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BIODEGRADABLE COMPOSITE FILMS WITH ANTIBACTERIAL EFFICACY: CELLULOSE AND KAPPA CARRAGEENAN

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ABSTRACT

For the purpose of to create biologically active wound dressings, cellulose and kappa carrageenan were combined in this study using a simple process that involved mixing their solutions and then connecting them with a glutaraldehyde solution. A range of cellulose to kappa carrageenan ratios, including 80:20, 60:40, 70:30, and 50:50, were utilized, and the mechanical, thermal, and swelling characteristics of the resultant films were assessed. These dressings were developed with a biological purpose in mind, namely for their use in aiding wound healing at various phases, including swelling, tissue growth, and remodeling. Mehndi, a naturally occurring bioactive ingredient with anti-inflammatory, antioxidant, and tissue-regeneration properties, was included into these films. These composite films were made with the help of mehndi enrichment and biopolymers (cellulose/kappa carrageenan) and the crosslinker glutaraldehyde. The resulting films were thoroughly examined using a variety of analytical methods, such as TGA (thermogravimetric analysis), XRD (X-ray diffraction), and FTIR (Fourier Transform Infrared Spectroscopy). An assessment about edema was also carried out. The mehndi extract was characterized using UV-visible spectroscopy. The morphological analysis supported the design and construction of the videos. The antibacterial characteristics of the cellulose-kappa carrageenan-mehndi composite films were evaluated in relation to the *Escherichia coli* (*E. coli*) bacterium. As a result, this all-natural composite material shows promise as a cost-effective substrate to encourage efficient wound healing.

Keywords: Cellulose, k-carrageenan, Mehndi (Heena), TGA, XRD, FTIR, Antibacterial activity

1. INTRODUCTION

Innovative materials like carrageenan and cellulose composite films have drawn interest from a variety of sectors because of their special qualities and prospective uses. Cellulose is a common biopolymer found in the cell walls of plants, whereas carrageenan is a naturally occurring polysaccharide generated from red seaweeds. When mixed, these two substances yield a flexible composite film with several applications in biomedical technology, environmental sustainability, and food packaging **[1]**.

The benefits of both materials are maximized when carrageenan and cellulose are combined to create a composite film. Excellent film-forming qualities offered by carrageenan include outstanding water barrier qualities, film flexibility, and biodegradability. Cellulose, on the other hand, provides durability, stability, and improved mechanical qualities. Researchers and producers can produce films with better qualities compared to single-component films by combining these two biopolymers **[2]**.

Composite films made of cellulose and carrageenan have several possible uses. They can be used as edible packaging materials in the food industry to increase food safety, decrease food waste, and increase the shelf life of perishable commodities. Due to their biocompatibility and capacity for controlled release, these films can be used in medicine as tissue scaffolds, wound dressings, and drug delivery systems. Additionally, they are sustainable and biodegradable, making them ecologically suitable substitutes for traditional plastic films **[3]**.

In the production of drug-loaded films, notably in the fields of pharmaceuticals and drug delivery, cellulose and carrageenan are two crucial ingredients. These films are cutting-edge drug delivery technologies that have drawn a lot of interest because of their adaptability and promise to enhance patient outcomes and medication administration.

The term "mehndi" refers to a thin, sticky film or patch that is placed to the skin and used as a delivery system for drugs. These films are frequently used for transdermal drug administration, which allows medications to enter the bloodstream through the skin instead of the digestive system **[4] [7]**.

Carrageenan and cellulose have various benefits when used in drug-loaded films. They offer a reliable foundation for combining a variety of medications, including hydrophobic and hydrophilic substances. Additionally, their capacity to regulate the medication release over time guarantees a prolonged and regulated therapeutic impact, limiting side effects and the need for frequent dosage.

Pharmaceutical industry research and development efforts are focusing on carrageenan and cellulose-based drug-loaded films, which is a promising direction. They are an invaluable tool for promoting patient compliance and comfort while also improving medication administration because to their compatibility with a variety of pharmaceuticals, controlled release capabilities, and non-invasive application. To satisfy the changing requirements of contemporary medicine, researchers continue to investigate and improve these ground-breaking films **[5]**.

In conclusion, carrageenan and cellulose composite films represent a fascinating development in materials science and have the potential to solve a variety of problems in numerous fields, ranging from food packaging to healthcare and environmental sustainability. They are attractive prospects for a variety of applications because to their special mix of features, which motivates continuing research and development in this area **[6] [7]**.

2. MATERIAL AND METHODS

2.1. Materials

Cellulose purchased in this study was obtained from Tarapur MIDC Boisar, Palghar, Maharashtra, India. Sisco Research Laboratories pvt.ltd, Taloja, Maharashtra (India) offered kappa- carrageenan. We bought mehndi leaves from Ayurveda garden Vadodara.

2.2. Fabrication of Kappa-Carrageenan Thin Film

Film-forming solutions were carefully created for the creation of flat -carrageenan films by dissolving 1 gram of -carrageenan in 100 milliliters of well distilled water. The dissolving procedure was carried out vigorously and precisely, at a temperature of 95 degrees Celsius. By carefully maintaining this temperature condition with the use of a cutting-edge magnetic stirrer, the -carrageenan was extensively distributed and integrated into the aqueous medium. It took this methodical approach, which lasted for 30 minutes, to produce the appropriate film-forming solution, which then served as the basis for the future film production process **[8]**.

2.3. Development of Biodegradable Films by Combining Kappa Carrageenan and Cellulose

1 gram of cellulose and 1 gram of carrageenan were carefully dissolved in 100 milliliters of water to form a biodegradable film that may be used as an environmentally friendly substitute for traditional plastic films. This process makes use of natural polymers. This sustainable film is an example of how environmentally conscious materials may be used to reduce the environmental impact of packaging and other applications. It was made possible by a 30-minute stirring operation at 45 degrees using a magnetic stirrer **[9]**.

2.4. Exploring the Medicinal Potential of Henna (Mehendi) Extract as a Natural Drug/ preparation of plant extracts

From 20 grams of powdered mehndi, a medicine extract is made by mixing the powder with 100 milliliters of water and heating the combination in a regulated chamber. Once the combination has been heated, it is carefully filtered to separate the medication extract. This is then kept in storage at 4 degrees Celsius to maintain its efficacy and integrity for a longer amount of time **[10]**.

2.5. Fabrication of Drug Loaded Film

Make a drug-loaded biopolymer composite film by adding 4 ml of the drug extract to a solution made of 0.50 grams of cellulose and 0.50 grams of kappa carrageenan dissolved in 50 milliliters of water. Use a magnetic stirrer set to 45 degrees Celsius to guarantee even dispersion and mixing, which will aid in the creation of a film that is enhanced by the pharmaceutical agent.

3. Chemical Analysis

3.1. Physiological fluid

Using the technique outlined by Gunter et al., the physiological fluid (PF) sample's water solubility (WS) was evaluated. Three tiny films, each 2 by 2 centimeters, were baked for 24 hours at room temperature in a dry oven to ascertain the initial solids composition. The samples were then mixed together and completely submerged in a 50 ml beaker that contained 30 ml of the PF solution. To find the solid content, the films were dried in a dry oven for a further twenty-four hours after being immersed for twenty-four hours. Readings were made every 30 minutes to track the change in solid content during the drying process. Put differently, this process entailed evaluating **Table 1**.

Table 1: Swelling Study

Time	k-carrageenan-Cellulose (80-20)	k-carrageenan-Cellulose (70-30)	K-carrageenan-Cellulose (60-40)
0 Min	0.244	0.125	0.123
30 Min	0.675	0.843	0.809
60 Min	0.871	0.957	1.098
90 Min	0.970	0.957	1.280
120 Min	1.009	1.074	1.342
150 Min	1.073	1.115	1.522
180 Min	1.112	1.213	1.608

3.2. Characterization

FTIR Spectroscopy:

Energy Dispersive Reflection (ATIR) FTIR Spectroscopy was used to analyze materials, kappa carrageenan, and cellulose films using infrared light at a wavelength of 4,000–600 cm. With Thermo Nicolet Corporation's proprietary software from the NEXUS-870 platform, a constant spectral resolution of 2 cm was maintained in every case **[11]**.

X-Ray diffraction (XRD):

Using a copper (Cu) target and 1.54 angstroms (Å) of X-ray radiation, X-ray diffraction (XRD) patterns were obtained using a Rigaku Miniflex X-ray diffractometer. The analysis was carried out in a stationary setup with the sample fixed in a sample holder and the detector ranging in angular range from 2 to 40 degrees **[12]**.

Thermo Gravimetric Analysis (TGA):

Using a Mettler Toledo thermogravimetric analyzer thermal stability and degradation evaluations of the composite films were carried out in a nitrogen environment. A temperature ramp was applied to every composite film and additional sample. The temperature was progressively raised from ambient temperature to 600 °C at a rate of 10 °C per minute **[13]**.

UV Visible of mehndi extract:

The transition of an electron from one electronic state to another would be represented by one or more distinct peaks in the ultraviolet or visible spectra of the chemical. If there are differences between two distinct electronic states' electronic energy levels. By comparing the quantity of light that passes through a sample to the amount of light that passes through a reference sample or a blank, one may quantitatively determine how much light a chemical molecule absorbs **[14]**.

Antibactarial Test:

Escherichia coli (*E. coli*) was utilized to test the antibacterial activity of henna-infused composite film produced with k-carrageenan and cellulose. First, make 2.8 grams of nutritional agar in a glass flask and Petri plate with 100 milliliters of distilled water. Using a bacterial spreader, uniformly distribute the *E. coli* test bacteria onto the solidified agar after allowing the growing medium to cool to room temperature following sterilization. After that, place a section of the composite film on an agar plate and incubate it for a whole day at 37 degrees Celsius. Next day, measure and document the diameter of the inhibitory zone that has formed.

4. RESULTS AND DISCUSSION:

4.1. UV visible of Mehndi drug extract:

The Parul Institute of Applied Sciences (PIAS) in Vadodara, Gujarat, India, methodically conducted precise UV-visible analytical studies. To determine the presence and quantity of several compounds in a solution, UV absorption spectroscopy—a frequently used method in analytical chemistry—was performed. In this case, the mehndi extract produced a unique signal at 298 nm in the wavelength range of 200 to 400 nm due to significant UV light absorption. As a point of reference and for comparison, this technique also used a water baseline **Figure 1**.

4.2. FTIR Spectroscopy:

The Parul Institute of Pharmaceutical Science and Research (PIPR) in Baroda,

Gujarat, India, performed the FTIR tests with the accuracy.

Figure 2 below displays the FTIR result for the 60:40 K-carrageenan/ Cellulose composite film. CO-O-CO stretching is present at wave number 1027.87 cm-1, which represents the apex. The peak appears at 3278.73 cm-1, indicating O-H stretching.

Figure 3 displays the k-carrageenan film's FTIR result. Peaks indicating the presence of s=o stretching in the k-carrageenan film were seen at 1034.78 cm-1. The peaks seen in the 700–900 cm-1 range could be the result of C=C mixing. O-H stretching is present at wave number 3381.50 cm-1, which is the peak.

4.3. Thermo Gravimetric Analysis (TGA):

Thermo Gravimetric analysis tests were performed with full precision at SPU (Sardar patel University) Anand (Gujarat, India). The temperature stability of the sample was evaluated with a thermogravimetric analyzer. A temperature gradient ranging from room temperature to 390.65 degrees Celsius was applied to a piece 4.577 mg film. The temperature increased at a constant rate of 10 degrees Celsius per minute **Figure 4**.

4.4. X-Ray Diffraction:

One effective analytical method for examining a material's crystal structure is X-ray diffraction (XRD). In X-ray reflectometry (XRD), a crystalline sample is exposed to X-rays, and the diffraction pattern that results is examined to ascertain the atoms' arrangement in the material. Peaks on the XRD graph, sometimes referred to as a diffractogram, represent the angles at which the crystal structure diffracts X-rays **[15]**. The orientation, size, and orientation of the crystal's grains are revealed by the position and strength of each peak. In order to define and identify crystalline phases in a broad range of materials, XRD is widely used in many scientific domains, including chemistry, physics, and materials science **Figure 5**.

4.5. Antibacterial test:

The antibacterial efficacy of a cellulose-kappa carrageenan composite film infused with mehndi extract was assessed against *E. coli*. A segment of the film laden with mehndi extract was positioned within a petri dish that housed *E. coli*. The diameter of the inhibition zone in the composite film with mehndi extract was found to be 2.9 centimeters **Figure 6 [15]**.

No.	P/V	Wavelength	Abs
1		298.00	3.972

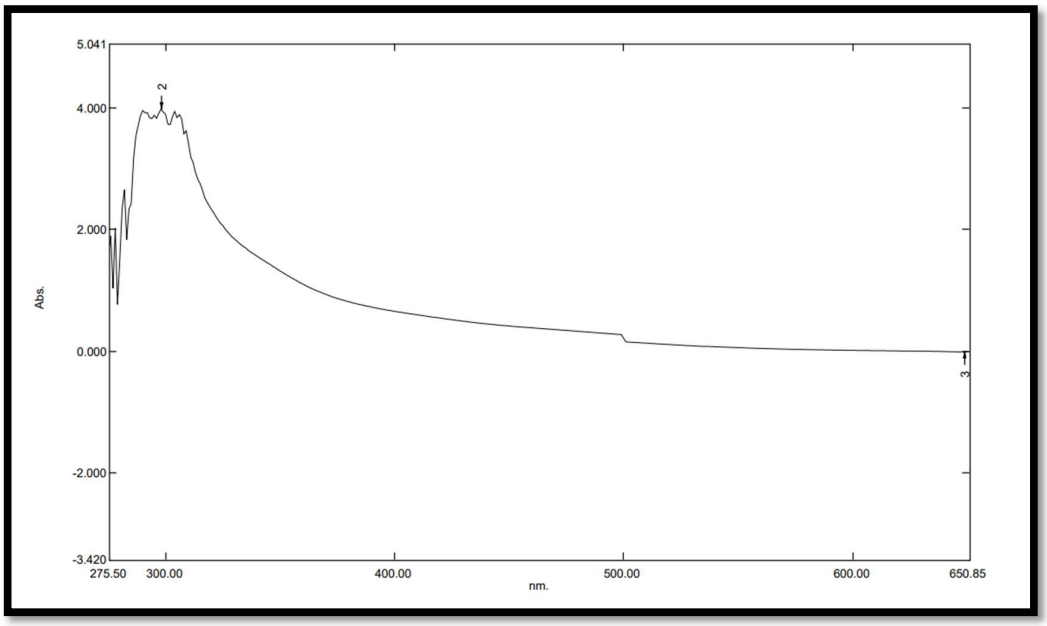

Figure 1: UV visible spectra of mehndi drug Extract

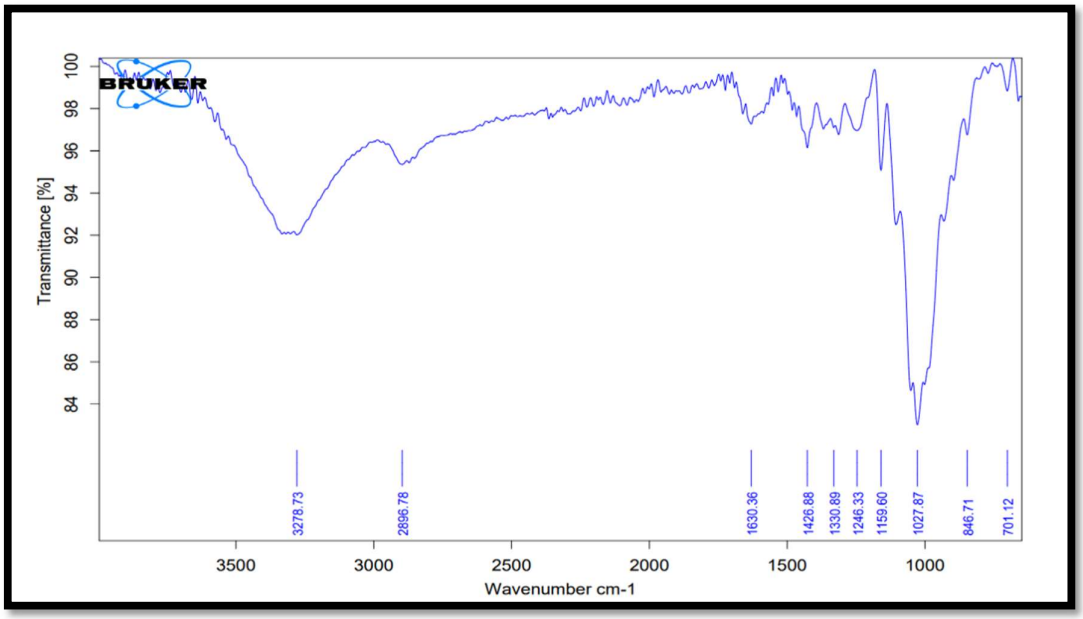

Figure 2: FTIR spectrum of 60:40 K-carrageenan/ Cellulose composite film

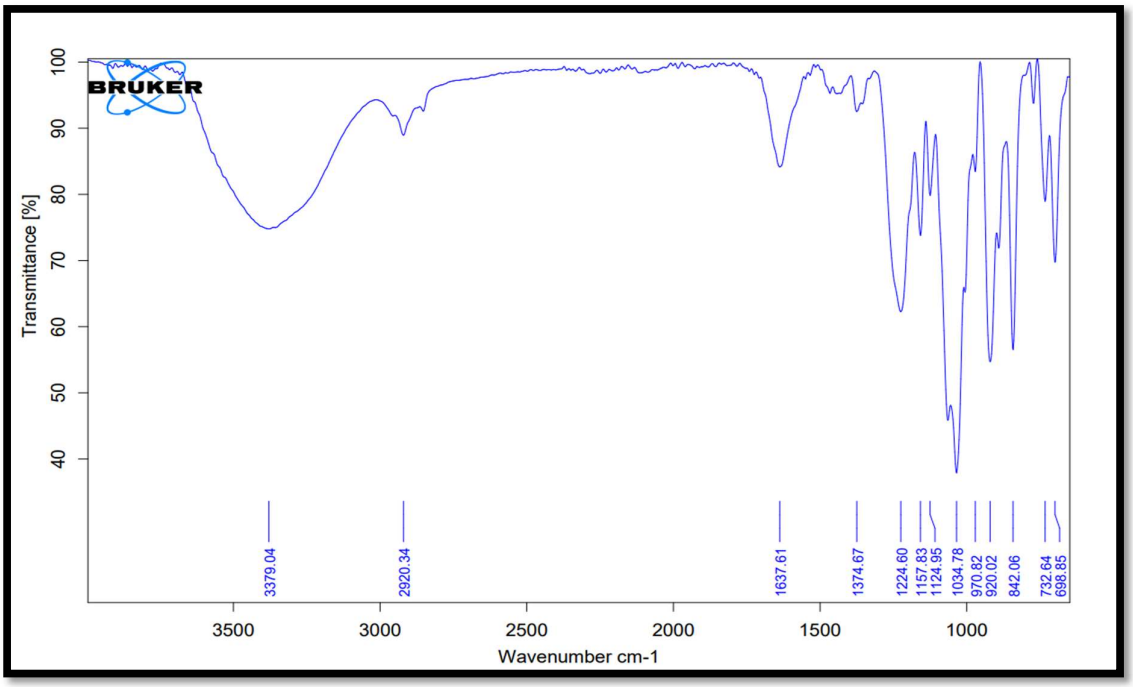

Figure 3: FTIR spectrum of K-carrageenan Plane film

Temperature (°C)	**390.65**
Weight (%)	**7.1324**

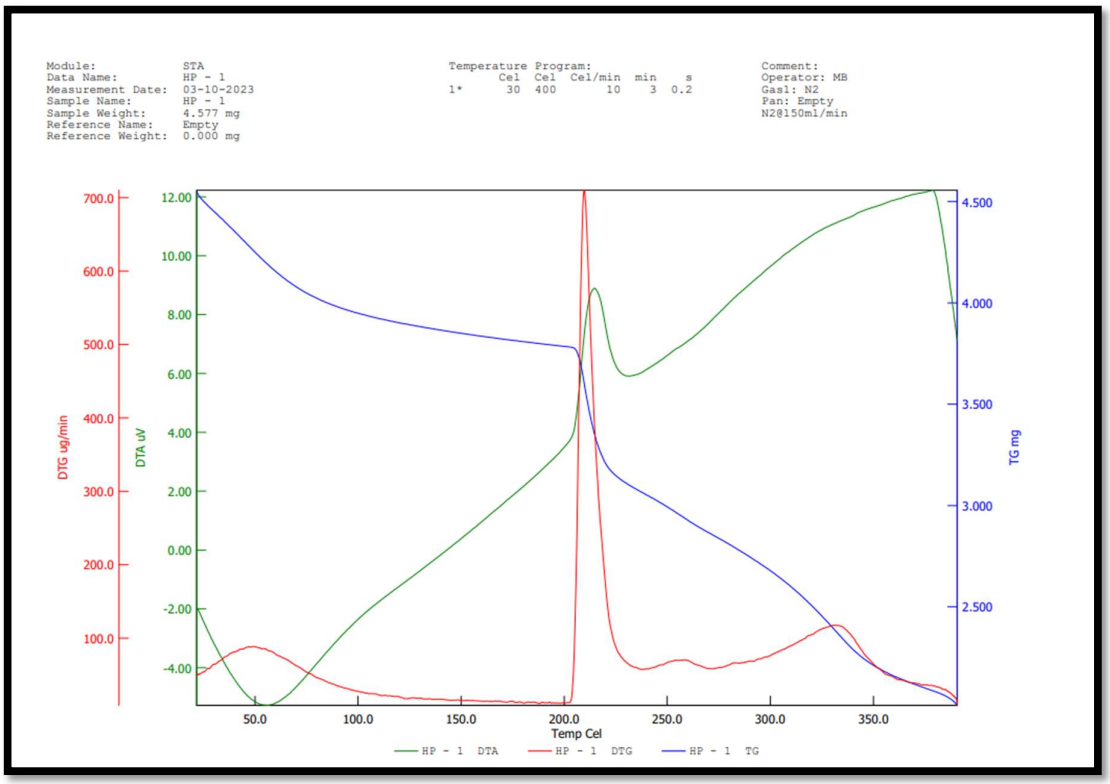

Figure 4: TGA (Thermogravimetric Analysis)

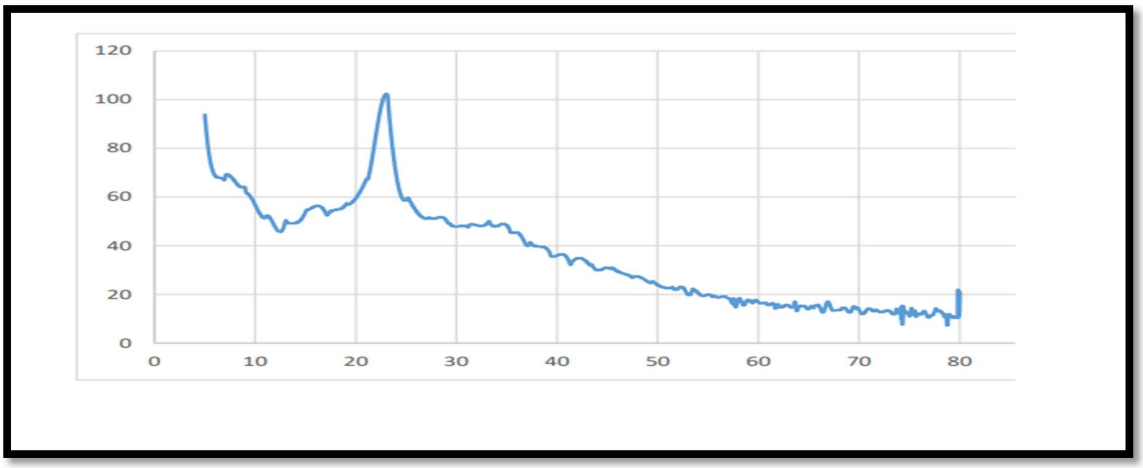

Figure 5: XRD (X-ray Diffraction)

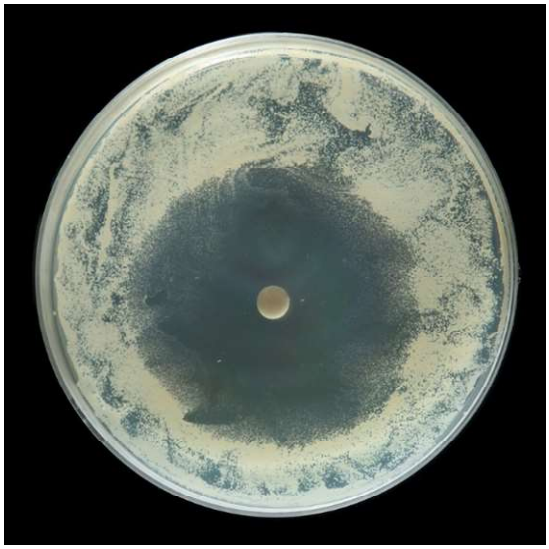

Figure 6: Antibacterial test

5. CONCLUSION:

By demonstrating improved structural integrity, thermal stability, and robust intermolecular interactions, the cellulose and kappa carrageenan composite film showed promising qualities in its XRD, TGA, and FTIR investigations. A protective barrier might be formed, as evidenced by the antibacterial tests' remarkable effectiveness against bacterial strains. The composite film's capacity to prevent the loaded mehndi medication from degrading and preserve its stability was also demonstrated by the UV analysis. Thus, with improved mechanical, thermal, antibacterial, and UV-protective qualities, this composite film offers a convincing solution that shows promise for use in protective film and drug delivery applications.

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Conflict of Interest

No conflicts of interest exist, according to the authors, with the publishing of this work.

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