Characterization of biodegradable seaweed-based film from *Kappaphycus alvarezii* incorporating aloe vera gel as a plasticizer

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Abstract

Introduction. Plastic packaging materials have been the perennial cause of global plastic pollution, highlighting the urgent need for alternative biodegradable substitutes. This study explored the potential of using aloe vera gel (AVG) as a sustainable plasticizer for *Kappaphycus alvarezii*-based films, comparing it to a traditional glycerol plasticizer.

Materials and methods. Different concentrations of AVG (10, 20 and 30%) were tested to prepare biodegradable films, and the properties of these films including water solubility, mechanical properties (tensile strength and elongation at break), biodegradability, and microbial load were evaluated.

Results and discussion. The results show that AVG concentration significantly affects film characteristics. Water solubility was significantly reduced with 20% and 30% AVG, showing values of 18.87% and 26.57%, respectively, compared to 84.87% for the control and 84.02% for 10% AVG. Notably, a lower concentration of AVG (10%) resulted in the highest tensile strength (61.64 N/mm²), while higher plasticizer concentrations exhibited lower values corresponding to 35.60 N/mm² and 29.90 N/mm² for 20% and 30% AVG, respectively. In addition, the elongation at break was significantly reduced in treatments with AVG (1.37% – 3.07%) when compared to the control (17.81%), indicating increased brittleness of the film with AVG. However, AVG enhanced the biodegradability at all concentrations, with more than 50% of the films decomposed within 12 days, exceeding the 37.63% biodegradability of the control. Furthermore, 10% AVG significantly reduced microbial load to 1 colony forming units per g, demonstrating antimicrobial properties compared to the control.

Conclusions. The study concluded that *Kappaphycus alvarezii* and aloe vera gel are promising components for the development of biodegradable films. *K. alvarezii* provides a strong and adaptable film matrix, while aloe vera gel serves as an effective alternative plasticizer. Further research is recommended to explore the potential application of these films as edible food packaging materials.

Introduction

Traditional plastic films pose significant environmental challenges due to their non-biodegradability, leading to their accumulation as persistent waste in the environment. Since the 1950s, over 8.3 billion metric tons of plastic have been produced, of which only about 9% has been recycled, 12% incinerated, and the remaining 79% either deposited in landfills or released into natural ecosystems (Geyer, 2020; Stabnikova et al., 2021). This environmental crisis underscores the urgent need for sustainable plastic alternatives.

Developing biodegradable films from biopolymers offers a viable solution to waste plastic concerns. These biodegradable films break down naturally and are suitable for medical, packaging, and agricultural uses (Mapossa, 2023; Chandra at al., 1998). *Kappaphycus alvarezii*, a widely cultivated red seaweed with established economic value (Bindu at al., 2010; Rupert et al., 2022; Stabnikova et al., 2025), shows promise as a source for these materials due to the film-forming properties of its carrageenan content (Tye et al., 2018). Its status as a top aquaculture commodity (Irawati et al., 2024) ensures cost-effectiveness and availability. Carrageenan provides a strong and flexible film foundation (Rhein-Knudsen et al., 2015) and has antimicrobial properties with versatile applications (Rupert et al., 2022), making *K. alvarezii* a sustainable alternative.

In biofilm production, plasticizers are essential to ensure the film's flexibility; however, common phthalate-based options are toxic (Hauser et al., 2005), driving demand for healthier substitutes. Aloe vera gel (AVG), known for its medicinal properties, is a suitable material in biopolymer research. Its polysaccharides, vitamins, enzymes, and amino acids suggest plasticizing effects (Hamman, 2008). Furthermore, research indicates it can enhance moisture content, mechanical strength, and gas barrier properties (Hadi et al., 2022a; Tambe, 2024). Its film-forming, antimicrobial, and biodegradable properties make it a good natural preservative coating (Berihu et al., 2022; Misir et al., 2014). Therefore, exploring the combination of *K. alvarezii* and aloe vera gel in film production could create enhanced, sustainable packaging materials, particularly for food applications.

Existing research has investigated other plasticizers, including aloe vera gel as an additive for different biopolymers (Hadi et al., 2021, 2022a). Research using *K. alvarezii* to create biodegradable films, as well as studies using aloe vera gel as a film additive, remains mostly independent from one another. Therefore, the optimal combination and interaction between these two specific materials for improved film performance remains largely unexplored.

This study aims to characterize the formulated films' physical (water solubility), mechanical (tensile strength and elongation at break), biodegradability properties, and antimicrobial potential. The findings of this research provide valuable insights and baseline data on biopolymer combinations for developing sustainable film that may used for various applications, particularly as a food packaging material.

Materials and methods

Materials

The Alkali-Treated Cotonii Chips (ATCC), a form of semi-refined carrageenan (SRC) and also known as the Philippine Natural Grade (PNG), was sourced from the Bureau of Fisheries and Aquatic Resources – National Seaweeds Technology Development Center (BFAR-NSTDC) in Cabid-an, Sorsogon. The ATCC is made from the species *K. alvarezii* using the alkali extraction method described in Bixler (1996). Fresh aloe vera leaves were purchased from Tabaco City, Albay.

**Figure 1. Alga *Kappaphycus alvarezii (a),*
fresh aloe vera leaves (b), aloe vera gel platicizer (c),
a *Kappaphycus alvarezii*-based film incorporating aloe vera gel as a plasticizer (d)**

Preparation of aloe vera gel

The extraction of AVG followed the method of Maan et al. (2021), where mature aloe vera leaves were washed, trimmed, and soaked for 1 hour to remove aloin. After removing tips and spines, one side of the rind was peeled, and the inner gel was scraped out. The extracted gel was then homogenized in a blender for 3 minutes, filtered through cheesecloth to remove impurities, and the resulting pure gel was refrigerated for later use.

Preparation of films

The solution was prepared following a slightly modified method based on Farhan and Hani (2017). The ATCC (2% w/w) was dissolved in 90°C distilled water with continuous stirring for 30 minutes. After adjusting the volume and filtering, AVG was added at varying concentrations (10%, 20%, and 30% w/w) and stirred for 2 minutes. A total of 150 mL of the solution was poured into plates, dried in a hot-air oven at 60 °C for 4 hours, and then carefully peeled off. Composition of prepared seaweed-based films is shown n Table 1.

Table 1
Composition of seaweed-based film using Alkali-Treated Cotonii Chips (ATCC) with varying plasticizers

Seaweed-based films	Compositions
Film (Control)	4g ATCC + 20% glycerol
Film 1	4g ATCC + 10% AVG
Film 2	4g ATCC + 20% AVG
Film 3	4g ATCC + 30% AVG

Determination of solubility in water

Water solubility was assessed using a slightly modified version of the Romero-Bastida et al. (2005) method. Film samples (2x2 cm) were dried at 60°C for 1 hour to obtain the initial dry weight (Si) and then immersed in 50 ml of distilled water at room temperature for 4 hours with periodic agitation. After immersion and filtering, the film pieces were dried again at 60°C for 3 hours to determine the final dry weight (Sf). Water solubility was calculated as the percentage weight loss using the formula:

$$\text{Solubility (\%)} = [(Si - Sf) / Si] \times 100.$$

Determination of tensile strength and elongation at break

Tensile strength and elongation at break were determined using a Universal Testing Machine (UTM) extensometer operated in accordance with the standard method ASTM D882 (ASTM, 2018). The prepared film samples were sent to the Materials R&D Consulting Facility at the University of the Philippines Diliman for testing. The samples were cut and measured, with an average thickness of 0.04628±0.00459 mm, a width of 15.00 mm, and a gauge length of 100.00 mm, before being tested.

Determination of biodegradability

Biodegradability was assessed through soil and burial tests following the method from Sari et al. (2024) with slight modification. Film strips (2 x 3 cm) were buried in plastic pots containing 300 g of damp soil and sand. Samples were retrieved every 4 days, cleaned, dried at 60°C for 1 hour, and weighed. The test lasted for 12 days when one treatment already achieved the 50% degradation. The percentage weight loss (WL) of the film was calculated using the following equation:

$$WL\% = (Wi - Wf / Wi) \times 100$$

where Wi is the film's initial weight, Wf is its weight after degradation.

Determination of microbial load

The microbial load of the film with the best mechanical properties was analyzed using the Compact Dry TC (total count) – AOAC 010404 method at the Bicol University Regional Center for Food Safety and Quality Assurance (BURCFSQA). Following the standard method, film samples were cut into thin strips, diluted 1:10 with distilled water, and standardized using the 0.5 McFarland turbidity test. One ml of the diluent was plated on Compact Dry TC and incubated for 24 hours at 35 ± 1°C, after which the number of colonies was counted to quantify bacterial growth.

Data analysis

Statistical analysis using Analysis of Variance (ANOVA) was performed to evaluate significant differences in the tested film properties among experimental groups, with normality and homogeneity of variances checked using the Shapiro-Wilk and Levene's tests, respectively. In cases of significant ANOVA results, Tukey's multiple-range test was used to identify significantly different groups. All statistical analyses were conducted at a 5% alpha level.

Results and discussion

Film solubility in water

Significant variations in water solubility were observed among seaweed-based films with different plasticizers (Figure 2). Specifically, seaweed-based films 2 and 3 have significantly low water solubility as compared to the control and seaweed-based film 1 ($p<0.05$). Thus, incorporation of higher amounts of AVG (>20%) into seaweed-based films will result in their lower solubility in water.

The high water solubility of film 1 (84.02%), comparable to the control film (84.87%), indicates that the addition of 10% AVG enhances water absorption and breakdown, likely due to AVG's inherent hydrophilic nature (Hadi et al., 2021) and plasticizing effect, which increases space between polymer chains (Hadi et al., 2022b). This comparable solubility suggests that AVG behaves similarly to glycerol in terms of water solubility at low concentrations. However, increasing AVG concentrations to 20% (film 2, 18.87%) and 30% (film 3, 26.57%) significantly decreased solubility. This finding contradicts the results of Hadi et al. (2022b) and may be due to differences in the base film composition or aloe vera gel properties.

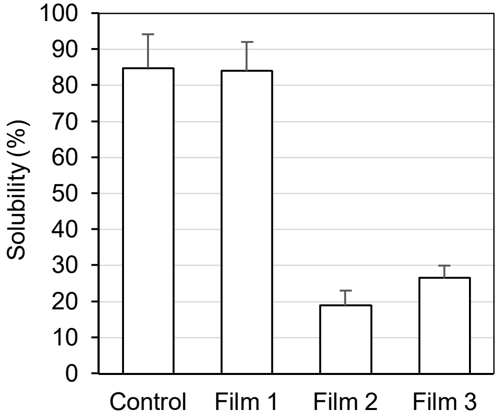

Figure 2. Comparison of the solubility properties of films with different contnent of aloe vera gel (AVG) relative to the control: film 1, 10% of AVG; film2, 20% of AVG; film 3, 30% of AVG

The film developed with 20% aloe vera gel exhibited properties comparable to the starch-based film reported by Chavan et al. (2022), which demonstrated a solubility range of 5.5% to 19.1% through the incorporation of nanostarch particles to enhance film's mechanical and barrier properties. Similarly, studies such as that of Bajer et al. (2020) have shown that water solubility in starch/chitosan/aloe vera composites decreases following UV irradiation, suggesting that external treatments can significantly influence solubility behavior. Meanwhile, based on Abd Karim et al. (2024), thermoplastic starch films formulated with 30% aloe vera experienced a significant reduction in water solubility from 48.46% to 32.39% with the incorporation of 10% polyethylene, a reduction that remained consistent even with higher polyethylene concentrations (20%-40%). These findings collectively underscore that while AVG concentration significantly influences solubility, with higher levels generally leading to reduced water interaction, additional factors such as film composition, polymer modifications, and external treatments like UV exposure are equally crucial in tailoring the film's water resistance properties.

The varying solubility of the developed films indicates their potential for diverse applications. Films with high solubility, such as film 1, are suitable for applications requiring rapid dissolution, including those in the food and detergent industries, similar to PVOH-based films for detergent capsules (Byrne et al., 2021) or edible films for instant food. Conversely, films with lower solubility, such as films 2 and 3, are more suitable for applications requiring water resistance, such as biodegradable food packaging for perishable goods. Thus, the balance between solubility and water resistance in these seaweed-aloe vera gel-based films allows for a range of practical uses in food packaging and agriculture.

Mechanical properties

All films incorporating aloe vera gel showed no significant differences in tensile strength compared to the control, with an average value of 42.64 ± 6.32 N/mm² ($p > 0.05$). On the contrary, film 1 has significantly higher tensile strength (61.63 ± 10.54 N/mm²) compared to film 3 (29.90 ± 1.42 N/mm²). In addition, film 1 with the lowest AVG concentration also shows the highest tensile strength among the films and control, indicating that 10% aloe vera gel is the most effective for enhancing the film's tensile strength. Further increasing the concentrations of aloe vera gel leads to reduced tensile strength (Figure 3).

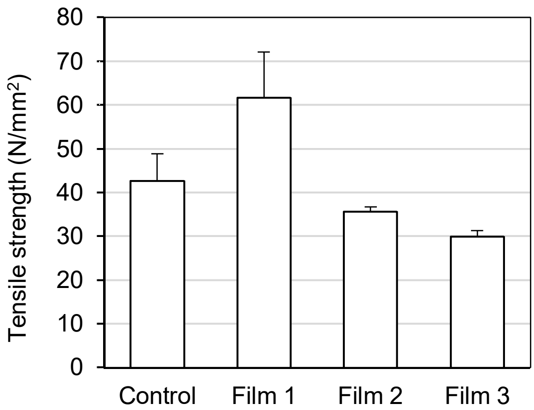

Figure 3. Comparison of the tensile strengths of films with different contnent of aloe vera gel (AVG) relative to the control: film 1, 10% of AVG; film2, 20% of AVG; film 3, 30% of AVG

Additionally, the incorporation of AVG into the *K. alvarezii*-based films significantly affected elongation at break (Figure 4). Analysis showed statistically significant reductions in elongation across all aloe vera gel films compared to the glycerol control (17.81 ± 3.34%, mean ± SE) ($p<0.05$). Subsequently, mean values (± SE) decreased from 3.07 ± 0.73% (film 1) to 1.49 ± 0.06% (film 2) and 1.37 ± 0.06% (film 3), indicating a clear inverse relationship between AVG concentration and film flexibility.

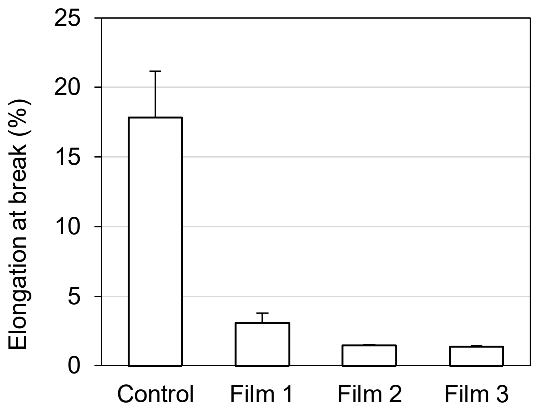

Figure 4. Comparison of the elongation at break (%) of films with different contnent of aloe vera gel (AVG) relative to the control: film 1, 10% of AVG; film2, 20% of AVG; film 3, 30% of AVG

The preceding results highlight a complex relationship between tensile strength and elongation at break in the *K. alvarezii*-based biodegradable films (Figure 5). The control films based on *K. alvarezii* exhibited a balance of moderate tensile strength and high elongation at break. On the contrary, presence of AVG in films indicates inverse relationship between film strength and elongation. This observation is a common trade-off in composite materials, likely because the aloe vera gel creates stronger connections within the film (Rahmiatiningrum et al., 2019; Tambe et al., 2024), which can make the material more brittle (Chen et al., 2019).

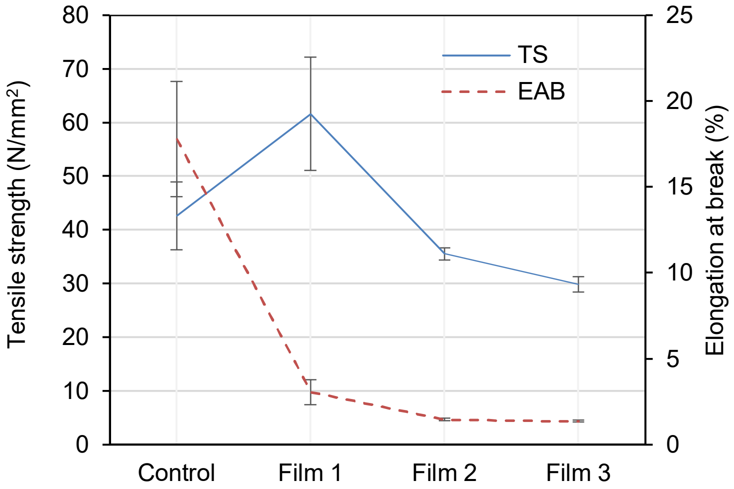

Figure 5. Relationship of tensile strength (TS) and elongation at break (EAB) of films with different contnent of aloe vera gel (AVG) relative to the control: film 1, 10% of AVG; film2, 20% of AVG; film 3, 30% of AVG

Specifically, when AVG content exceeded 10%, tensile strength decreased while elongation at break remained low. This might be because the higher amount of AVG disrupts the film's structure (Lagos et al., 2015; Ramos et al., 2013), making it difficult to create flexible films with high AVG content. Therefore, plasticizer addition requires an optimal point beyond which strength decreases.

Compared to traditional plastics, the *K. alvarezii*-based films exhibit similar if not superior strength, but limited flexibility. For instance, Pradhan et al. (2020) have shown that high-density polyethylene has a tensile strength of 20–40 N/mm² with high elongation at break (100-1000%), while low-density polyethylene shows 7–17 N/mm² tensile strength with elongation at break of 200-900%. In addition, the same study suggests that polypropylene has 28-40 N/mm² tensile strength with moderate elongation at break of 20–75%. In contrast, the film with 10% of AVG has a higher tensile strength (61.63 N/mm²), but significantly reduced elongation (3.07%), while other films with AVG displayed comparable or slightly lower tensile strength alongside similarly limited flexibility. Thus, the impressive tensile strength exhibited by the developed film shows its potential for applications requiring mechanical durability such as food packaging.

Biodegradability

The results demonstrate that addition of AVG significantly enhances the biodegradability of the films compared to the glycerol-plasticized control (Figure 6). Notably, all films incorporating AVG resulted in over 50% film degradation after 12 days. Specifically, the biodegradability of film 2 (53.55%) is significantly higher than the control (37.63%) ($p<0.05$). These findings confirm the positive impact of aloe vera addition on film degradation and prompt further examination of the optimal concentration range for maximum biodegradability.

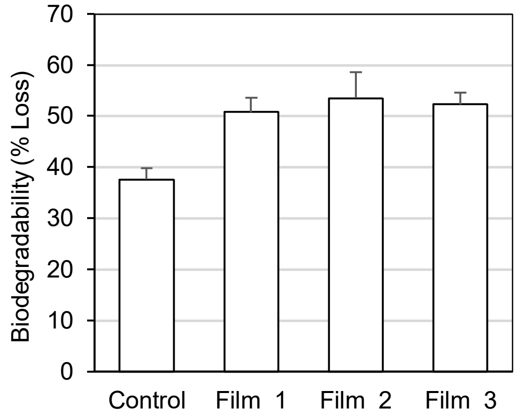

Figure 6. Comparison of biodegradability of the different films with AVG relative to the control

The rapid degradation of the AVG-plasticized films, with over 50% degradation within 12 days, indicates that AVG might accelerate biodegradation compared to some glycerol-plasticized carrageenan films. For example, findings from Sari et al. (2024) show biodegradable film with glycerol took about 40 days to reach similar levels, emphasizing the effect of plasticizer type on the film's natural degradation. This enhanced biodegradability with AVG is likely due to its complex composition, which provides readily available microbial carbon sources like polysaccharides, organic acids, and enzymes (Babu et al., 2020). Therefore, the overall faster degradation of the aloe vera gel-plasticized films highlights AVG's potential to enhance the biodegradability of polymer matrices. This suggests that incorporating AVG into seaweed-based films could be a significant step in developing sustainable plastic alternatives suitable for applications prioritizing environmental compatibility.

Effects on microbial load

Adding 10% AVG to the film decreased aerobic bacterial counts, indicating its antimicrobial contribution. The minimal bacterial count (1.0 colony forming units per g) in film 1 indicates the effective control of bacterial accumulation. The control film demonstrated bacterial contamination with a high level too numerous to count (TNTC), indicating the lack of antimicrobial properties. These differences show AVG's antimicrobial ability as an essential additive for creating biodegradable plastics.

The observed antimicrobial effects are consistent with previously published research. For instance, Ghafoor et al. (2016) found that biodegradable polymer films containing aloe vera showed substantial bacterial growth reduction, confirming the current study results. Similarly, Yoshida et al. (2021) found that biofilms made from chitosan had enhanced antimicrobial activity when they included aloe vera extract. Research evidence demonstrates that particular compounds in aloe vera, including anthraquinones, saponins, tannins, flavonoids, ascorbic acid, and pyrocatechols, provide broad-spectrum antibacterial effects. The antimicrobial properties of anthraquinones in aloe vera are due to their ability to inhibit protein synthesis in bacteria (Fani at al., 2012; Zahra et al., 2022). The compounds penetrate microbial membranes to cause bacterial cell lysis, resulting in decreased bacterial viability, especially against Gram-positive *Staphylococcus aureus* strains (Chelu et al., 2023; Parnomo et al., 2021). The current research, along with previous studies, demonstrates how aloe vera gel enhances biodegradable film antimicrobial properties, which drives the creation of safer, sustainable alternatives.

Conclusions

In conclusion, this study demonstrates the promising potential of aloe vera gel as a sustainable plasticizer in seaweed-based biodegradable films. Varying the concentration of aloe vera gel produced films with properties suitable for a wide array of applications, particularly as food packaging materials. Notably, aloe vera gel enhanced biodegradability and provided significant antimicrobial activity, surpassing the performance of traditional glycerol-plasticized films. While lower concentrations improved tensile strength, higher concentrations led to reduced solubility and increased brittleness, highlighting the importance of precise formulation. Overall, the findings suggest that aloe vera gel offers a promising alternative to conventional plasticizers, contributing to the development of enhanced, environmentally friendly packaging materials. Future research into the optimization of aloe vera gel concentration and its applications within specific packaging applications would be useful in exploring the full extent of its potential.

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References

Abd Karim S.F., Jai J., Abdol Aziz R.A., Maqsood-Ul-Haque S.N.S., Ku Hamid K.H., Mulana F. (2024), Production of thermoplastic starch-aloe vera gel film embedded with polyethylene for improved tensile strength and water absorption, *Journal of Mechanical Engineering*, 21(3), pp. 93-107.

Alahmed A., Simsek S. (2024), Improving biodegradable films from corn bran arabinoxylan for hydrophobic material and green food packaging, *Foods*, 13(12), 1914, https://doi.org/10.3390/foods13121914

ASTM (2018), *Standard test method for tensile properties of thin plastic sheeting (ASTM D882)*, ASTM International.

Babu S.N., Noor A. (2020), Bioactive constituents of the genus *Aloe* and their potential therapeutic and pharmacological applications: A review, *Journal of Applied Pharmaceutical Science*, 10(11), pp. 133–145, https://doi.org/10.7324/japs.2020.101118

Bajer D., Janczak K., Bajer K. (2020), Novel starch/chitosan/aloe vera composites as promising biopackaging materials, *Journal of Polymers and the Environmen,* 28, pp. 1021–1039, https://doi.org/10.1007/s10924-020-01661-7

Bixler H.J. (1996), Recent developments in manufacturing and marketing carrageenan, *Hydrobiologia*, 326(1), pp. 35-57, https://doi.org/10.1007/BF00047785

Berihu H., Zegeye A. (2022), Enhancement of quality and storability of avocado (*Persea americana*) fruit using a blend of aloe vera gel and corn starch as surface coating, *International Journal of Food Engineering and Technology*, 6(1), pp. 21–27, https://doi.org/10.11648/j.ijfet.20220601.14

Bindu M.S., Levine I.A. (2010), The commercial red seaweed *Kappaphycus alvarezii* – an overview on farming and environment, *Journal of Applied Phycology*, 23, pp. 789–796, https://doi.org/10.1007/s10811-010-9570-2

Byrne D., Boeije G., Croft I., Hüttmann G., Luijkx G., Meier F., Parulekar Y., Stijntjes G. (2021), Biodegradability of polyvinyl alcohol-based film used for liquid detergent capsules, *Tenside Surfactants Detergents*, 58(2), pp. 88–96, https://doi.org/10.1515/tsd-2020-2326

Campo V.L., Kawano D.F., da Silva D.B., Carvalho I. (2009), Carrageenans: Biological properties, chemical modifications and structural analysis – A review, *Carbohydrate Polymers*, 77(2), pp. 167–180, https://doi.org/10.1016/j.carbpol.2009.01.020

Chandra R., Rustgi R. (1998), Biodegradable polymers, *Progress in Polymer Science*, 23(7), pp. 1273–1335, https://doi.org/10.1016/s0079-6700(97)00039-7

Chavan P., Sinhmar A., Sharma S.D., Dufresne A., Thory R., Kaur M., Sandhu K.S., Nehra M., Nain V. (2022), Nanocomposite starch films: A new approach for biodegradable packaging materials, *Starch – Stärke*, 74(5–6), 2100302, https://doi.org/10.1002/star.202100302

Chelu M., Musuc A.M., Aricov L., Ozon E.A., Iosageanu A., Stefan L.M., Prelipcean A.M., Popa M., Moreno J.C. (2023), Antibacterial aloe vera based biocompatible hydrogel for use in dermatological applications, *International Journal of Molecular Sciences*, 24(4), 3893, https://doi.org/10.3390/ijms24043893

Chen J., Li H., Fang C., Cheng Y., Tan T., Han H. (2019), *In situ* synthesis and properties of Ag NPs/carboxymethyl cellulose/starch composite films for antibacterial application, *Polymer Composites*, 41(3), pp. 838–847, https://doi.org/10.1002/pc.25414

Fani M., Kohanteb J. (2012), Inhibitory activity of aloe vera gel on some clinically isolated cariogenic and periodontopathic bacteria, *Journal of Oral Science*, 54(1), pp. 15–21, https://doi.org/10.2334/josnusd.54.15

Farhan A., Hani N.M. (2017), Characterization of edible packaging films based on semi-refined kappa-carrageenan plasticized with glycerol and sorbitol, *Food Hydrocolloids*, 64, pp. 48–58, https://doi.org/10.1016/j.foodhyd.2016.10.034

Freile-Pelegrín Y., Madera-Santana T.J. (2017), Biodegradable polymer blends and composites from seaweeds, *Handbook of Composites from Renewable Materials*, pp. 419–438, https://doi.org/10.1002/9781119441632.ch98

Geyer R. (2020), Production, use, and fate of synthetic polymers, In: T.M. Letcher (Ed.), *Plastic Waste and Recycling*, pp. 13–32, Academic Press, London, https://doi.org/10.1016/B978-0-12-817880-5.00002-5

Ghafoor B., Ali M.N., Ansari U., Bhatti M.F., Mir M., Akhtar H., Darakhshan F. (2016), New biofunctional loading of natural antimicrobial agent in biodegradable polymeric films for biomedical applications, *International Journal of Biomaterials*, pp. 1–9, https://doi.org/10.1155/2016/6964938

Hadi A., Nawab A., Alam F., Zehra K. (2021), Physical, mechanical, optical, barrier, and antioxidant properties of sodium alginate – aloe vera biocomposite film, *Journal of Food Processing and Preservation*, 45(5), https://doi.org/10.1111/jfpp.15444

Hadi A., Nawab A., Alam F., Zehra K. (2022a), Sustainable alginate/aloe vera composite biodegradable films reinforced with carboxymethyl cellulose and hydroxypropyl methylcellulose, *Polymer Composites*, 43(6), pp. 3471–3480, https://doi.org/10.1002/pc.26629

Hadi A., Nawab, A., Alam, F., Zehra, K. (2022b), Sustainable food packaging films based on alginate and aloe vera, *Polymer Engineering and Science*, 62(7), pp. 2111–2118, https://doi.org/10.1002/pen.25992

Hamman J.H. (2008), Composition and applications of aloe vera leaf gel, *Molecules*, 13(8), pp. 1599–1616, https://doi.org/10.3390/molecules13081599

Hauser R., Calafat A.M. (2005), Phthalates and human health, *Occupational and Environmental Medicine*, 62(11), pp. 806–818, https://doi.org/10.1136/oem.2004.017590

Irawati B.A., Affandi R.I. (2024), Tissue culture of *Kappaphycus alvarezii* seaweed by somatic embryogenesis method, *Ganec Swara*, 18(1), 358, https://doi.org/10.35327/gara.v18i1.768

Lagos J.B., Vicentini N.M., Dos Santos R.M.C., Bittante A.M.Q.B., Sobral P.J.A. (2015), Mechanical properties of cassava starch films as affected by different plasticizers and different relative humidity conditions, *International Journal of Food Studies*, 4(1), pp. 116–125, https://doi.org/10.7455/ijfs/4.1.2015.a10

Lim H., Hoag S.W. (2013), Plasticizer effects on physical–mechanical properties of solvent cast Soluplus® Films, *American Association of Pharmaceutical Scientists PharmSciTech*, 14, pp. 903–910, https://doi.org/10.1208/s12249-013-9971-z

Maan A.A., Reiad Ahmed Z.F., Khan M.K.I., Riaz A., Nazir A. (2021), Aloe vera gel, an excellent base material for edible films and coatings, *Trends in Food Science & Technology*, 116, pp. 329–341, https://doi.org/10.1016/j.tifs.2021.07.035

Mapossa A.B., da Silva Júnior A.H., de Oliveira C.R., Mhike W. (2023), Thermal, morphological and mechanical properties of multifunctional composites based on biodegradable polymers/bentonite clay: A review, *Polymers*, 15(16), 3443, https://doi.org/10.3390/polym15163443

Misir J., Brishti F.H., Hoque M.M. (2014), Aloe vera gel as a novel edible coating for fresh fruits: A review, *American Journal of Food Science and Technology*, 2(3), pp. 93–97, https://doi.org/10.12691/ajfst-2-3-3

Parnomo T., Pohan D.J. (2021), Test the effectiveness of aloe vera extract on the growth of *Escherichia coli* in vitro, *International Journal of Health Sciences and Research*, 11(8), pp. 211–224, https://doi.org/10.52403/ijhsr.20210831

Pradhan S., Dikshit P.K., Moholkar V.S. (2020), Production, characterization, and applications of biodegradable polymer: Polyhydroxyalkanoates. In: V. Katiyar, A. Kumar, N. Mulchandani (Eds.), *Advances in Sustainable Polymers. Materials Horizons: From Nature to Nanomaterials*, pp. 51-94, Springer, Singapore, https://doi.org/10.1007/978-981-15-1251-3_4

Rahmiatiningrum N., Sukardi S., Warkoyo W. (2019), Study of physical characteristic, water vapor transmission rate and inhibition zones of edible films from aloe vera (*Aloe barbadensis*) incorporated with yellow sweet potato starch and glycerol, *Food Technology and Halal Science Journal*, 2(2), 195, https://doi.org/10.22219/fths.v2i2.12985

Ramos Ó.L., Reinas I., Silva S.I., Fernandes J.C., Cerqueira M.A., Pereira R.N., Vicente A.A., Poças M.F., Pintado M.E., Malcata F.X. (2013), Effect of whey protein purity and glycerol content upon physical properties of edible films manufactured therefrom, *Food Hydrocolloids*, 30(1), pp. 110–122, https://doi.org/10.1016/j.foodhyd.2012.05.001

Rhein-Knudsen N., Ale M., Meyer A. (2015), Seaweed hydrocolloid production: An update on enzyme assisted extraction and modification technologies, *Marine Drugs*, 13(6), pp. 3340–3359, https://doi.org/10.3390/md13063340

Romero-Bastida C.A., Bello-Pérez L.A., García M.A., Martino M.N., Solorza-Feria J., Zaritzky N.E. (2005), Physicochemical and microstructural characterization of films prepared by thermal and cold gelatinization from non-conventional sources of starches, *Carbohydrate Polymers*, 60(2), pp. 235–244, https://doi.org/10.1016/j.carbpol.2005.01.004

Rupert R., Rodrigues K.F., Thien V.Y., Yong W.T. (2022), Carrageenan from *Kappaphycus alvarezii* (*Rhodophyta*, *Solieriaceae*): Metabolism, structure, production, and application, *Frontiers in Plant Science*, 13, https://doi.org/10.3389/fpls.2022.859635

Sari W.M., Supartono W., Suharno. (2024), Characterization of biodegradable films from raw seaweed (*Kappaphycus alvarezii*) and glycerol, *IOP Conference Series: Earth and Environmental Science*, 1364, 012081, https://doi.org/10.1088/1755-1315/1364/1/012081

Siracusa V., Rocculi P., Romani S., Rosa M.D. (2008), Biodegradable polymers for food packaging: A review, *Trends in Food Science & Technology*, 19(12), pp. 634–643, https://doi.org/10.1016/j.tifs.2008.07.003

Stabnikova O., Stabnikov V., Marinin A., Klavins M., Klavins L., Vaseashta A. (2021), Microbial life on the surface of microplastics in natural waters, *Applied Sciences*, 11, 11692, https://doi.org/10.3390/app112411692

Stabnikova O., Stabnikov V., Paredes-López O. (2025), Wild edible plants, berries, mushrooms and seaweeds in food production, In: S. Gubsky, O. Stabnikova, V. Stabnikov, O. Paredes-López (Eds.), *Wild Edible Plants: Improving Foods Nutritional Value and Human Health through Biotechnology*, pp. 1-47, CRC Press, Boca Raton, https://doi.org/10.1201/9781003486794-1

Tambe S.S., Zinjarde S., Athawale A.A. (2024), Aloe vera gel–reinforced biodegradable starch–PVA blends for sustainable packaging of green chillies, *Packaging Technology and Science*, 37(7), pp. 605–617, https://doi.org/10.1002/pts.2812

Tye Y.Y., Abdul Khalil H.P., Kok C.Y., Saurabh C.K. (2018), Preparation and characterization of modified and unmodified carrageenan based films, *IOP Conference Series: Materials Science and Engineering*, 368, https://doi.org/10.1088/1757-899x/368/1/012020

Yoshida C.M.P., Pacheco M.S., de Moraes M.A., Lopes P.S., Severino P., Souto E.B., da Silva C.F. (2021), Effect of chitosan and aloe vera extract concentrations on the physicochemical properties of chitosan biofilms, *Polymers*, 13(8), 1187, https://doi.org/10.3390/polym13081187

Zahra N., Saeed M., Nawaz S., Gulzar E. (2022), Aloe vera cookies preparation, nutritional aspects, DPPH assay and physicochemical assay, *Bangladesh Journal of Scientific and Industrial Research*, 57(2), pp. 117–122, https://doi.org/10.3329/bjsir.v57i2.60408

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