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Preparation And Characterization Of Carrageenan/Alginate Composite Bioplastics With The Addition Of Seaweed Extraction Waste *K. Alvarezii* (Doty) Doty Ex P. C. Silva, 1966

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ABSTRACT. Single biopolymer materials such as alginate and carrageenan do not have sufficient physico-chemical and mechanical properties to be used as bioplastics. This study prepared and characterized carrageenan and sodium alginate composite bioplastics incorporated with *Kappaphycus alvarezii* seaweed extraction waste 0%, 20%; 40%; 60%; and 80% as biofiller. The bioplastics were prepared by solution casting method at 90ºC for 45 min at 1000rpm, and soaked in $CaCl_2$ 2% for 5 min and dried at 60ºC for 18h. the bioplastics were characterized for their physical, mechanical, and biodegradation properties. Incorporation of seaweed extract increase biodegradability but reduce the tensile strength of bioplastics. Scanning electron micrograph showed homogenous and does not form fracture. The FTIR spectra does not suggest the occurrence any noticiable interaction between components in the composite bioplastics. Overall, the incorporation of seaweed extractiaon waste enhance the propertise of carrageenan-alginate composite for short-life product application.

Keywords : Bioplastics, biofiller, composite, extraction waste, *Kappaphycus alvarezii*

INTRODUCTION

Seaweed is an important source of polysaccharide-based biomaterials. The three types of polysaccharides that have been exploited from seaweed are agar, alginate, and carrageenan (Paula *et al*., 2015). Studies on biodegradability, biocompatibility and bioeconomic contribution show that carrageenan and alginate are suitable for use as biodegradable film materials and as composite materials with other polymers for various applications, such as food and biomedical uses (Jumaidin *et al*., 2017) due to their non-toxic nature (Akhtar *et al*., 2024). The development of bioplastics and renewable packaging materials with low emissions is very important because petroleum-based plastics are not degraded in nature, resulting in environmental pollution (Perera *et al*., 2023).

Carrageenan is a linear sulfated galactan hydrocolloid composed of β-D-galactopyranose units linked at the C3 position with α-D-galactopyranose or 3,6-anhydro-α-D-galactopyranose linked at the C4 position, forming disaccharide units that constitute the polymer chain of carrageenan (Paula *et al*., 2015; Nurani *et al*., 2024). Carrageenan gel can form a thin layer, making it a potential material for bioplastic production (Farhan and Hani, 2017). However, its mechanical quality, water retention, and thermal properties are relatively low. These deficiencies can be addressed by adding fillers, chemical modifications, or blending with other biopolymers such as cellulose and alginate (Khalil *et al*., 2017).

Alginate is a hydrophilic polymer extracted from brown algae (Phaeophyta), composed of β-D-mannuronic acid (M) and α-L-guluronic acid (G) monomers. The G/M ratio of alginate depends on the type, origin, age, and harvest time of the seaweed (Gao *et al*., 2017). Alginate is a natural ionic polysaccharide that forms hydrogels through interchain associations in the presence of divalent ions such as Ca^{2+} (Pascalau *et al.*, 2012). Its advantages in biocompatibility, biodegradability, gelation capacity, flexibility and film formation, contribute to its use as a matrix for plastic and packaging materials (Akhtar *et al*., 2024). However, alginate has low mechanical strength, thermal stability and water barrier (Lade *et al*., 2023).

Carrageenan and alginate are polyelectrolytes and form hydrogels with uni/polyvalent metal cations such as K^+ and Ca^{2+}, which can improve mechanical properties and chemical stability. They are compatible, allowing for their combination to form composites with improved mechanical properties due to inter-chain interactions through hydrogen bonding (Behera *et al*.., 2022). The resulting composite can be used as an alternative to conventional plastic.

Several researchers have prepared kappa-carrageenan-alginate composites. Roh and Shin (2006) found that the best composition was achieved at an alginate-carrageenan ratio of 6:4 (w/w). Kappa-carrageenan can increase the water resistance and tensile strength of carrageenan-alginate composite biofilms, while alginate makes them more homogeneous and transparent (Paula *et al.*, 2015). Various efforts to improve the bioplastic properties of hydrocolloids have been researched, including the addition of nanocrystalline cellulose, microcellulose, nanoclay, and others, as reviewed by Khalil *et al*. (2017), while efforts to improve the characteristics of carrageenan-based biofilm properties have been reviewed by Sedayu *et al*. (2019).

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The extraction process of carrageenan from *K. alvarezii* seaweed produces solid waste amounting to 60-70% (w/w), where one-third is cellulose, 4.5% is lignin, and 4.5% is hemicellulose (Sedayu *et al*., 2018). The sustainable and rational utilization of this waste into economically valuable bioproducts is an innovative and environmentally friendly step that benefits the development of high-value biomaterials, such as nanocomposites (El Achaby *et al*., 2018), bioethanol (Sedayu *et al*., 2018), bioplastic film reinforcing agents and nanocrystalline cellulose (Khalil *et al*., 2017), and biofilm materials (Sudharsan *et al*., 2016),
Wang *et al*. (2024) adding peanut shells as antioxidants in carrageenan-alginate films applied as preservatives for frozen meat. Natural biofillers such as talc, clay, and eggshells are reported to be able to improve the mechanical properties of starch bioplastics (Jumaidin *et al*., 2017). The application of seaweed waste for reinforcement has been carried out on starch-based bioplastics (Sudharsan *et al*., 2016). Arief *et al*. (2021) utilized cellulose from carrageenan waste as a raw material for bioplastics using sorbitol as a plasticizer, while Fauziyah *et al*. (2021) using a glycerol plasticizer. In this study, the addition of *K. Alvarezii* seaweed extraction waste and its effect on the characteristics of carrageenan-alginate composite bioplastics with glycerol plastiser and $CaCl_2$ crosslinker were carried out.

EXPERIMENTAL SECTION

Chemicals and materials

Carrageenan is obtained from the extraction of *K. alvarezii* seaweed, *K. alvarezii* seaweed extraction waste, alginate, hydrogen peroxide, glycerol, aquadest, potassium chloride, potassium hydroxide, isopropyl alcohol, sodium hypochlorite, and hydrochloric acid.

Preparation of Carrageenan-Alginate Composite Bioplastic with the Addition of K. alvarezii Extraction Waste

Bioplastic was made using the method of Lim et al. (2018). 146.25 mL of distilled water was heated using a hot plate stirrer until the temperature reached 90°C. Then, a mixture of carrageenan and alginate (4:6) (Roh & Shin, 2006) was added according to the composition shown in **Table 1**, along with seaweed extraction waste (0% (control); 0.45g (20%); 0.9g (40%); 1.35g (60%); 1.8g (80%) and 2.25g (100%) (waste without the addition of carrageenan-alginate), and homogenized for another 45 minutes at a speed of ±1000 rpm. After 45 minutes, 1.5mL of glycerol was added and homogenized again for 15 minutes. The mixture was poured into a polypropylene mold (17x22x3.5 cm) and leveled, then dried in an oven at 60°C for 18 hours. The bioplastic was removed from the mold and then soaked in a 4% $CaCl_2$ crosslinker solution for 5 minutes (Roh & Shin, 2006; Mazni *et al.* 2021), followed by drying at room temperature for 6 hours.

Table 1. Bioplastic Formulations

Code of Treatment	Mixed Composition				
	Waste (g)	Carrageenan (g)	Alginate (g)	Glycerol (mL)	Aquades (mL)
EL0	0	0,9	1,35	1,5	146,25
EL20	0,45	0,72	1,08	1,5	146,25
EL40	0,9	0,54	0,81	1,5	146,25
EL60	1,35	0,36	0,54	1,5	146,25
EL80	1,8	0,18	0,27	1,5	146,25
EL100	2,25	0	0	1,5	146,25

The carrageenan used was obtained from the extraction of *K. alvarezii* seaweed with aquadest. Carrageenan is white, moisture content 14±0.11%, ash content 21±841.57%, viscosity 39.75±2.3cP, and gel strength 57.0 ± 2.56g/cm^2. The carrageenan extraction waste from *K. alvarezii* is in the form of a brownish, unflavored semi-solid viscous liquid, with an ash content of 21.1%, protein 5.01%, carbohydrate 68.9%, fat 0%, and lignin 5.01% (**Figure 1**).

Figure 1. (a) K. *alvarezii seaweed*, (b) Carrageenan, (c) Extraction waste

Characterization of Bioplastics

Thickness

The thickness of bioplastics was measured based on Choi *et al*., (2022) using the ASTM D882-18 method with a Micrometer Screw Gauge 0–25 mm.

Opacity

The opacity of bioplastics is determined using a luxmeter (Brandelero *et al*., 2016). The value of the ambient light intensity is measured (lux i), then the bioplastic is placed on top of the luxmeter sensor and the light intensity is measured (lux f).

$$\text{Opacity (\%)} = \frac{\text{Lux i-Lux f}}{\text{Lux i}} \times 100$$

Water Resistance

The water resistance test was conducted according to Yang *et al*. (2022). Bioplastics are cut to a size of 20x20 mm. The pieces are weighed (M0) then put in a container filled with water (50 mL) for 24 hours. The bioplastic pieces are then lifted and dried at 105ºC until dry, then weighed (M1).

$$\text{Water Resistance (\%)} = \frac{M0-M1}{M0} \text{ x } 100\%$$

Biodegradability

The test was carried out using the Behera *et al*. method. (2022). The bioplastic sample was cut into 2x2cm, and put into a desicator for 24 hours and weighed (W0). The samples were buried in the soil at a depth of 2cm for 6 days, after which they were washed using aquadest, then dried with a tissue and dried in a desiccator for 24 hours, then weighed (W1).

$$\text{Biodegradation (\%)} = \frac{W0-W1}{W0} \text{ x } 100\%$$

Mechanical Properties (Tensile Strength and Elongation)

The tensile strength and elongation at breaks was measured by the ASTM D882-18 method using the Universal Testing Machine at a speed of 10mm/min, the distance between the clamps was 10cm pulled until the bioplastic sample broke. The tensile strength is calculated from the maximum force divided by the cross-sectional area (A) Elongation is calculated by dividing the length of the bioplastic after being drawn (L1) by the initial length (L).
Tensile Strength : Fmax (N)/A(cm2)
Elongation : L1/L x 100%

Fourier Transform Infrared (FTIR) Spectroscopy

The functional group in bioplastics were analyzed with the FTIR Thermo Scientific Nicolet IS10, a DTGS detector in the wave number range of 650-4000 cm^{-1}, a resolution of 4 cm^{-1}, a scan count of 50, a KBr beam splitter, in transmitance format, at room temperature of 25ºC, and a humidity of 58%. This test was carried out on waste and waste bioplastics + 1% glycerol.

Scanning Electron Microscopy (SEM)

SEM scans are performed to determine surface morphology such as structure formation, crack identification, porosity, roughness, and density of bioplastic structures (Lisitsyn *et al.*, 2021). Small pieces of bioplastic were vacuum-dried for 30 minutes, with Au/Pt coating at a pressure of 3.2 Pa, and scanned with an electron microscope SEM JEOL JSM-6510LA, at 25ºC, and 55% humidity. This test was carried out on waste bioplastic + 1% glycerol.

Data Analysis

All data obtained (thickness, opacity, water resistance, elongation at breaks, and tensile strength) were analyzed *by* parametric statistics with normality test, homogeneity test, and Anova test. The determination of the different variants was carried out by looking at the comparison value using the Tukey test at a 95% confidence level. The data of the biodegradability test and elongation test were carried out non-parametric statistical tests with the Kruskal Walls test. The statistical test was carried out using *IBM SPSS 25* software.

RESULT AND DISCUSSION

Characteristics of the composite bioplastics

The components of the bioplastic consist of carrageenan, carrageenan extraction waste, alginate, and glycerol in various compositions, as well as soaking in a 2% $CaCl_2$ crosslinker. The plasticizer glycerol is added to reduce brittleness, increase flexibility, and improve the hardness of the bioplastic (Rhim, 2012). Glycerol is the most commonly used plasticizer (Khalil *et al*., 2017). Soaking in the $CaCl_2$ solution aims to enhance the water resistance of the bioplastic by forming cross-links between the alginate polymer chains (Rhim, 2004). However, treatment with $CaCl_2$ causes the film to dry faster, become slightly opaque (less transparent), and have a rougher surface. Carrageenan-alginate bioplastic with up to

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80% waste addition could form sheets, but the bioplastic with 100% waste without carrageenan-alginate could not be removed from the mold (torn), so no further testing was conducted.
The visual appearance of bioplastics with varying levels of waste is presented in **Figure 2.** Bioplastics containing waste were visually transparent and not sticky, whereas the control bioplastic without the added waste was less transparent and more adhesive. The observed changes were caused by the effective incorporation of waste components into the composite matrix, which is confirmed by the results of the FTIR and SEM study.

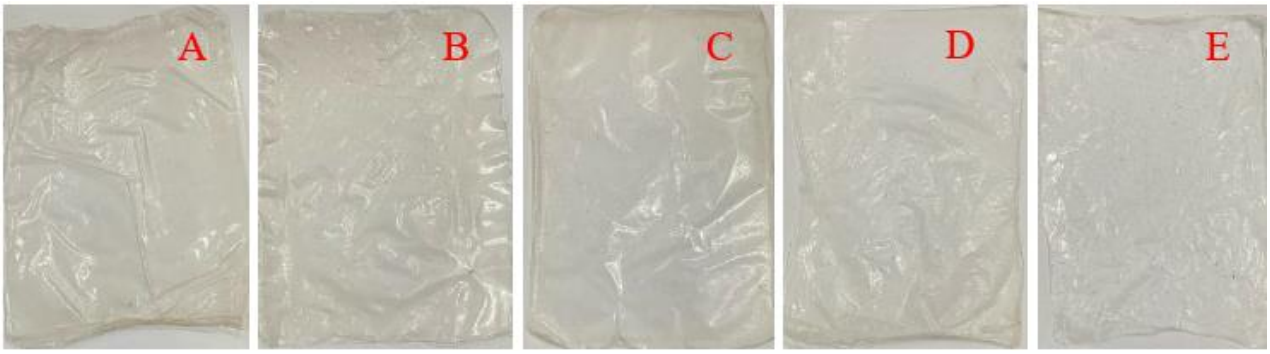

Figure 1. Composite bioplastics (a) EL0, (b) EL20, (c) EL40, (d) EL60, (e) EL80.

Opacity
All bioplastics exhibited relatively high transparency, as indicated by their low opacity values, ranging from 11.22% (EL20) to 12.64% (EL80) (Figure 2). This is likely due to the mobility of the polymer chains and the presence of intermolecular spaces within the alginate and carrageenan polymer matrix, allowing light to penetrate through the bioplastic (Farhan and Hani, 2017). Soaking the bioplastic in a $CaCl_2$ solution resulted in increased opacity, attributed to the formation of cross-linked networks between the alginate polymer chains and $CaCl_2$ salt crystals, which obstructed light transmission (Rhim, 2004; Choi *et al.*, 2022). The high cellulose/carbohydrate content in the extraction waste (68.9%) further increased the opacity of the bioplastic (Sedayu *et al*., 2019).

Thickness
The thickness of carrageenan-alginate-waste bioplastics decreased with increasing waste concentration (**Figure 3**). The thickness of the bioplastic without waste addition (EL0) was 67.56 µm, where as the thickness of the bioplastic with the addition of 80% de-carrageenan waste (EL80) was only 45.22 µm. The reduction in carrageenan and alginate content led to less dispersion of the glycerol plasticizer within the polymer matrix, resulting in decreased bioplastic thickness (Farhan and Hani, 2017). As the waste concentration increased, the concentrations of carrageenan and alginate decreased, leading to a corresponding reduction in bioplastic thickness.

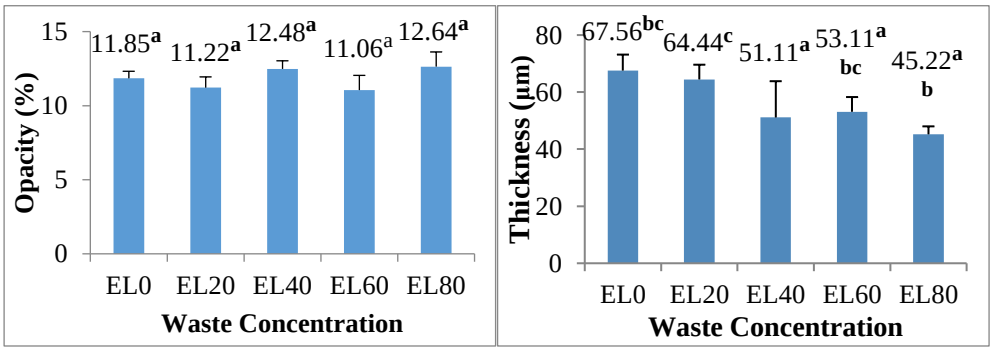

Figure 2. Effect of seaweed extraction waste content on *Opacity* and bioplastic thickness

Mechanical properties
Bioplastics without the addition of waste (EL0) exhibited the highest tensile strength, at 49.57 N/mm², which decreased with increasing amounts of de-carrageenan waste. The lowest tensile strength was observed with the addition of 80% waste (EL80), at 5.25 N/mm² (Figure 4). These results different from Jumaidin *et al.* (2017), where the optimum tensile strength occurred with the addition of 30% to 40% extraction waste filler, after which it declined with further waste addition. This decrease in tensile strength is attributed to the discontinuity in the matrix caused by the high waste concentration, reducing stress transfer from the matrix to the waste (Farhan and Hani, 2017). The reduction in tensile strength is also suspected to be due to the presence of materials in the waste that are incompatible with carrageenan and

alginate (Fauziyah *et al.*, 2021). Tensile strength of bioplastics increases when the components have similar characteristics, such as hydrophilicity, which enhances adhesion.
The tensile strength of pure alginate without glycerol varies according to different references: 60 MPa, 122 MPa, or 34 MPa (Rhim, 2004; Choi *et al*., 2022). The tensile strength of carrageenan is reported as 40.30 MPa (Farhan and Hani, 2017) and 42.5 MPa (Sedayu *et al*., 2019). Tensile strength is influenced by the source and treatment of the seaweed (e.g., M/G ratio, viscosity, composition), the method of film production (casting or thermomechanical, mixing time, and thickness), the degree of dryness (humidity, drying time), and testing parameters (speed).
Partially cross-linking generates a significant increase of the maximum elongation at breaks and moderate chanhe of the E-modulus, depending on carrageenan-alginate ratio. The fully cross-linking effect is an increase of the Young's modulus and ultimate stress and decrease of the elongation and tensile strength, in compliance with more rigid structure induced by cross-linking.
The glycerol plasticizer causes partial destructuring of alginate and carrageenan granules, increasing polymer chain mobility and restructuring, leading to increased crystallization of alginate and carrageenan, which in turn reduces tensile strength and young's modulus (Gao *et al*., 2017). The tensile strength and elongation values in this study are still lower than those of commonly used plastic films such as polyvinyl alcohol (44-64 MPa), HDPE (22-31 MPa), polypropylene (31-38 MPa) and polystyrene (45-83 MPa) (Rhim, 2012).
The elongation at breaks of bioplastics treated with waste fluctuated (Figure 4). The highest elongation was achieved with 20% waste addition (EL20) at 4.5%, but it decreased with 40% waste addition (2.01%) and then increased again with 60% and 80% treatments. This result differs slightly from Jumaidin *et al*. (2017), where maximum elongation occurred with 30% waste filler addition and decreased with higher waste additions. The reduction in elongation with 40% and 60% waste addition is likely due to the formation of new hydrogen bonds (Figure 6) between carrageenan, alginate, and waste components such as cellulose, reducing polymer chain mobility and increasing material resistance to deformation. Additionally, residual carrageenan in the waste is thought to form a good network with alginate and glycerol, thereby strengthening the matrix (Nurani *et al*., 2024).

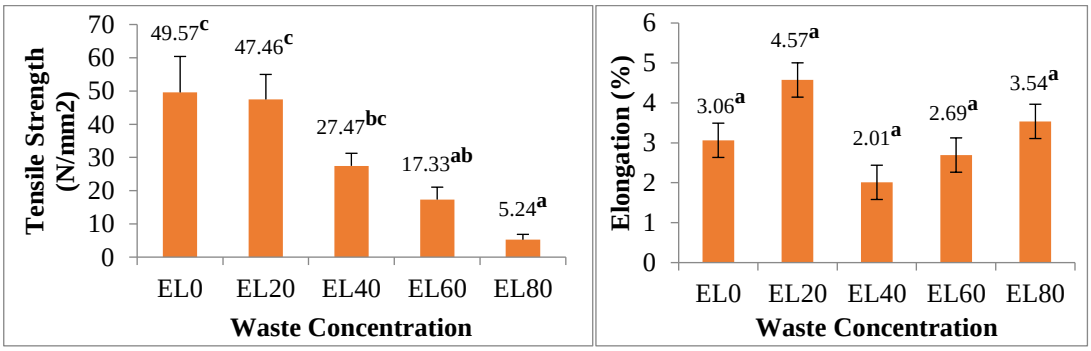

Figure 3. Effect of seaweed extraction waste content on the tensile strength and elongation at breaks of bioplastics

The elongation at breaks of carrageenan films can be enhanced by adding plasticizers, though this reduces tensile strength and Young's modulus. A concentration of 25-30% glycerol and sorbitol can increase tensile strength, elongation at breaks, solubility, and water vapor permeability of carrageenan bioplastics due to structural modification that makes the matrix less dense (Farhan and Hani, 2017). The elongation of alginate is influenced by the G/M ratio, viscosity, and extraction method (Gao *et al*., 2017). For application as food packaging, bioplastics with good mechanical properties (tensile strength and elongation) are essential to maintain and protect food integrity from damage or spoilage during storage and transportation.
The results of determining the mechanical properties (tensile strength and elongation at breaks) of the bioplastics showed that the samples containing waste exhibited lower tensile strength compared to the controls. The control sample had the greatest tensile strength. The elongation with 40% waste was lower than that of the control and other samples. The EL20 sample (20% waste) had the greatest elongation (**Figure 4**).

Water Resistance
Water resistance is a crucial property for bioplastics, as it determines their versatility. Lower water absorption indicates better water resistance. The study showed that the addition of waste reduced water absorption of bioplastics, enhancing their water resistance, which was visually evident as the bioplastics remained intact when immersed in water for 24 hours. This is likely due to the cellulose content in the waste acting as a reinforcement agent in the bioplastics (Khalil *et al*., 2017; Sedayu *et al.*, 2019). The results presented in **Figure 5** showed that the incorporation of waste had a significant impact on bioplastic solubility. As the waste concentration increased, the solubility of the film decreased. Ionic crosslinking due to immersion in Ca^{2+} solution quickly forms a stable, heat-resistant gel up to 100°C that is insoluble in

water (Gao *et al*., 2017). When alginate forms a gel, diaxially bonded guluronate (G) residues form cavities that act as binding sites for Ca^{2+} ions, enhancing the gel's characteristics and properties (Choi *et al*., 2022).
The polyguluronates in the alginate polymer bond with other alginate polymers through Ca^{2+} ions and match the structure of guuronic acid, so that the Ca^{2+} ions function as an adhesive between the 2 alginate polymers which increases the water resistance of bioplastics (Rhim, 2004). Alginate molecules occupy a position on the outside of the film surface because alginate is more hydrophilic than carrageenan (Choi *et al.*, 2022).
Solubility is also an important indicator for bioplastics, depending on their purpose. Edible food films require high solubility, while packaging materials for products with high moisture content should have low solubility. Highly soluble films are not suitable as primary packaging for food products with high water activity but can be used as soluble sachets for individual food portions (Zinina *et al.*, 2023).

Biodegradability
When assessing the degradability of polymeric materials derived from natural polymers, it is important to determine the time required for material degradation under exposure to microorganisms and enzymes present in the environment. A bioplastic is considered biodegradable when 90% of its material decomposes due to biological action within six months (Zinina *et al*., 2023). Biodegradability is an indicator of a material's ease of degradation in the environment, shown by the reduction in bioplastic weight during soil burial.
The addition of de-carrageenan waste to the carrageenan-alginate matrix resulted in a decrease in composite weight, indicating rapid and aggressive biodegradation. The study showed that the addition of de-carrageenan waste increased the biodegradability of bioplastics by up to 36.4% (**Figure 5**). The more waste added, the greater the biodegradability of the bioplastic. The cellulose content in the waste facilitates the degradation process (Behera *et al.*, 2022).
This suggests that de-carrageenan waste enhances the hygroscopic characteristics of the carrageenan-alginate composite, promoting microbial growth and increasing bioplastic weight loss (Zinina *et al*., 2023). Similar results were reported with the addition of agar, carrageenan, and Na-alginate in thermoplastic starch matrices (Behera *et al.*, 2022). These results differ from Khalil et al. (2017), who stated that cellulose in the waste is a water-insoluble polymer that enhances mechanical properties, water vapor barrier, and is more difficult to degrade. The data obtained were consistent with the results of Zinina *et al.* (2023), who established the decomposition period of alginate-based film in soil to be about 20 days.

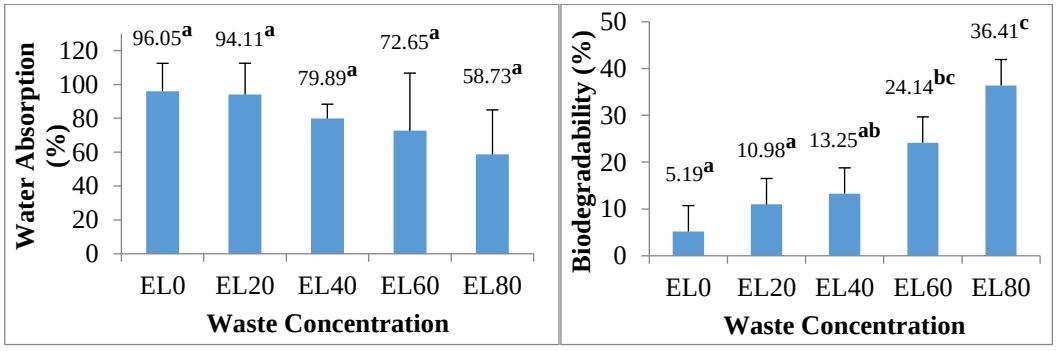

Figure 4. Effect of seaweed extraction waste on water resistance and biodegradability of bioplastics

Biodegradability is influenced by the cellulose content in seaweed extraction waste. Additionally, it is affected by the type of soil, microorganisms, and moisture levels. Water serves as a medium for most microorganisms, such as bacteria, penetrating the bioplastic structure and facilitating microbial activity. The cellulose content in the waste also affects biodegradability, along with soil type, microorganism type, and humidity.

Bioplastic Microstructure (FTIR Spectroscopy)
The effects induced by the seaweed extraction waste addition to the composite matrix were investigated by FTIR spectroscopy. The peaks corresponding to the main absorption capacity of the bioplastics are presented in **Figure 6**. The waste-containing bioplastics showed all the characteristic FTIR absorption band reported for carrageenan and alginate Pascalau *et al.* (2012) and Wang *et al*. (2024). The broad area from 3256-3317 cm^{-1} attributed to the stretching vibrations of the hydroxyl group in the carrageenan and alginate polymer. 1022-1024 cm $card^{-1}$ peaks are correlated to the glycoside bond. 1606-1594 cm $card^{-1}$ peaks and 1416 cm^{-1} are attributed to the asymmetric and symmetric vibrations of the COO^- groups in the alginate polymeric backbone. The k-carrageenan spectrum presents a characteristic band at 1300-1326 cm^{-1} due to S=O of sulphate strech.
The FTIR spectrum of the carrageenan-alginate-waste composite shows interactions between the carrageenan-alginate matrix and waste components like cellulose and hemicellulose. Lower wavenumbers indicate stronger interactions among components. When sodium alginate is mixed with carrageenan, the absorption peak wavelength generated by the –OH

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stretching vibration shifts towards longer wavelengths (Wang *et al*., 2024). The FTIR spectra exhibit shifts in the hydroxyl (-OH) group peaks for each treatment. The -OH group peak shifts from 3256.53 cm^{-1} (EL0) to 3318.03 cm^{-1} (EL80) (**Figure 6**). A shift of the -OH peak towards lower wavenumbers indicates the formation of new hydrogen bonds among the bioplastic components (Choi *et al.*, 2022). Conversely, a shift towards higher wavenumbers implies a reduction in hydrogen bonds. This reduction in hydrogen bonds likely causes the decrease in tensile strength of the bioplastic due to waste addition (**Figure 6**). The absence of new peaks suggests no chemical reactions among the components, with each component functioning independently (Paula *et al.*, 2015).

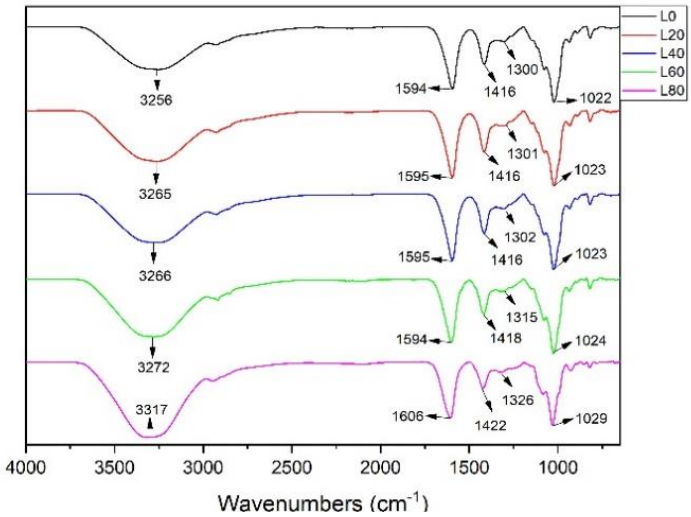

Figure 6. Bioplastic FTIR Spectra

Bioplastic Surfaces

According to SEM analysis (**Figure 7**), the surface of bioplastics without seaweed extraction waste addition appears rough, whereas bioplastics with added waste appear uniform and homogeneous. No phase separation occurs in the composite, indicating good compatibility between the waste and carrageenan, alginate, and glycerol. This is attributed to the hydrophilic nature of the waste, which matches the carrageenan-alginate matrix, resulting in good adhesion. Additionally, carrageenan, alginate, and waste melt together during heating and stirring, mixing well and producing a homogeneous surface (Rhim, 2012).

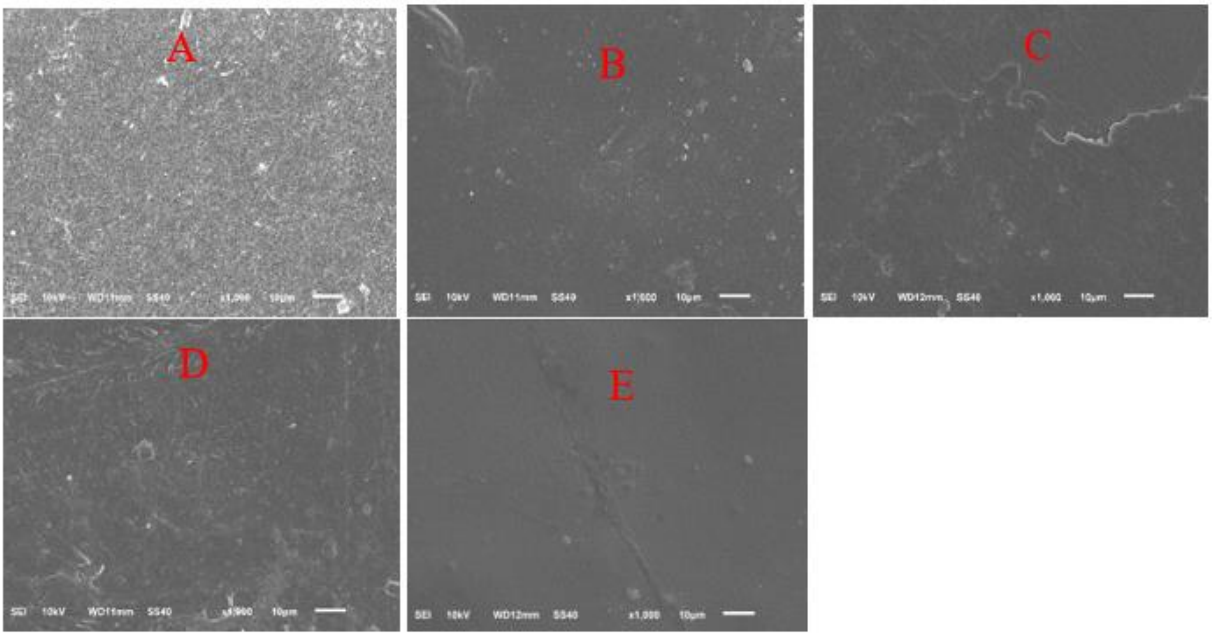

Figure 7. SEM Bioplastic Surfaces (A) EL0, (B) EL20, (C) EL40, (D) EL60, and (E) EL80

The bioplastics with different concentration of seaweed extraction waste had smoother and more uniform surface compared to the control (EL0), which demonstrated excellent compatibility between, caraageenan, alginate, gliserol and

waste (Zinina *et al*., 2023) Granulated particles observed of EL20, EL40 and EL60 bioplastics reducing the mechanical propperties and increasing the solubility (**Figure 4** and **Figure 5**). Cellulose in waste causes agglomeration of particles in the carrageenan-alginate film, leading to multiple small cracks and holes that negatively impact the mechanical properties of composite film (Zhang *et al.*, 2022)

CONCLUSIONS

Composite carrageenan-alginate have been produced at various Kappaphycus alvarezii extraction waste content and their physical and mechanical properties have been investigated. The addition of extraction waste increase biodegradability and water resistance, but has no significant effect on the mechanical properties of bioplastics. SEM result indicates the incorporation of seaweed extraction waste into the carrageenan-alginate does not cause fracture or cleavage, suggesting good compatibility between waste material and carrageenan-alginate composite and. These results support that the bioplastics produced can be used in the form of sachet for the preparation of individual portion of food

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