



**International Journal of Biology, Pharmacy
and Allied Sciences (IJBPAS)**

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

**FABRICATION AND EVALUATION OF PLA-KAPPA CARRAGEENAN
COMPOSITE FILMS WITH ANTIBACTERIAL PROPERTIES**

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Received 24th Oct. 2023; Revised 25th Nov. 2023; Accepted 25th March 2024; Available online 1st Dec. 2024

<https://doi.org/10.31032/IJBPAS/2024/13.12.8567>

ABSTRACT

In this research, PLA (poly lactic acid) and kappa carrageenan were combined utilizing a simple procedure that required combining their solutions and then crosslinking them with a glutaraldehyde solution to create bioactive wound dressings. Various ratios of PLA to kappa carrageenan, such as 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 bandages for wounds were created with biomedical uses in mind, specifically to aid in the healing of wounds at different phases, such as edema, tissue proliferation, and remodeling. The films contained marigold, a naturally occurring bioactive component with anti-inflammatory, antioxidant, and tissue-regeneration qualities. These composite films were made with biopolymers (PLA/kappa carrageenan) and the crosslinker glutaraldehyde, and they were further enhanced with marigold. The produced films were characterized using a variety of analytical methods, including FTIR (Fourier Transform Infrared Spectroscopy), TGA (Thermo gravimetric analysis), and XRD (X-ray diffraction). Furthermore, a research on edema was carried out. UV-visible spectroscopy was used to characterize the marigold extract. The morphological study verified the films' creation and structure. The PLA-kappa carrageenan-marigold composite films were evaluated for their antibacterial properties against the *Escherichia coli* (*E. coli*) bacterium. As a result, this all-natural composite material has potential as an affordable base for encouraging good wound healing.

Keywords: Poly lactic acid (PLA), k-carrageenan, marigold, TGA, XRD, FTIR, Antibacterial activity

1. INTRODUCTION

Under certain environmental circumstances, living organisms—typically microbes like bacteria or fungi—can break down biodegradable polymers, also known as biopolymers, into simpler chemicals. Biodegradable polymers present a viable way forward for addressing the worldwide problem of plastic pollution, in contrast to conventional polymers that can linger in the environment for hundreds of years. Both renewable and non-renewable materials can be used to create these polymers; some are created artificially, while others are obtained naturally. Their capacity to break down into non-toxic components without leaving behind hazardous residues makes them useful in a variety of industries, including biotechnology, packaging, agriculture, and medicine.

PLA: Poly lactic acid, or PLA, is a well-liked thermoplastic polymer that is both environmentally benign and biodegradable. Because it is made from renewable materials like sugarcane or corn starch, it is an environmentally friendly option for packaging, 3D printing, and other uses. In 3D printing, PLA is renowned for its simplicity of use, low toxicity, and capacity to create accurate and detailed prints. Due to its adaptability and eco-friendliness, this material is widely used in many different sectors [1].

K-carrageenan: Red seaweed is the natural source of K-carrageenan, also known as carrageenan, which is used as a thickening agent and food additive. It is frequently used in the food industry to enhance the mouthfeel, texture, and stability of a variety of goods, including dairy, meat, and plant-based substitutes. In many culinary applications, carrageenan is renowned for its capacity to gel and give food a smooth, creamy mouthfeel. It has been used for centuries and is now very important for product development and food processing [2] [3].

Marigold: *Calendula officinalis*, the scientific name for marigold, is a unique plant with antibacterial and wound-healing qualities. Since ancient times, traditional medicine has utilized this vivid yellow-orange blossom for its strong therapeutic properties. The antibacterial effects of marigold stem from the presence of bioactive components, including flavonoids, saponins, and essential oils [4]. Through their ability to stop the growth of dangerous germs, marigold extracts and ointments can be used topically to treat and prevent bacterial infections in wounds. Furthermore, marigold is a useful natural treatment for a variety of skin diseases and small injuries because of its anti-inflammatory and tissue-regenerating qualities, which aid in wound healing. Marigold is a common ingredient in

both traditional and contemporary herbal therapy due to its adaptability and potency in promoting skin health and battling infections.

We will discuss the significance of characterizing PLA and K Carrageenan composite films, the associated techniques, and the anticipated advantages in this introduction. The composite's mechanical, thermal, barrier, and biodegradation capabilities are only a few of the qualities that are usefully revealed during this characterisation method. These understandings are essential for modifying the material for particular applications, such as food packaging, healthcare devices, or agricultural applications, where a balance between mechanical strength, biodegradability, and barrier characteristics is frequently needed [5].

Understanding the properties of PLA and K Carrageenan composite films not only aids in the production of environmentally friendly materials, but also creates prospects for reducing plastic waste and advancing sustainable practices in a variety of industries. As a result, this research has a lot of potential for tackling environmental issues and producing cutting-edge materials for the future [6].

2. MATERIAL AND METHODS

2.1. Materials

Banka Bio Limited (IND) offered PLA (Poly lactic acid) in pellete form (PLA: 92%

L-lactic acid and 8% meso-lactic). Sisco Research Laboratories pvt.ltd, Talaja, Maharashtra (India) offered kappa-carrageenan. We bought Marigold flowers from local market Vadodara.

2.2. Process of Producing Kappa carrageenan Thin Film

One gram of -carrageenan was carefully dissolved in 100 milliliters of distilled water to create the film solutions that were used to create the -carrageenan flat films. Using a magnetic stirrer to achieve extensive mixing and homogenization of the -carrageenan and water components, this dissolution procedure was carried out at a temperature of 95 degrees Celsius. This was made possible by vigorously churning the solution for 30 minutes [7].

2.3. Preparation of Poly lactic acid (PLA) plane film

Two grams of Poly lactic Acid (PLA), a biodegradable polymer, were carefully dissolved in 100 milliliters of chloroform, the solvent. This dissolution procedure was carried out in a controlled lab setting, specifically at room temperature, with a magnetic stirrer used to ensure thorough and effective mixing. The homogeneous dispersion of PLA within the chloroform solvent was promoted by strong agitation of the solution caused by the magnetic stirrer being run at a high enough rotating speed to do so. This methodological strategy was selected to make it easier to generate a well-

dispersed PLA solution in chloroform, which can be extremely important in a variety of scientific and industrial applications [8] [9].

2.4. Development of Biodegradable Films by Blending PLA and Kappa Carrageenan

By utilizing natural polymers and creating a more environmentally friendly substitute for traditional plastic films, a sustainable biodegradable film was cleverly created by carefully measuring and dissolving one gram of PLA and one gram of kappa carrageenan in one hundred ml of water. To guarantee a uniform mixture of the ingredients, this novel solution was carefully shaken for half an hour at room temperature using a magnetic stirrer. This represents a major advancement toward environmentally friendly materials for a range of uses.

2.5. Preparation of Marigold drug extracts:

The process for making a medicine extract from 20 grams of marigold powder is mixing the powder with 100 ml of water and heating the combination in a regulated chamber. After heating, the resulting mixture is carefully filtered to separate the medication extract, which is then kept at a certain temperature of 4 degrees Celsius to

maintain its efficacy and integrity for a longer amount of time [10].

2.6. Formulation of drug loaded film

To make a viscous solution, mix 50 ml of water with 0.50 grams of kappa carrageenan and the same quantity of PLA. After that, add 4 ml of a properly strained medication solution to this concoction. Use a magnetic stirrer set to a regulated temperature of 45 degrees Celsius to thoroughly homogenize the mixture. Stir the mixture with diligence. This painstakingly manufactured drug-loaded solution, with its perfect homogeneity and accuracy in drug encapsulation, will be turned into a thin, coherent film, a biocompatible matrix suited for controlled drug release and possible biological uses.

3. Chemical Analysis

3.1. Swelling Study

The swelling test evaluates how long a composite film can stay wet. For thirty minutes, the PLA and kappa carrageenan composite film was submerged in a solution that included NaCl and CaCl₂. The following formula was used to calculate the swelling ratio (SR): $(M_t - M_o) / M_o$ (in grams per gram) is the formula for SR. In this case, the mass at different times is represented by M_t , while the original mass is represented by M_o [11].

Table 1: Swelling Study

Time	PLA- k-carrageenan (80-20)	PLA- k-carrageenan (70-30)	PLA- k-carrageenan (60-40)
0 Min	0.032	0.041	0.039
30 Min	0.043	0.056	0.047
60 Min	0.058	0.069	0.059
90 Min	0.070	0.082	0.071
120 Min	0.081	0.095	0.083
150 Min	0.093	0.103	0.094
180 Min	0.104	0.108	0.099

3.2. FTIR characterization:

Grind a milligram or two of the material being examined with 300 milligrams of potassium bromide that is appropriate for infrared analysis. Compact the mixture with a 13 mm die at a pressure of around 10 tons. To get infrared absorption spectra in the 400–4000 cm⁻¹ region, use this pellet.

3.3. X-ray diffraction (XRD):

The analytical technique known as X-ray diffraction is used to clarify the crystalline structure of various materials. To gain insight into their structural properties, X-ray diffraction analysis was performed on the PLA and k carrageenan powder samples in the context of your research. Another term that might be used to characterize the method is "crystallography".

3.4. UV visible of marigold drug extract:

The investigation of drug extraction from marigold, a plant with well-known therapeutic benefits, depends heavily on ultraviolet (UV) characterisation. Drug extracts from marigolds usually show characteristic absorption peaks in the UV spectrum, usually in the 200–400 nm region. The presence of several bioactive chemicals,

such as flavonoids, carotenoids, and other polyphenolic compounds, is responsible for these peaks and for the medicinal qualities of marigold. Pharmaceutical goods made from marigold are standardized and quality-controlled with the use of UV spectroscopy, which measures the concentration and purity of certain chemicals. Marigold extracts have a unique UV fingerprint that makes them an invaluable tool for developing effective extraction and purification procedures for use in medicine [12].

3.5. Antibacterial activity:

The antibacterial activity of a composite film infused with marigold and composed of PLA and k-carrageenan was evaluated using *Escherichia coli* (*E. coli*). Start by preparing 2.8 grams of nutrient-rich agar in a glass flask and filling a Petri plate with 100 ml of distilled water. After sterilizing the growing medium and allowing it to cool to room temperature, uniformly distribute the *E. coli* test germs on the solidified agar using a bacterial spreader. Next, place a piece of the composite film onto an agar plate and let it to incubate at 37°C for an entire day. Measure the diameter of the established

inhibitory zone the next day and record it [13].

4. RESULTS AND DISCUSSION:

4.1. UV visible of marigold drug extract:

UV-visible analysis tests were conducted with utmost accuracy at Parul Institute of Applied Sciences (PIAS) in Vadodara, Gujarat, India. UV absorption spectroscopy is a widely used method in analytical chemistry to determine the presence and concentration of various compounds in a solution [13]. The wavelength range at which the marigold medicine extract efficiently absorbs UV light in this specific situation is 300–400 nm, resulting in a signal at 335 nm. This approach also uses a water baseline for reference and comparison **Figure 1** [14].

4.2. FTIR Spectroscopy:

The Parul Institute of Pharmaceutical Science and Research (PIPR) in Baroda, Gujarat, India, performed the FTIR tests with the highest precision.

The FTIR result of 80:20 PLA/k-carrageenan composite film is shown in below **Figure 2**. The peak with wave number 1747.01 cm⁻¹ is the presence of strong c=O stretching. The peak arise at 1080.82 cm⁻¹ gives s=o stretching. The peak at 1451.40 cm⁻¹ gives C-H blending. The FTIR result of k-carrageenan film is shown in **Figure 3**. Peaks was observed at 1034.78 cm⁻¹ is presence of s=o stretching in k-carrageenan film. The peaks observed

between 700-900cm⁻¹ may be due to the C=C blending. The peak with wave number 3381.50 cm⁻¹ is the presence of O-H stretching.

In this **Figure 4**, the peak with wave number 1746.92cm⁻¹ is due to the presence of C=O stretching. The peak observed at 1078.54cm⁻¹ is due to the C-O stretching. The peak between 1300-1400 Cm⁻¹ may be due to the C-H blending [15].

4.3. TGA (Thermogravimetric Analysis):

Thermogravimetric analysis tests were performed with full precision at SPU (Saradar patel University) Anand (Gujarat, India). A thermogravimetric analyzer was used to evaluate the sample's thermal stability. On a 1.359 mg film, a temperature range of room temperature to 390.53 degrees Celsius was applied. Ten degrees Celsius were added to the temperature every minute. This was done gradually **Figure 5**.

4.4. Antibacterial test:

The efficacy of a biodegradable film made of PLA and kappa carrageenan with a marigold extract infusion was assessed in terms of its capacity to inhibit *E. coli* bacteria. This film was partially saturated with marigold extract and put into a culture plate containing *E. coli*. Because of the marigold extract, the area of the composite film that was left free of bacterial growth was 3.1 cm in diameter **Figure 6**.

4.5. X-ray diffraction (XRD):

In material science, X-ray diffraction (XRD) is a potent method for examining a substance's crystal structure. A diffractogram, another name for the XRD graph, shows the intensity of X-rays diffracted by a crystal at different angles. The positions and intensities of the peaks on the graph reveal details about the crystal lattice characteristics and orientation. Each

peak on the graph represents a distinct collection of crystallographic planes within the material. Researchers can identify the crystalline phases in a sample, ascertain their relative quantities, and learn more about the material's structural characteristics, such as crystallite size and strain, by examining the XRD graph **Figure 7 [16]**.

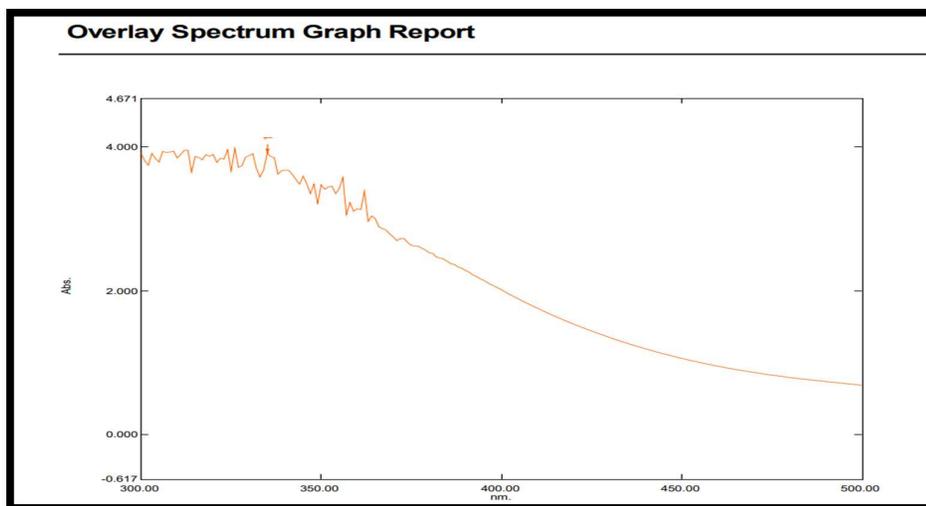


Figure 1: UV visible spectra of marigold drug Extract

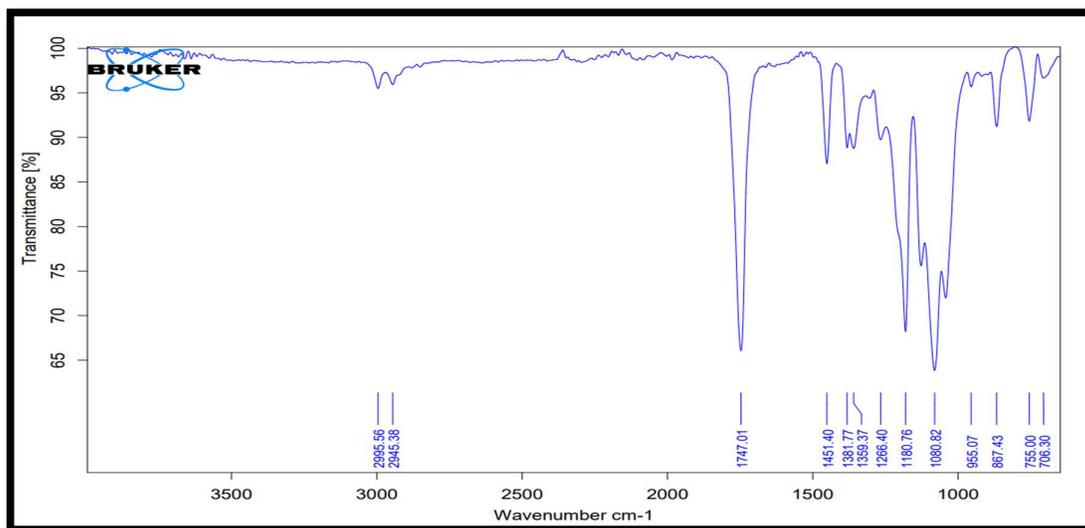


Figure 2: FTIR spectrum of 80:20 PLA/K-carrageenan composite film

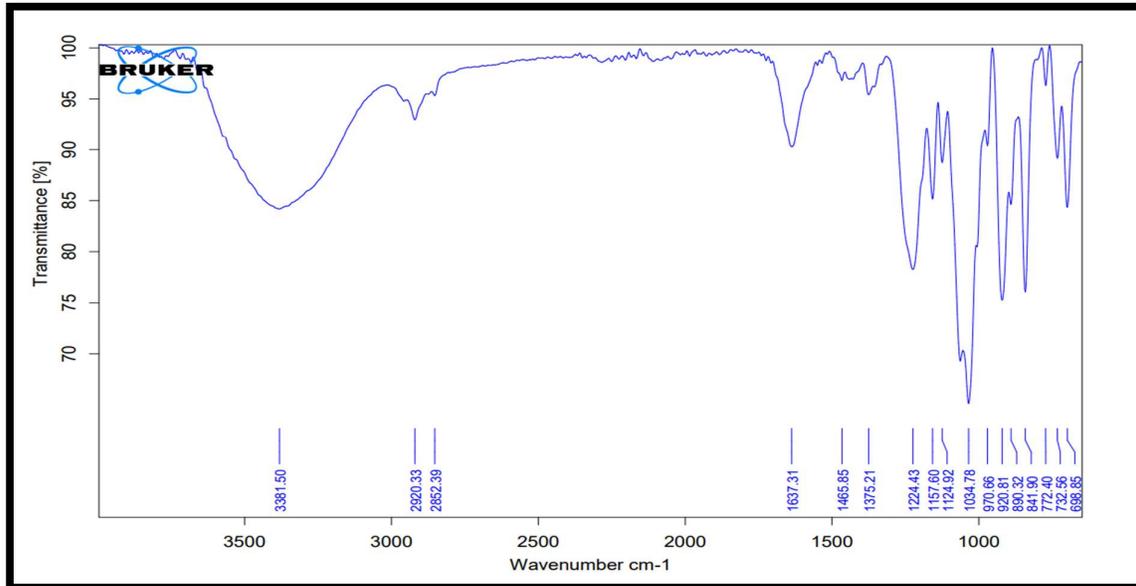


Figure 3: FTIR spectrum of K-carrageenan Plane film

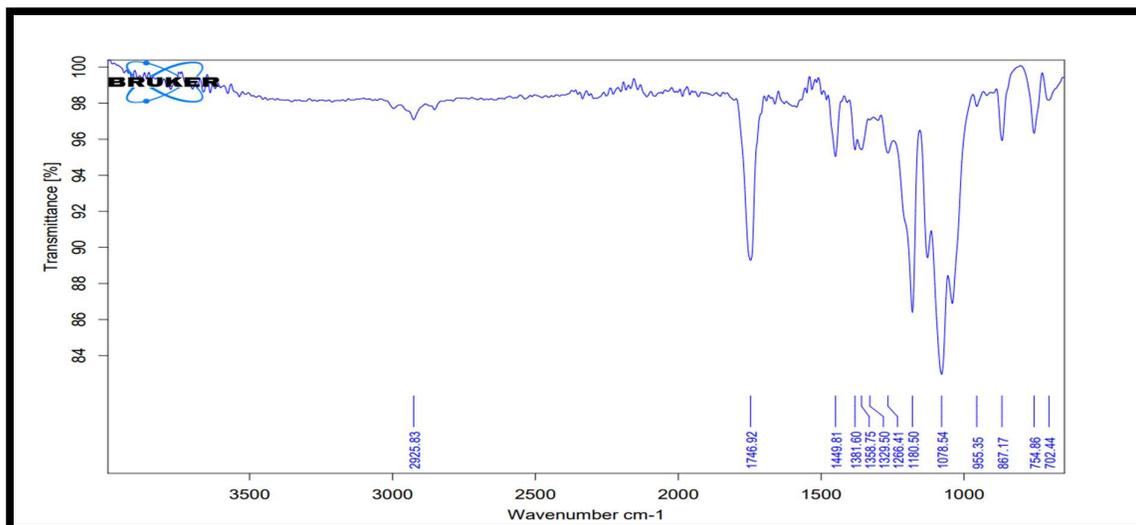


Figure 4: FTIR spectrum of PLA Plane film

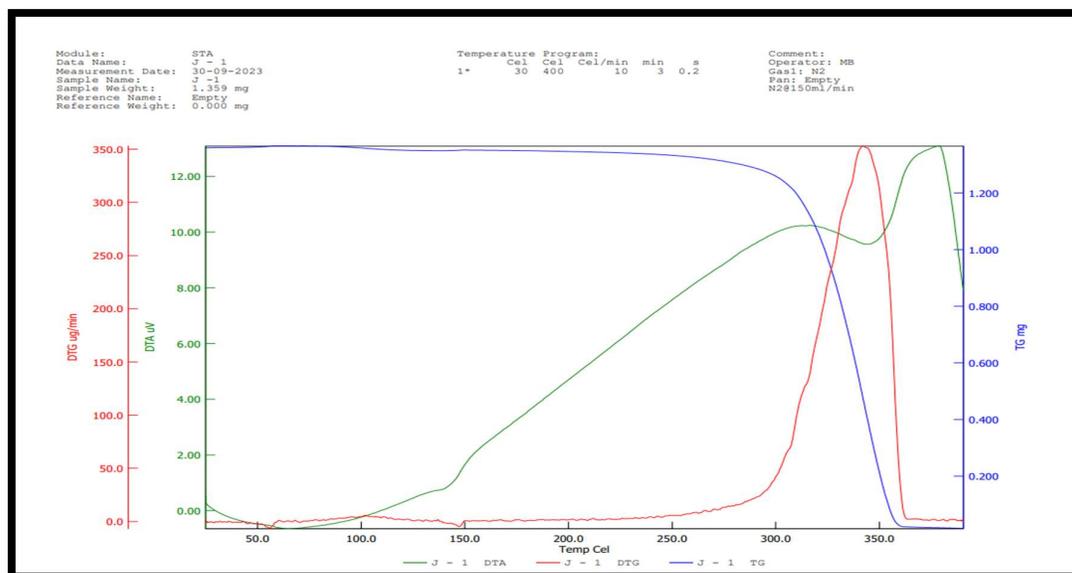


Figure 5: TGA (Thermogravimetric Analysis)



Figure 6: Antibacterial test

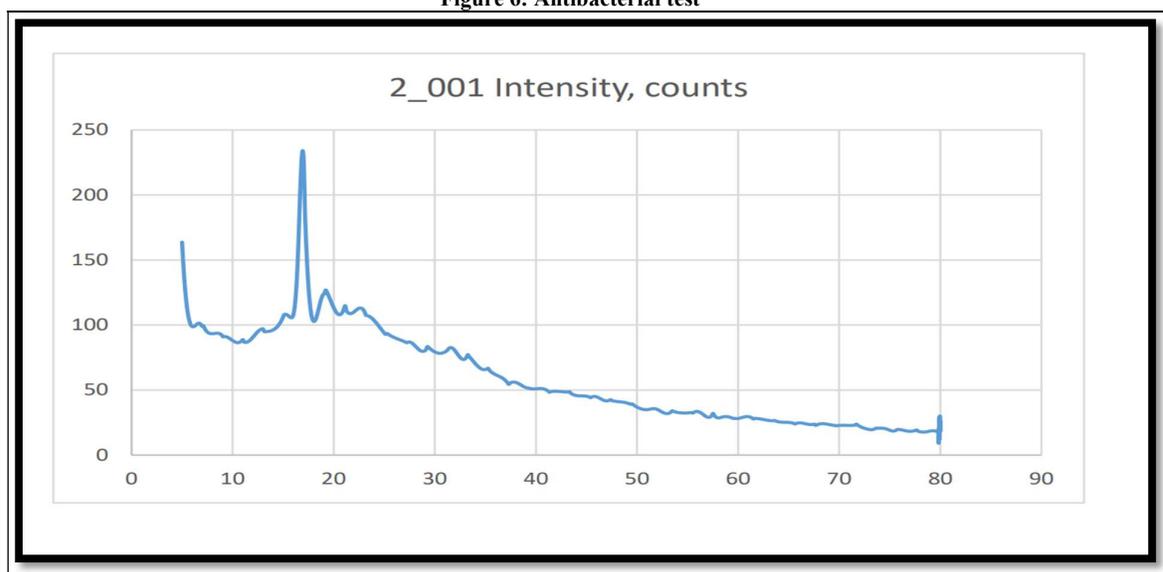


Figure 7: X-Ray diffraction (XRD)

5. CONCLUSION:

Through XRD, TGA, and FTIR investigations, the PLA and kappa carrageenan composite film had promising features, demonstrating increased mechanical capabilities and thermal stability due to their synergistic interaction. Tests for antibacterial agents shown significant reduction of bacterial growth, suggesting possible uses in the biomedical or food packaging industries. Additionally, the marigold drug-loaded films showed sustained release behavior in the UV analysis, indicating that they may be used in controlled drug delivery applications. All things considered, these evaluations show the many benefits of the PLA and kappa carrageenan composite film, emphasizing its potential for drug delivery, mechanical, thermal, and antibacterial properties, and establishing it as a flexible material for a range of industrial and biomedical uses.

Acknowledgement:

I would like to thank Parul university for providing the scientific instrument for this work and also thanks to Parul Institute of Pharmacy and Research, PNP analytical solution, CHARUSAT University.

Conflict of Interest

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

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