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BIODEGRADABLE POLYMER FILM: A STUDY OF KAPPA - CARRAGEENAN AND SODIUM ALGINATE BLEND

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ABSTRACT

The study of natural polymers can development of biodegradable purpose to reduce plastic material. Using kappa carrageenan and sodium alginate for designed for potential applications of food packaging materials and medical purpose. Research introduces characterization of polymeric film like, thermal, mechanism and barrier properties. Help of orange peel extract with kappa carrageenan and sodium alginate composite film to enhance the antibacterial properties and check the effectiveness against bacteria. To check it's structural, thermal, morphological, chemical and optical properties with the help of X-ray diffraction method, Fourier transform infrared spectroscopy, Thermogravimetric analysis, Scanning electron microscopy and Ultraviolet visible spectroscopy of kappa carrageenan and sodium alginate composite polymeric film. These two polymers are biological effective for pharmaceutical and food industries.

Keywords: **sodium alginate, kappa carrageenan, antibacterial, pf study, KNO_3 study, UV-visible spectroscopy, fourier-transform infrared, thermogravimetric analysis, scanning electron microscopy, X-ray diffraction analysis**

1. INTRODUCTION:

Biodegradable materials undergo decomposition by bacteria, fungi of biological processes, contributing to environmental sustainability. Their controllable degradation through reasonable modification is crucial in minimizing pollution. The expanding realm of biodegradable polymeric materials, encompassing both synthetic and natural variants is integral to various aspects of daily life. However, the effectiveness of biodegradation is influenced by specific factor, shaping the environmental impact of these materials **[1]**. Studying ancient food packaging materials is challenging due to their limited preservation over time. The vulnerability of food to decay during post-processing, distribution and storage has hindered the preservation of these materials. Consequently, there's a growing need for antibacterial solution in modern food packaging to address these challenges **[2]**. Kappa-carrageenan derived from red algae is a water soluble polysaccharide with excellent film-forming properties making it valuable in cosmetics, pharmaceuticals and food industry as an additive and stabilizer. its self-aggregation through helical structure makes it versatile for edible film in various food application **[3]**. In simpler terms, kappa carrageenan a common biopolymer is often used to make eco-friendly packaging due to its great film-forming abilities. Researchers have found that adding antibacterial properties. This is significant because antibacterial packaging plays a crucial role in preserving food quality and extending shelf life **[4]**. In essence bio-based polymer materials, such as alginate derived from brown algae of synthesized by microorganism were created as alternative to oil based material. Alginates being water soluble polysaccharides, exhibit a valuable property. The ability to form robust gels of polymer through interaction with polyvalent metal cation, notably calcium ion. This unique characteristic makes alginate particularly popular and extensively studied among hydrocolloids **[5]**. The versatile polysaccharide sodium-alginate exhibits promising application across various domain including, food, drug delivery, gene delivery, tissue engineering, wound dressing and waste water treatment. Notably its drug delivery technology plays a crucial role in bio-technology facilitating show release in application such as intestinal drug, leukemia, immune therapy, NRT and hepatocarcinoma cells. Additionally, Na-alginate demonstrates valuable contribution to gene delivery, aiding in protease cancer identification, theophylline sensing and topical chemotherapy within the bio-medical field **[6]**. In summary, the traditional approach to drug discovery, relying on whole plant extracts and single compound-based medicines faced challenges in terms of cost approval time and performance issue. Modern medicine has shifted towards more targeted approaches, leveraging scientific and technological advancement for quicker and more efficient development of novel drug candidates. High-throughput methods and genome sequencing have played pivotal role in transforming the drug discovery process **[7]**.

2. METHOD AND MATERIALS:

2.1. Materials:

Sodium alginate (Cas no:9005-38-3) was purchase from suvidhinath chemicals, vadodara.Kappa carrageenan (11114-20-8) was obtained from yashvi fine chemicals, ankleshwar. Orange essential oil extracted from orange peels was purchased from local market.

2.2. Method:

2.2.1 Formation Of Kappa Carrageenan Film:

In similar terms, a kappa carrageenan film was created by mixing 1 gm of substance with 50 ml of distilled water. The mixture was heated for 15 to 20 minutes at 40 to 50 C with magnetic stirrer. Once the solution was fully dissolved, it was left to cool at room temperature for certain periods.

2.2.2 Formation Of Sodium Alginate film:

A sodium alginate film was created by mixing 1 gm of the substance with 50 ml distilled water. The mixture was heated for 20 to 25 minutes at 30 to 40 C with magnetic stirrer, Once the solution was fully dissolved it was left to cool at room temperature.

2.2.3 Formation Of k-carrageenan & sodium alginate Composite Film:

Sodium alginate and kappa carrageenan were precisely measured at different ratio (100:0, 80:20, 70:30, 60:40 and 50:50) and mixed in separate beakers until uniform. The resulting mixtures were transferred to individual petri dishes and dried in the oven for 2 to 3 days before removed.

2.2.4 Natural Drug Extraction (Citrus x aurantium):

Certainly! Take 5 gm of dried orange peel's powder and soaked it in a solution made of 10 ml of methanol and 50 ml of water for 24 hour period. Afterwards, filtered the mixture using whatman No 1 filter paper. This process likely aimed to extract compounds from the orange peel into the liquid solution, and filtering helped separate any solid residue from the liquid **[8]**.

2.2.5 Formation of Drug Loaded Film:

In a single step, combine 0.50 gm kappa-carrageenan and 0.50 gm sodium alginate in 50 ml water. stir thoroughly to create a unified solution. introduce the 5 ml of orange peel extract as desired drug directly into the solution. Stir continuously to ensure even dispersion of the drug within the mixture. Immediately pour the entire the solution onto a flat surface or mold suitable for film casting. Spread it evenly to form a thin, uniform film. Allow the film to dry at room temperature of under controlled condition. The drying process in this single step forms a solid film with incorporated drug and natural enhancement.

3. Chemical Analysis:

3.1 Swelling Analysis:

Pf solution made by adding 0.307 gm of NaCl and 0.376 gm of CaCl2 in a one liters distilled water It's known as swelling test. Now cut 80:20,70:30,60:40 ratio film into small pieces and weighted it carefully and note down it's weight. Put this three ratio polymeric film into pf solution filled different beaker. Around 30 minutes take all the polymeric film onto the filter paper and dried it. Now weighted the all polymeric film and take reading. Repeat this process for the 6 to 7 times and take reading

$$SR = (Mt-Mo)/Mo \quad gm/gm$$

Where Mo is initial mass & Mt is mass at time

3.2 Gelatin Expansion studies:

Gelatin solution made by 10 gm of gelatin powder dissolve in 100 ml of distilled water. Take small piece of 80:20,70:30,60:40 ratio film. Pour 20 ml of the gelatin solution into three separate petri dishes. Place the ratio film in the middle of each dishes. After 20 minutes check the diameter of each ratio film and record reading. Repeat this experiment 4 to 5 times, including diameter for each ratio film.

$$ER = (Dt)/ (Do)$$

Where Dt is diameter at time & Do is initial diameter

3.3 Dynamic Moisture Absorption Studies:

Mix a good amount of KNO_3 powder in water until it won't dissolve anymore. Now cut small pieces of film in ratio of 80;20,70:30,60:40 and measure the weight of each set of film pieces. Put the film pieces in a plastic box, away from the KNO_3 solution and seal the box tightly. Leave it alone for 15 minutes. No peeking! After 15 minutes carefully take out each set of film pieces. Weight them again and write down reading. Do this experiment 4 to 5 times. It helps us get a good understanding of what's going on. Compare the weight before and after for each set of film pieces, look for any patterns or differences. Keep a record of what you observe especially if you notice changes in the film pieces.

4. Characterization:

4.1 Antibacterial studies:

Create a nutrient agar solution by mixing 2.9 grams of nutritional agar powder with 100 ml of distilled water in a conical flask. Ensure cleanliness, pour the solution into clean petri dishes and let it cool. Place *Escherichia coli* bacteria on the agar in a petri dish. Introduce small pieces of kappa carrageenan and sodium alginate film loaded with drug into the same dish. Now place the petri dish in controlled environment for 24 hours to observed how the drug-loaded materials impact Escherichia coli bacteria growth, serving as an antibacterial test.

4.2 X-ray Diffraction (XRD):

In essence, x-ray crystallography established for over sixty years, stands as the foremost accurate method for revealing detailed structure information about biological macromolecules. By relying on high-quality crystals. This approach unveils molecular mechanism and intricate intermolecular interaction, offering vital insights into the functioning of macromolecules and the formation of complex supramolecular assemblies. Additionally x-ray diffraction by crystalline powder emerges as a powerful and widely employed method for analyzing matter, providing fundamental details on intra/inter-molecular interaction and physicochemical properties. The three-dimensional structural characterization attained through this technique is crucial for comprehending the mechanism of action of biological macromolecules **[9]**.

4.3 Scanning Electron Microscopy (SEM):

Recent advancements in scanning electron microscopy (SEM) have led to a consistent improvement in achievable resolution. Electron diffraction a robust characterization method utilized in various field and instruments has seen notable progress. A cost-effective and versatile setup has been introduced for detecting transmission nanobeam diffraction patterns in scanning electron microscopy (SEM), operating within the energy range of 0.5-30 keV. This innovation setup is adaptable and can be easily integrated into exiting SEM system **[10]**.

4.4 Ultraviolet-Visible Spectroscopy:

Ultraviolet-visible absorption spectro-photometry involves measuring the attenuation of electromagnetic radiation (190-800 nm) by a substance. This attenuation can result from reflection, scattering, absorption and interferences. The paper aims to emphasize advancements in detectors, detection system and strategies in Uv-Visible spectrophotometry. Showcasing applications in determining organic compounds **[11]**.

4.5 Fourier Transform Infrared (FTIR) Spectroscopy:

In simpler terms, Fourier transform infrared (FTIR) spectroscopy is valuable tool in fields like medicine for tasks such as disease diagnosis and drug discovery. It identifies functional group and gathers structural information by measuring the absorption of infrared light due to vibrational transitions in covalent bonds. Technological advancements, such as high-flux light sources have enabled faster and more precise FTIR analysis, making each spectrum unique based on contributing factors **[12]**.

4.6 Thermogravimetric Analysis (TGA):

Thermogravimetric analysis (TGA) is a valuable technique in research. It measures changes in sample weight as a function of temperature. Researchers often use TGA to study material properties, decomposition kinetics and thermal stability. Thermogravimetric analysis provides valuable insights across various industries aiding in material characterization, quality assurance and process optimization. One specific application of thermogravimetric analysis in research is the analysis of polymer degradation. Thermogravimetric analysis can be employed to study the thermal stability of polymer, providing insights into their decomposition behavior, temperature ranges for stability and composition of degradation products. This information is crucial in various industries, including plastics where understanding polymer behavior under different condition is essential for product development and quality control.

5. RESULTS AND DISCUSSION:

5.1 Chemical Analysis

5.1.1 Swelling Analysis:

Swelling analysis in polymeric films involves studying the response of a film to the absorption of a solvent or another substance. Researchers often measure changes in film thickness, weight and other properties as the film absorbs the solvent.

Creating polymeric films using different ratio of kappa carrageenan and sodium alginate. Immerse these films in a pf solution and record the weight at 30 minutes intervals, noticing an increase over time. This process helps observe how the films absorb swell in the solution. **Table 1** presents the swelling analysis reading, depicting the progressive weight increase over time.

Figure 1 visually represents the ascending trend in the weight of the polymeric film through a graph, illustrating the result of the swelling analysis.

5.1.2 Gelatin expansion studies:

Gelatin expansion studies in polymeric film typically focus on understanding how gelatin a protein based material interacts with and expands within a polymer matrix. Researchers investigate factor such as film composite, gelatin concentration and processing condition to optimize properties like film strength, flexibility and permeability. These studies contribute to the development of biodegradable film or various application including food packaging material and biomedical devices. Gelatin expansion in polymeric film with round shaped pieces allows researchers to investigate how the diameter of this pieces affected gelatin's behavior within the film. Increasing the diameter may impact factors such as swelling, mechanism properties and surface characterization. **Table 2** displays the growth in a diameter of the polymeric film when immersed in a gelatin solution.

Figure 2 illustrates gelatin expansion studies and demonstrating a progressive increase in the diameter of the polymeric film over time interval.

5.1.3 Dynamic Moisture absorption Studies:

Investigating dynamic moisture absorption in polymeric films involves tracking water uptake over time under varying condition. Dynamic moisture absorption in polymeric film using a KNO_3 solution involves immersing the film and monitoring water absorption. KNO_3 acts as a desiccant, facilitating controlled humidity condition for accurate absorption analysis in polymer research. **Table 3** demonstrates the progressive increase in the weight of the polymeric film during dynamic moisture absorption study in a KNO_3 solution.

5.2 Characterization

5.2.1 Antibacterial Study:

Antibacterial studies in drug loaded polymeric film involve investigating the film's efficiency in inhibiting bacterial growth. The study may include testing against specific bacteria strains, evaluating zones of inhibition and analyzing release kinetics of the antibacterial drug from the film. Such research aims to develop antimicrobial polymeric films for application like wound dressing or medical implants, where controlled drug release and bacterial inhibition are critical for therapeutic effectiveness. **Figure 3** illustrates the antibacterial activity of drug loaded polymeric film, showcasing its capability to inhibit the growth of bacteria.

5.2.2 X-ray Diffraction (XRD):

X-ray diffraction (XRD) provides rapid measurements by capturing diffraction patterns from multiple crystals simultaneously. This quick data acquisition even with standard lab equipment allows for in situ experiments where the same sample undergoes repeated measurements while changing external variables such as time. This versatility makes XRD valuable in studying dynamic processes and structural changes **[13]**. **Figure 4** depicts the X-ray diffraction graph of the polymeric film with an 80:20 ratio of kappa carrageenan and sodium alginate.

5.2.3 Scanning Electron Microscopy (SEM):

Scanning electron microscopy (SEM) utilized electrons not light waves to generate highly magnified images. Pioneering research focused on SEM's physical principles and beam-specimen interactions. The electron beam impact on the sample results in emitted electrons and radiation, offering insights into surface morphology, composition, crystallography and other properties. The excitation volume size and shape are primarily influenced by the sample's composition and the accelerating voltage used **[14]**. **Figure 5 (a) & Figure 5 (b)** are shown the images of SEM analysis data of kappa carrageenan and sodium alginate composite polymeric film.

5.2.4 Ultraviolet-Visible Spectroscopy:

UV-Visible spectroscopy of orange peel extract involves analyzing the absorbance of light at different wavelengths. The spectrum can provide information about the compounds present potentially including carotenoids responsible for the orange color. The characteristics absorbance peaks can help identify and quantify specific components in the extracts. Analyzing the UV spectrum of an orange peel extract used in polymeric film for drug delivery involves studying how the extract absorbs ultraviolet (UV) light at various wavelengths **(Figure 6)**.

5.2.5 Fourier Transform Infrared Spectroscopy (FTIR): (Figure 7a, b, c)

FTIR spectroscopy advancing notably in the last decade, facilitates swift and objective diagnoses by analyzing the unique spectrum fingerprint of molecules based on their interaction with electromagnetic radiation. This nondestructive method proves effective in monitoring cellular alteration offering valuable insights into molecular composition and structure **[15]**.

k-carrageenan polymeric film:

First peak at 3356.71 cm^{-1} it's range between 3200-3600 cm^{-1} this peak indicating broad 0-H stretching peak it linked with polysaccharides. C=O stretching vibration at 1636.13 cm^{-1}. 1228.65 cm^{-1} indicates sulphur ester group. C-O stretching vibration of linkages with polysaccharides at 1068.33 cm^{-1}. 923.18 cm^{-1} repeat sulphur ester group.

Sodium alginate polymeric film:

Peak at 3777.93 cm^{-1} broad peak associated with O-H stretching. Again O-H stretching at 3301.96 cm^{-1} it range between 3200-3600 cm^{-1}. 1600.92 cm^{-1} at C=O stretching vibration of carboxylate group. At 1065.16 cm^{-1} C-O stretching vibration of ester or ether groups.

Kappa carrageenan and sodium alginate composite film:

First peak 1660.59 cm^{-1} it indicating C=O stretching carbonyl group. C=C alkene stretching at 1601.93 cm^{-1}. 1426.36 cm^{-1} stretching of alkene or alkyl group. C-N stretching found in amines at 1191.31cm $-^{1}$ 1026.68 indicates the C-O stretching of ether function group. 923.00 cm^{-1} C-H bending in aromatic ring. C-H bending in alkene or alkyne group at 844.24 cm^{-1}. 700.76 cm^{-1} C-H bending in an alkene.

5.2.6 Thermogravimetric Analysis (TGA):

Performing thermogravimetric analysis (TGA) on a kappa carrageenan and sodium alginate composite polymeric film at 400 ^{0}C for 10 minutes involves subjecting the sample to controlled temperature condition to observed its weight changes over time. This analysis helps assess the thermal stability and degradation characteristics of the composite. **Figure 8** displays information from TGA of a composite film made from kappa-carrageenan and sodium alginate.

Table 1: Swelling analysis (pf studies)

S. No.	Time (min)	k-carrageenan & sodium alginate (80:20) gm	k-carrageenan & sodium alginate (70:30) gm	k-carrageenan & sodium alginate (60:40) gm
1	0 min	0.337 gm	0.503 gm	0.314 gm
2	30 min	1.20 gm	2.85 gm	3.78 gm
3	1 hour	1.37 gm	3.21 gm	3.95 gm
4	1.5 hour	1.48 gm	3.32 gm	4.13 gm
5	2 hour	1.61 gm	3.36 gm	4.24 gm
6	2.5 hour	1.67 gm	3.52 gm	4.34 gm
7	3 hour	1.81 gm	3.56 gm	4.37 gm
8	3.5 hour	1.92 gm	3.62 gm	4.40 gm
9	4 hour	2.02 gm	3.68 gm	4.48 gm

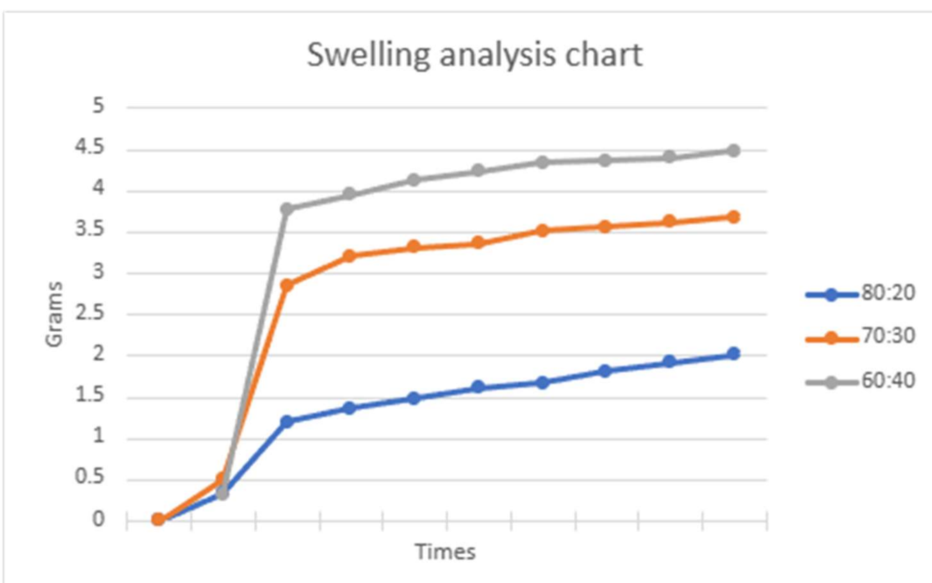

Figure 1: Swelling Analysis Chart of k-carrageenan & sodium alginate composite film

Table 2: Gelatin Expansion Studies

S. No.	Time (min)	k-carrageenan & sodium alginate (80:20) cm	k-carrageenan & sodium alginate (70:30) cm	k-carrageenan & sodium alginate (60:40) cm
1	0 min	0.90 cm	0.90 cm	0.90 cm
2	20 min	1.15 cm	1.25 cm	1.30 cm
3	40 min	1.35 cm	1.35 cm	1.45 cm
4	60 min	1.40 cm	1.45 cm	1.50 cm
5	80 min	1.50 cm	1.55 cm	1.55 cm

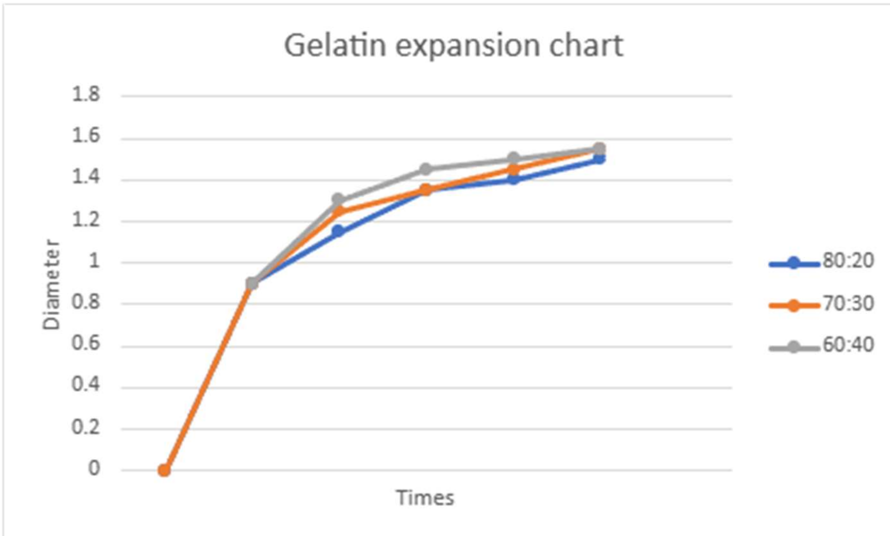

Figure 2: Gelatin expansion chart of k-carrageenan and sodium alginate composite film

Table 3: Dynamic Moisture Absorption Studies

S. No.	Time (min)	k-carrageenan & sodium alginate (80:20) gm	k-carrageenan & sodium alginate (70:30) gm	k-carrageenan & sodium alginate (60:40) gm
1	0 min	0.9 gm	0.10 gm	0.9 gm
2	15 min	0.13 gm	0.15 gm	0.11 gm
3	30 min	0.15 gm	0.16 gm	0.13 gm
4	45 min	0.16 gm	0.18 gm	0.15 gm
5	60 min	0.18 gm	0.19 gm	0.17 gm
6	75 min	0.20 gm	0.21 gm	0.20 gm

Figure 3: Antibacterial study of drug loaded film

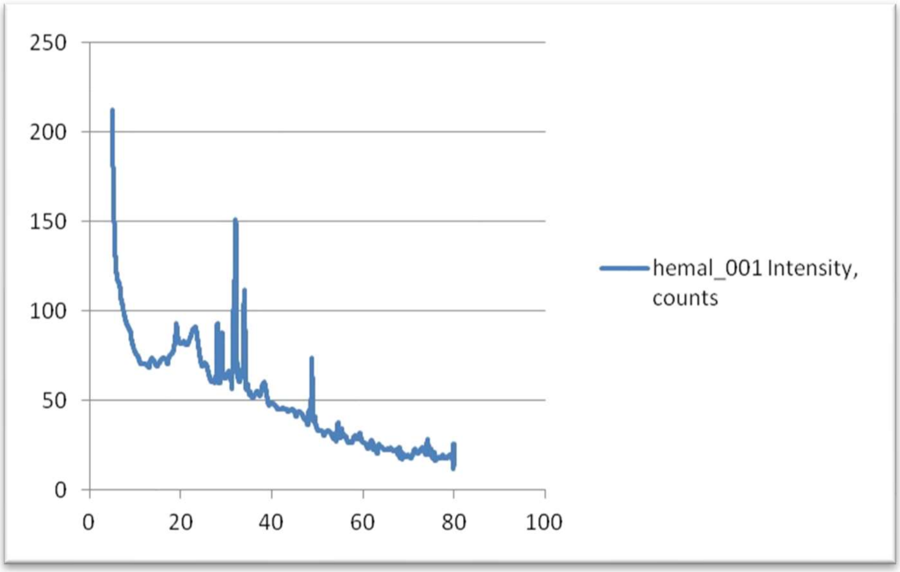

Figure 4: Graph of x-ray diffraction (XRD)

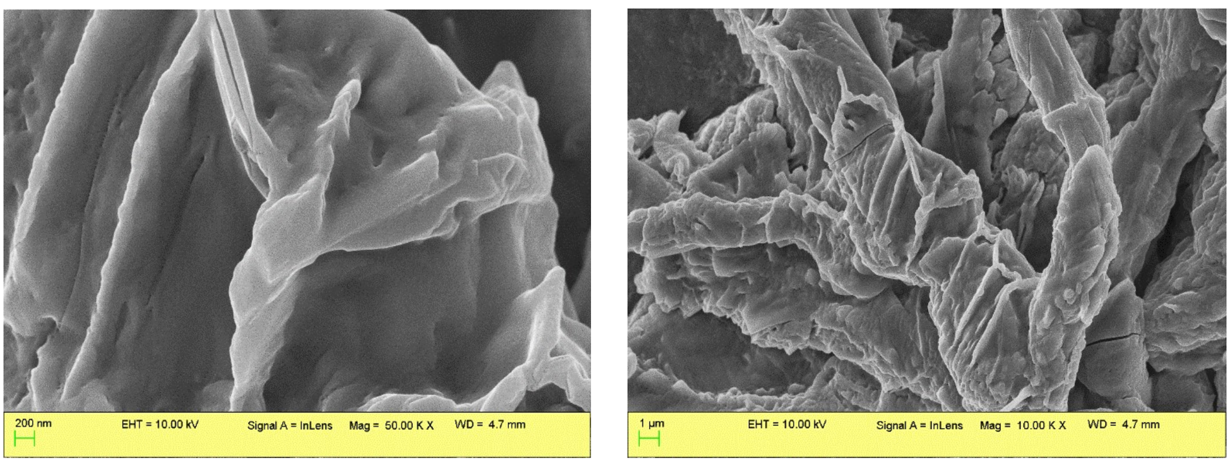

Figure 5 (a): SEM images of kappa-carrageenan and sodium alginate composite polymeric film

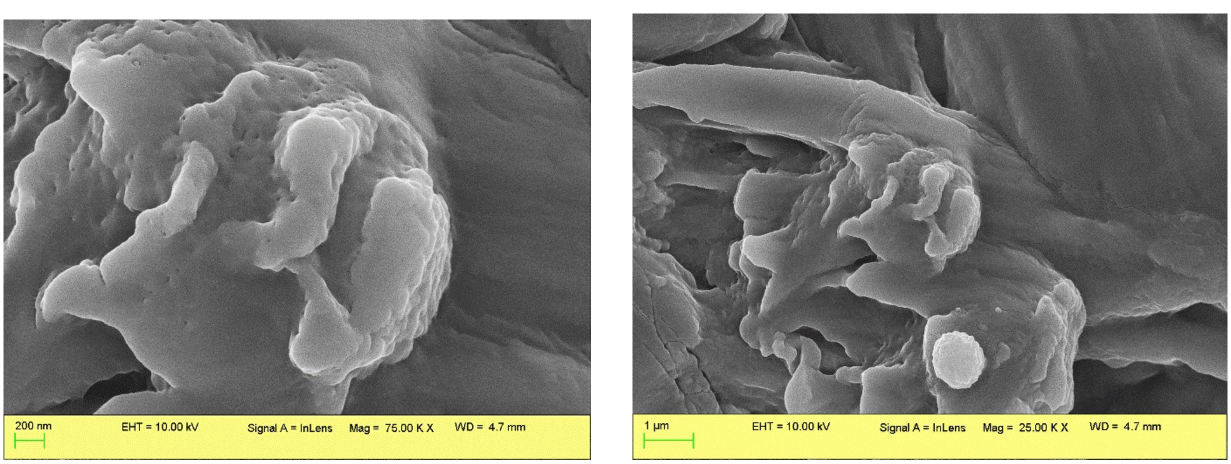

Figure 5 (b): SEM images of kappa-carrageenan and sodium alginate composite polymeric film

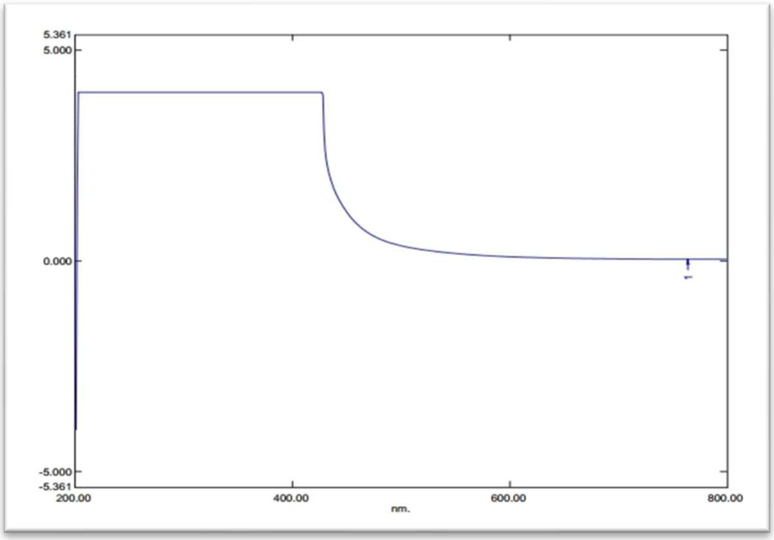

Figure 6: UV spectra of Natural Drug Extract (orange peel extract

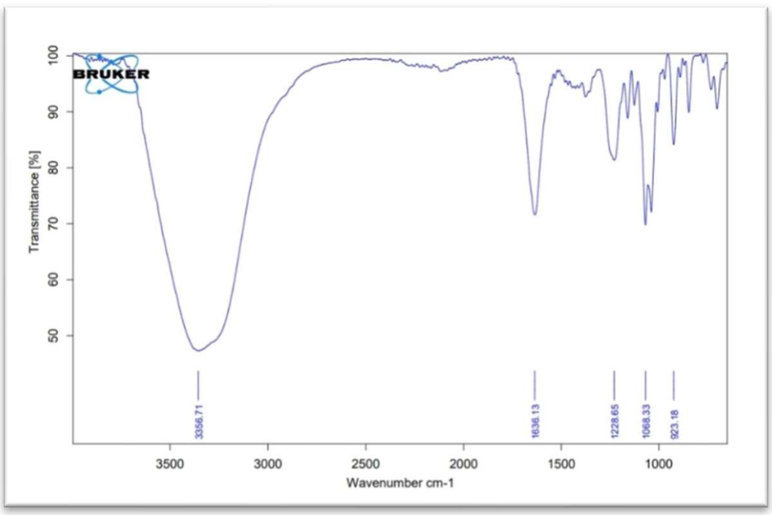

Figure 7 (a): FTIR spectra of kappa carrageenan polymeric film

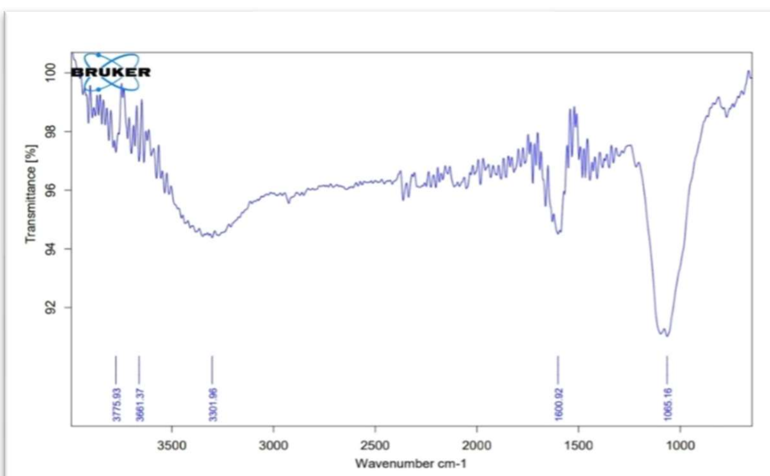

Figure 7 (b): FTIR spectra of sodium alginate polymeric film

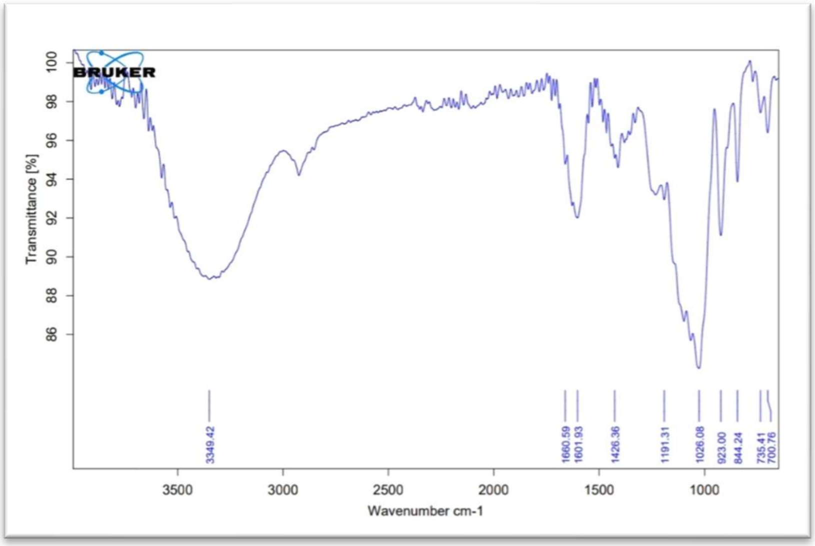

Figure 7 (c): FTIR spectra of kappa carrageenan & sodium alginate composite film

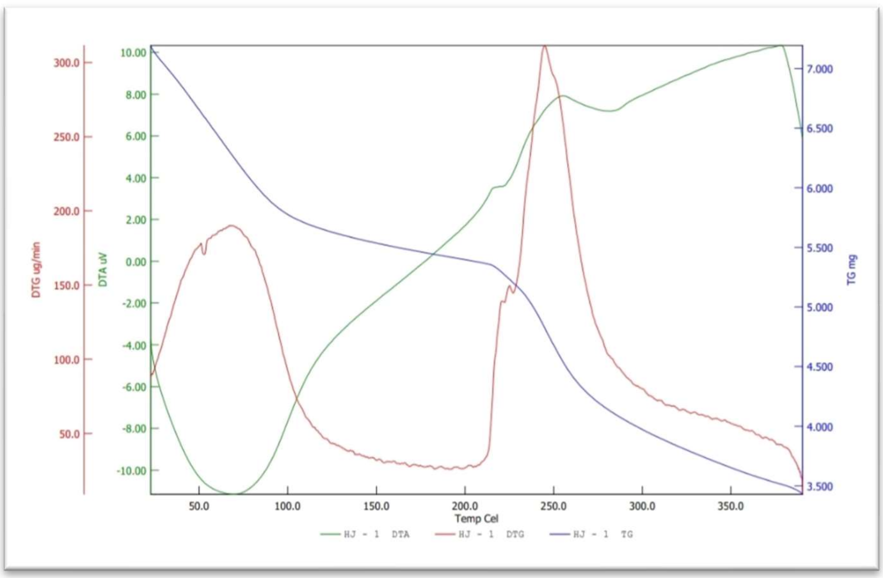

Figure 8: Thermogravimetric analysis of k-carrageenan & sodium alginate composite film

6. CONCLUSION:

Kappa carrageenan and sodium alginate are natural and biodegradable polymer. They are used in pharmaceutical and food industries. Commonly used in the food industry as a thickening, gelling and stabilizing agent. Enhance the texture of certain food packaging to improved moisture retention and self-life. Use of natural drug like orange peel are rich in antioxidant. It used in food and cosmetic industries for flavoring, fragrance, and as a natural preservative. Natural drug composite film is used for antibacterial properties. These natural polymers are break down easily than traditional plastics, it provides both functional and eco-friendly benefits. Biodegradable polymers offer environmental benefits as reducing plastic pollution.

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