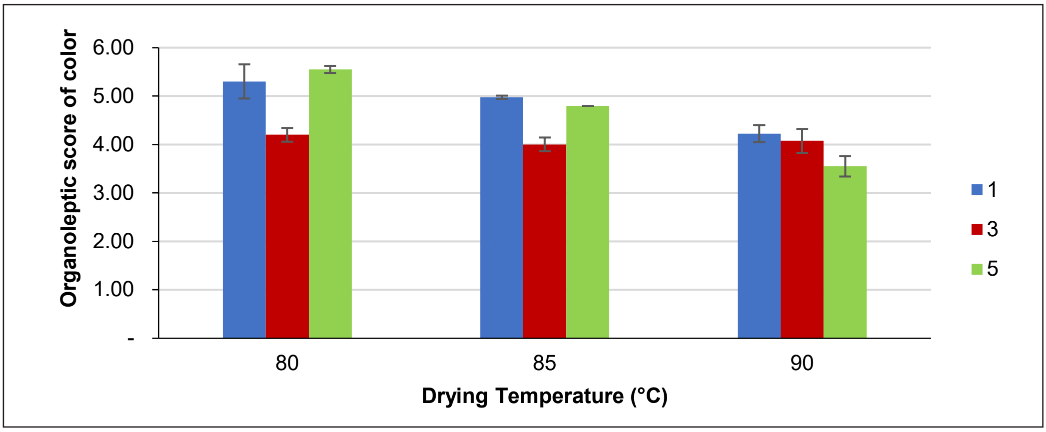

Figure 8. Effect of different percentages of carrageenan (1%, 3% and 5%) and drying temperatures (80°C, 85°C and 90°C) regarding the color of tea brewing

according to the panelists, the color faded when steeping the tea. Analysis of variance showed that there was a significant difference in drying temperature and color hedonic parameters. Variance analysis showed a significant difference in color hedonic parameters dependent on the drying temperature. According to Aluthgama et al. (2020), in black tea, the color is primarily attributed to the presence of theaflavins and thearubigins, responsible for the bright red color and dark-brown pigments, respectively. Referring to Figure 4, it is evident that solubility decreases with an increase in drying temperature. If the film is highly soluble, it may interact more readily with these compounds, resulting in a darker rather than faded appearance. Consequently, the relationship between solubility, drying temperature, and the interaction with these compounds can affect the final color outcome of the brewed tea.

CONCLUSION

Ultimately, this study investigates the feasibility of using carrageenan-based edible film derived from seaweed as an eco-friendly alternative to tea bag production. A novel finding that emerged in this study reveals a direct relationship between carrageenan percentage and solubility across different drying temperatures. This correlation, influenced by solvent temperature, leads to lower solubility for higher carrageenan percentages. The study also determined the ideal parameters for producing the edible film based on carrageenan, indicating a 3% carrageenan concentration and a 90°C drying temperature. This specific combination complies with commercial-grade quality standards. However, it also addresses critical factors such as the requirement for lower thickness and solubility, enhanced mechanical strength, and favorable aroma and color characteristics, as determined by hedonic evaluation. These parameters, which balance economic efficiency and desirable film characteristics, provide an environmentally conscious alternative material for producing high-quality tea bags. Overall, this investigation lays the groundwork for developing biodegradable and eco-friendly tea bags, presenting a sustainable solution to environmental concerns associated with conventional tea bag materials.

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REFERENCES

Afrin, S., Rahman, M. M., Akbor, M. A., Siddique, M. A. B., Uddin, M. K., & Malafaia, G. (2022). Is there tea complemented with the appealing flavor of microplastics? A pioneering study on plastic pollution in commercially available tea bags in Bangladesh. *Science of The Total Environment*, *837*, 155833. https://doi.org/10.1016/j.scitotenv.2022.155833.

Aluthgama, A. G. S. R., Bandarab, N. P. S. N., Dissanayakeb, P. K., & Dissanayakec, R. M. B. B. B. (2020). Evaluation of physicochemical and organoleptic properties of wild tea (*Camellia sinensis*) compared to selected commercially grown tea cultivars in Sri Lanka. *Journal of Agriculture and Value Addition*, *3*(1), 1-10. https://doi.org/10.4038/java.v3i1.115

Chen, D., Xing, B., Yi, H., Li, Y., Zheng, B., Wang, Y., & Shao, Q. (2020). Effects of different drying methods on appearance, microstructure, bioactive compounds and aroma compounds of saffron (*Crocus sativus* L.). *LWT*, *120*, 108913.https://doi.org/10.1016/j.lwt.2019.108913

Darawati, M., & Pranoto, Y. (2010). Penyalutan kacang rendah lemak menggunakan selulosa eter dengan pencelupan untuk mengurangi penyerapan minyak selama penggorengan dan meningkatkan stabilitas oksidatif selama penyimpanan [Ether cellulose coatings by dipping on partially defatted peanuts]. *Jurnal Teknologi dan Industri Pangan, 21*(2), 20-26.

Dwimayasanti, R., & Kumayanjati, B. (2019). Karakterisasi edible film dari karagenan dan kitosan dengan metode layer by layer [Characterization of edible film from carrageenan and chitosan using the layer-by-layer method]. *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan*, *14*(2), 141-150.

Fardhyanti, D. S., & Julianur, S. S. (2015). Karakterisasi *edible film* berbahan dasar ekstrak karagenan dari rumput laut (*Eucheuma cottonii*) [Characterization of Edible Film Based on Carrageenan Extract from Seaweed (*Eucheuma Cottonii*)]. *Jurnal Bahan Alam Terbarukan, 4(2), 68-73*.

Fernandes, E., & Kurniawan, D. (2014). Perancangan media promosi menu afternoon tea Café Hare and Hatter Surabaya [Designing promotional media for the afternoon tea menu of Café Hare and Hatter Surabaya]. *Jurnal DKV Adiwarna*. *1*(4), 15-21.

Handito, D. (2011). Pengaruh konsentrasi karagenan terhadap sifat fisik dan mekanik edible film [The effect of carrageenan concentrations on mechanical and physical properties of edible films]. *Agroteksos*, *21*, 151-7.

Japanese Industrial Standard. (1975). *Japanese Standards Association* (Vol. 2: 1707).

POM Agency. (2016, December 7). Penjelasan BPOM terkait berita tentang kantong teh celup yang mengandung racun. *Badan BPOM*. https://www.pom.go.id/penjelasan-publik/penjelasan-bpom-terkait-berita-tentang-kantong-teh-celup-yang-mengandung-racun

Qu, F., Zhu, X., Ai, Z., Ai, Y., Qiu, F., & Ni, D. (2019). Effect of different drying methods on the sensory quality and chemical components of black tea. *LWT*, *99*, 112-118. https://doi.org/10.1016/j.lwt.2018.09.036

Rahmawati, M., Arief, M., & Satyantini, W. H. (2019, February). The effect of sorbitol addition on the characteristic of carrageenan edible film. In *IOP Conference Series: Earth and Environmental Science* (Vol. 236, No. 1, p. 012129). IOP Publishing. https://doi.org/10.1088/1755-1315/236/1/012129

Rani, H., & Kalsum, N. (2016). Kajian proses pembuatan *edible film* dari rumput laut *gracilaria* sp. dengan penambahan gliserol [Study of the process of making edible film from seaweed *gracilaria* sp. with the addition of glycerol]. In *Prosiding Seminar Nasional Pengembangan Teknologi Pertanian* (Vol. 1 No. 1 pp. 219-225).

Rusli, A., Metusalach, M., & Tahir, M. M. (2017). Karakterisasi *edible film* karagenan dengan pemlastis gliserol [Characterization of edible film carrageenan with glycerol plasticizer]. *Indonesian Journal of Fishery Product Processing, 20*(2), 219–229. https://doi.org/10.17844/jphpi.v20i2.17499.

Siah, W M., Aminah, A., & Ishak, A. (2015). Edible films from seaweed (*Kappaphycus alvarezii*). *International Food Research Journal*. *22*(6), 2230-2236.

Supeni, G. (2012). Pengaruh formulasi *edible film* dari karagenan terhadap sifat mekanik dan penghalang [Effect of edible film formulation from carrageenan to mechanical and barrier properties]. *Jurnal Kimia dan Kemasan. 34*(2), 282–286. https://doi.org/10.24817/jkk.v34i2.1864

Sutharsan, J., Boyer, C. A., & Zhao, J. (2023). Effect of molecular weight and drying temperature on the physicochemical properties of chitosan edible film. *JSFA Reports*, *3*(8), 387-396. https://doi.org/10.1002/jsf2.142

Wansi, S., & Wael, S. (2014). Analisis kadar klorin pada teh celup berdasarkan waktu seduhan [Analysis of chlorine levels in tea bags based on steeping time]. *BIOPENDIX: Journal of Biology, Education and Applications, 1*(1), 22–31. https://doi.org/10.30598/biopendixvol1issue1page22-31