



## Research article

# Pectin/PVA and pectin-MgO/PVA films: Preparation, characterization and biodegradation studies

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## ABSTRACT

There is a great demand to replace non-renewable materials with eco-friendly renewable materials for many applications in recent times. In the present study, such an attempt was made to substitute synthetic polymer-based films used for food packaging applications with films prepared out of renewable materials derived from waste. The pectin/polyvinyl alcohol (PP) and pectin-MgO/polyvinyl alcohol (PMP) films were prepared and characterized to ascertain their suitability for packaging applications. To improve the mechanical strength and thermal stability of films, MgO nanoparticles were incorporated in situ into the polymer matrix. The pectin used in the study was extracted from citrus fruit peel. The prepared nanocomposite films were evaluated for physico-mechanical properties, water contact angle, thermal stability, crystallinity, morphology, compositional purity and biodegradability. The elongation at break for PP film was 42.24% and for PMP film it was 39.18%. Also, the ultimate modulus in terms of MPa for PP film was 6.8 and for PMP it was 7.9. So, it was found that PMP films have better ductility and modulus than PP films due to the presence of MgO nanoparticles. The spectral studies confirmed the compositional purity of the prepared films. The biodegradation studies revealed that both films

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could be degraded at ambient conditions at appreciable time span, suggesting them to be a better choice as an environmentally friendly food packaging material.

## 1. Introduction

Around 36% of total plastics produced are used in food packaging applications, out of which nearly 85% of it ends up as unregulated waste or in landfills. The level of greenhouse gas release associated with the manufacture, use and disposal of fossil fuel-based plastics is forecasted to rise to 19% of the global carbon budget by 2040 [1]. Hence to safeguard the environment, there is a great urge on usage of eco-friendly food packaging materials. In the present study an attempt was made to prepare the biodegradable food packaging film using waste materials like citrus fruit peel pectin. Pectin is a class of naturally occurring polymer that exist in all land-growing plants. They are found in plant cell walls, where they act as a structural element, hydrating agent and binder for the web of cellulose fibres [2,3]. Pectins are abundant in citrus albedo and apple pomace, which are vital raw materials for pectin manufacturing worldwide [4]. When pectin is properly mixed with water and/or other chemicals, it can serve as a thickener, stabiliser, gelling agent, emulsifier, cation-binding agent etc. [5]. Pectin-based materials have been the subject of extensive research recently because of the need to develop biodegradable and renewable materials to reduce the quantity of non-renewable petroleum source-based trash in landfills [6]. However, pristine pectin-based films have few drawbacks like weak mechanical strength, brittleness, poor moisture and gas barrier properties. It has been suggested that blending pectin with other polymers such as chitosan, starch, polyethylene glycol, polylactic acid, polyvinyl alcohol, natural proteins etc., or addition of hydrophobic materials, such as essential oils into the polymer matrix are effective ways to improve the barrier properties of pectin [7]. As an adaptable, tailor-made biomaterial, pectin has a bright future. It has been used for various biomedical applications like drug administration, gene transport, wound healing and tissue engineering due to its cytocompatibility. Pectin-based coatings are also used to prolong the shelf life of many fruits [8,9].

Another significant biodegradable polymer is polyvinyl alcohol (PVA), which is utilized in a variety of commercial, medicinal, industrial and food applications as resins, lacquers, eyedrops, tablet coating agents, paper coating agents and food packaging material. The PVA can also be combined with water-soluble fabric material to produce biodegradable protective garments, hospital laundry bags, rags, sponges, sheets, covers, surgical threads and other physiological sanitization goods. When used as a sizing and coating agent with paper, PVA offers good rigidity, making it useful for winding, carton sealing and lamination applications [10]. In most cases, petrochemical-based polymers are commonly used for food packaging applications because of their low cost, good barrier properties, better mechanical strength and easy processability. However, they are non-biodegradable and lead to major environmental issues upon disposal. As a result, eco-friendly packing materials are in high demand [11]. It is reported that PVA/starch/pectin with glycerol as a plasticizer produces eco-friendly films with improved properties [12]. The film prepared by PVA combined with chitosan and clove oil can be used as packing material as they have antimicrobial properties [13]. PVA-bacterial cellulose composite mimics the structural and biochemical properties of natural intertribal discs, suggesting its use as a material for third-generation artificial IVDs that anatomically and mechanically resemble natural IVDs [14].

Polymer blending is an effective route for preparing desired polymeric materials for a wide range of tailor-made applications. Pectin is miscible in all proportions with polyvinyl alcohol resulting in miscible blends. Proposed uses for pectin/PVA films include flushable liners and bags, water-soluble detergent and pesticide pouches, drug delivery aids and wound dressing materials [15]. *Hibiscus rosa-sinensis* leaves mucilage (HLM)/polyvinyl alcohol (PVA)/pectin-based blend nanofibers mat fabricated was reported as a novel material for wound-healing applications [16]. It is reported PVA/starch-based biodegradable nanocomposite films reinforced with starch nanocrystals were considered as potential alternative for synthetic packaging material [17]. The PVA/pectin-based active packaging material enriched with itaconic acid was developed, which showed an extended shelf life of food packed [18]. A nanocomposite film based on PVA/starch/glycerol/halloysite nanotube with outstanding water resistance, transparency and biodegradability for sustainable food packaging targeting acidic and lipophilic foodstuffs was reported [19]. According to the previous reports, PVA based biodegradable nano composite film reinforced with coconut cellulose nano fiber was prepared as a better alternative to synthetic plastic food packaging. Essential oils like lemon oil and linseed oil were also incorporated into the prepared film to get the antimicrobial properties to the packaging film [20,21].

Biodegradation studies of pectin films incorporated with *Salicornia ramosissima* showed great potential as a sustainable food packaging material of the future [22]. From the literature survey, it is prominent that the incorporation of MgO nanoparticles into pectin matrix enhances the antimicrobial properties [23]. Bionanocomposite film with magnesium oxide nanoparticles also displayed increased antioxidant activity, low solubility, and decreased water vapor permeability [24]. The eco-friendly and biodegradable PVA/starch/pectin films can replace plastic materials used in food packaging with almost equal mechanical strength [12]. Also, microfibrillated cellulose-reinforced pectin/fenugreek gum biocomposite film is reported as a better packaging material with good shelf life [25]. Thus, pectin and PVA can be extensively used in food and pharmaceutical industries for various applications. Natural polymers like pectin alone may be of limited usage due to its inherent limitations, which can be overcome by blending with biodegradable polymers like PVA or by reinforcing with nanofillers. In the present study, pectin/PVA and MgO nanoparticle-based films were prepared and characterized to ascertain it as better alternative to existing petroleum based synthetic food packaging material.

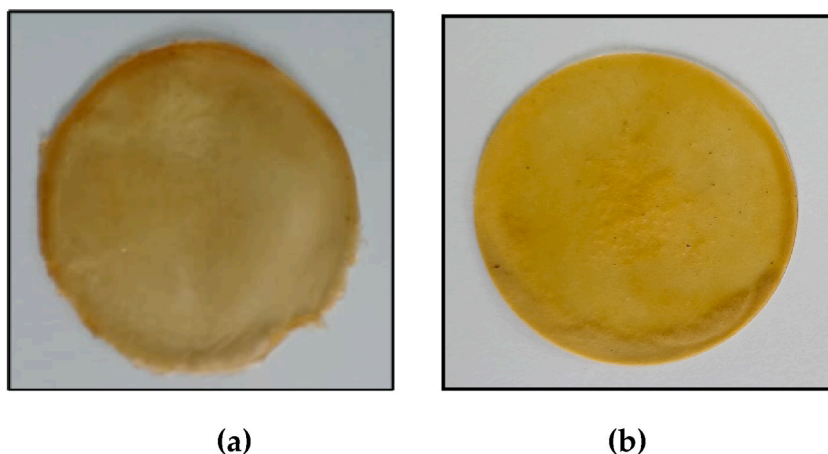


Fig. 1. Images of (a) PP film and (b) PMP film.

## 2. Materials and methods

### 2.1. Materials

Ethanol for extraction of pectin, glycerol for synthesizing film and magnesium nitrate used as precursor for MgO nanoparticle were procured by Sigma Aldrich, Bangalore, India. Polyvinyl alcohol of average molecular weight 94,000, Fehling's solution, lead acetate, citric acid, hydrochloric acid and sodium hydroxide were procured from SD Fine Chem Ltd., Mumbai, India. The orange, pomelo and citrus fruits were purchased from a local fruit market in Mysuru, Karnataka, India and their peels were collected.

### 2.2. Methods

#### 2.2.1. Extraction of pectin from citrus fruits' peel

The freshly gathered peels of each fruit were washed multiple times with tap water to remove dirt and debris from the surface and then chopped into small slices. The slices were sun-dried for a week and ground into powder with a blender. The powder obtained from each type of fruit peel was mixed in an equal ratio and packed in a polythene cover until further use for pectin extraction. About 9 g of citrus fruits peel powder was weighed and transferred into a beaker containing 200 ml of distilled water. To adjust the pH value to 1.06, 1–2 ml of concentrated HCl was added. The resultant mixture was heated at 80 °C for about 1 h with constant stirring on a hot plate. Then, it is cooled and filtered using a muslin cloth. The collected filtrate was mixed with ethanol in 1:1 ratio under constant stirring. The resultant mixture was allowed to stand undisturbed for a few minutes. The pectin gel was later separated from ethanol and water by filtration using a muslin cloth. The resulting pectin was air dried at room temperature until a constant weight was reached and stored.

#### 2.2.2. Qualitative and quantitative estimation of the extracted pectin

The visual colour of the pectin was noted and its solubility in both water and an alkaline media under cold and hot condition was examined. The extracted citrus pectin was subjected to chemical tests using Fehling's solution, lead acetate, alcohol, sugar and citric acid for its chemical confirmation. In quantitative analysis, the yield of pectin, equivalent weight, degree of esterification and methoxy content were estimated as per Ranganna's method [26,27].

#### 2.2.3. Preparation of pectin-MgO nanocomposite

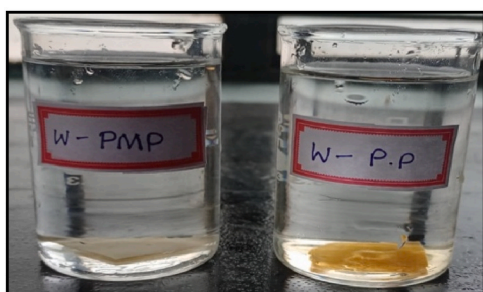
The pectin-MgO nanocomposite was prepared using the co-precipitation technique [28]. Exactly 0.5 g of extracted pectin and 2.4 g of  $Mg(NO_3)_2 \cdot 6H_2O$  was weighed into a beaker, to this 40 ml of 0.2 M NaOH solution was added dropwise with constant stirring. The mixture was agitated with an overhead stirrer for 2 h on a hot plate that was maintained at 35 °C. The reaction mixture was kept undisturbed at room temperature for a day. The resultant precipitate was then filtered and washed with distilled water several times to eliminate the by-products. After 24 h of drying at room temperature, a pale-yellow-coloured product was obtained.

#### 2.2.4. Preparation of pectin/PVA film

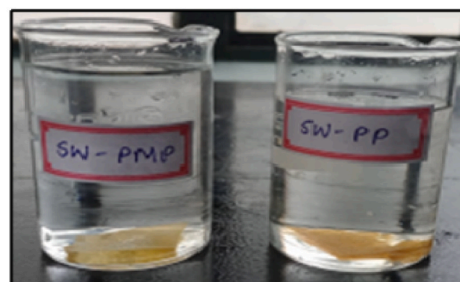
The pectin/PVA (PP) film was prepared by the casting technique. About 0.5 g of pectin powder was dissolved in 20 ml of distilled water, and to this, 0.15 g of PVA dissolved separately in 10 ml of water was added and stirred well at 60–70 °C. To the resultant mixture, about 0.6 g of glycerol was added and mechanically stirred for 2 h at 800 rpm. The filmogenic solution was then transferred into petri dishes and placed in a hot air oven at 45 °C for 24 h. The dried film obtained was used for further testing and characterization.



Fig. 2. Films taken for biodegradation studies in soil.



(a)



(b)

Fig. 3. Films taken for biodegradation in (a) Water and (b) Sea water.

#### 2.2.5. Preparation of pectin-MgO/PVA nanocomposite film

About 0.5 g of pectin-MgO powder was dissolved in 20 ml of water, and to this, 0.15 g of PVA dissolved in 10 ml of water was added and stirred well at 60–70 °C. After clear solution was formed, about 0.6 g of glycerol was added, and the resultant mixture was mechanically stirred for 2 h at 800 rpm. The filmogenic solution was then poured into petri dishes and placed in a hot air oven that was maintained at 45 °C for 24 h. The pectin-MgO/PVA (PMP) nanocomposite dried film obtained was used for further testing and characterizations. The appearance of the prepared PP and PMP films is shown in Fig. 1(a) and (b) respectively.

#### 2.2.6. Film thickness measurement

The thickness of the PP and PMP film was measured with an accuracy of 0.01 mm using a screw gauge. Each film thickness was measured at five random locations, and an average value is reported.

#### 2.2.7. Water contact angle

The water contact angles of prepared films were measured using a contact angle measuring instrument (*HO-IAD-CAM-01A*, Holmarc opto-mechtronic PVT. LTD., India). Water was dropped onto the surface of the prepared films and photos were captured at the instant of dropping. The contact angle of each film was measured at five different spots, and an average value is reported.

#### 2.2.8. Tensile testing

The tensile testing of films were carried out using a universal testing machine (UTM) (International Equipment, Mumbai, India) at a crosshead speed of 5 mm/min using a 50 kg load cell following ASTM D 638 standard. During the testing, data was collected using the built-in software, which calculates the stress, strain, elongation and modulus. Five trials were taken for each sample type and an average value is reported.

#### 2.2.9. Spectral and thermal characterization of PP and PMP films

The PP and PMP films were characterized by different spectral techniques. The FT-IR spectra of the films were recorded in attenuated total reflectance mode in the 4000–400  $\text{cm}^{-1}$  range (Jasco FT/IR-4100, Japan). The X-Ray diffraction pattern was obtained from a Proto AXRD tabletop diffractometer (Proto, Canada) in the  $2\theta$  range of 5–80°. The morphological analysis of the films were



Fig. 4. Beaker 1-Alcohol test, Beaker 2-Citric acid and Sugar solution test, Beaker 3-Fehling solution test and Beaker 4-Lead acetate test.

**Table 1**  
Quantitative test results of citrus pectin.

Parameters measured	Values
Percentage yield	12 wt%
pH	4
Equivalent weight	166.7 g/mol
Degree of esterification	66.6%
Methoxy content	9.92%

carried out using SEM (JEOL, USA). The TGA analysis (Q50, TA Instruments, USA) was performed at a heating rate of 2 °C/min between 30 and 900 °C to understand the thermal degradation behaviour.

### 2.2.10. Biodegradation studies

**2.2.10.1. Biodegradation in soil.** The biodegradation studies in soil were conducted as per the methodology used by Accinelli et al. [29] with some modifications. The PP and PMP films were cut into small pieces and their initial weights were noted. Six different containers were filled with soil, and in each container, one PP and one PMP film of known weights were buried, as shown in Fig. 2. These containers were left aside at room temperature. During the degradation studies, the soil was watered with 20 ml of water every three days. Every 7 days, the films were removed from the container, and the weight of the films was recorded. This process was repeated for four weeks. Throughout the experiment, the weight loss was measured on week basis [30,31].

### 2.2.11. Biodegradation in water

The degradation studies were carried out both with water and seawater. The films were cut into 2 cm × 2 cm sizes and immersed in a beaker with water and sea water, as shown in Fig. 3(a) and (b) respectively. The film appearance was photographed during the time course of the experiment to assess the changes.

## 3. Results and discussion

### 3.1. Qualitative and quantitative analysis of the extracted pectin

The pectin extracted had a light brownish-yellow tint, was insoluble in cold water, and was hardly soluble in hot water. Upon heating, it was soluble in 2 N NaOH. The chemical confirmation of the citrus pectin was done by carrying out different chemical tests [32]. In the alcohol test, pectin gave a white precipitate when tested with ethanol, and in the citric acid and sugar solution, it formed a firm jelly. This confirms the pectin's gelling property. Pectin tested with Fehling's solution gave a blue-coloured jelly-like precipitate, which confirms pectin is a non-reducing sugar. When pectin was tested with lead acetate, it gave white gelatinous precipitate, and this confirmed its glycoside nature [33]. Fig. 4 shows the changes seen during the above-mentioned chemical tests for the extracted pectin.

The yield, equivalent weight, methoxy content, and degree of esterification of pectin are reported in Table 1. Since the degree of esterification calculated is >50%, and methoxy content is 9.92%, it can be considered as high methoxy pectin.

### 3.2. Physico-mechanical properties of prepared PP and PMP films

#### 3.2.1. Film thickness

The thicknesses of prepared films were measured using screw gauge. It was found that the PP film had an average thickness of 23 μm and the PMP film had an average thickness of 29 μm. This shows that there is not much variation in the thickness of the films with the incorporation of MgO nanoparticles as co-precipitate.

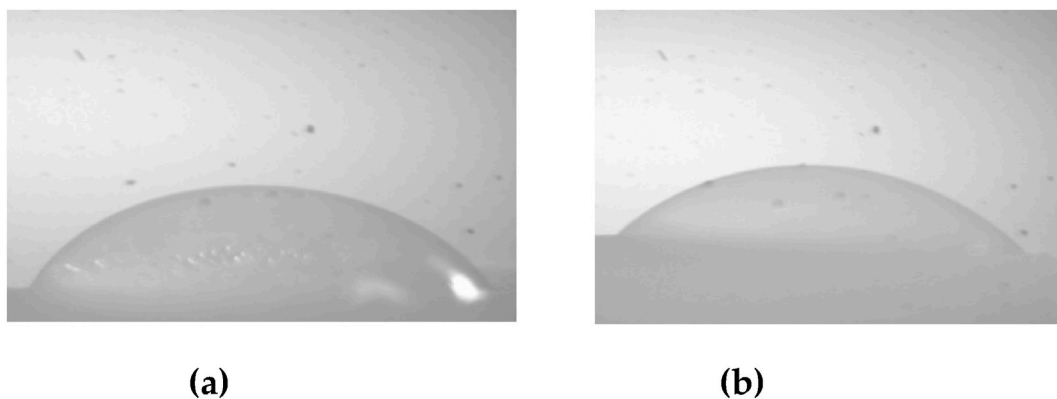


Fig. 5. Water contact angle photograph of (a) PP film and (b) PMP film.

**Table 2**

The tensile properties of PP and PMP film.

Film Type	Tensile strength at peak load (MPa)	Elongation at break (%)	Ultimate modulus (MPa)
PP	$0.21 \pm 0.02$	$42.24 \pm 1.38$	$6.8 \pm 0.65$
PMP	$0.38 \pm 0.04$	$39.18 \pm 1.05$	$7.9 \pm 0.28$

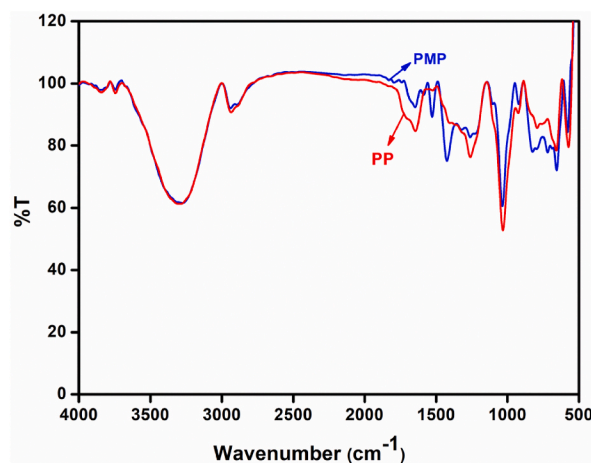


Fig. 6. FT-IR spectra of PP and PMP films.

### 3.2.2. Water contact angle

The most frequent parameter used to describe the hydrophilicity of the film surface is the water contact angle ( $\theta$ ). The contact angle of hydrophilic materials falls in the range of  $0^\circ < \theta < 90^\circ$ , whereas the contact angle of hydrophobic materials is in  $90^\circ < \theta < 180^\circ$  range. Water contact angle photograph of PP and PMP films is as shown in Fig. 5(a) and (b) respectively. The results showed that the PMP film had an average contact angle of  $50.93^\circ$ , whereas the PP film displayed a value of  $61.19^\circ$ , which indicates hydrophilic nature. The values are in par with the other reported biopolymers contact angle [34]. The water contact angle for PMP film is lower than that of PP film, as shown in Fig. 5, which can be attributed to an increase in the surface roughness of PMP film due to the presence of MgO nanoparticles. The influence of surface roughness on contact angle is reported by Wang et al. [35].

### 3.2.3. Tensile testing

Packaging application anticipated materials have to possess sufficient mechanical strength, otherwise it may cause the accidental failure of material during handling and processing condition [36]. The tensile testing of films was carried out according to ASTM D 638. The results of the test are shown in Table 2. The tensile strength, percent elongation and ultimate modulus were directly given by the software. The PMP film exhibited higher tensile strength and ultimate modulus compared to PP film. This can be attributed to the presence of inorganic MgO nanoparticles, which reinforces the film. The PP film exhibited higher elongation than the PMP film, suggesting more flexibility. The percent elongation of the prepared film is superior to the pectin blend film reported by Ngo et al. [37],

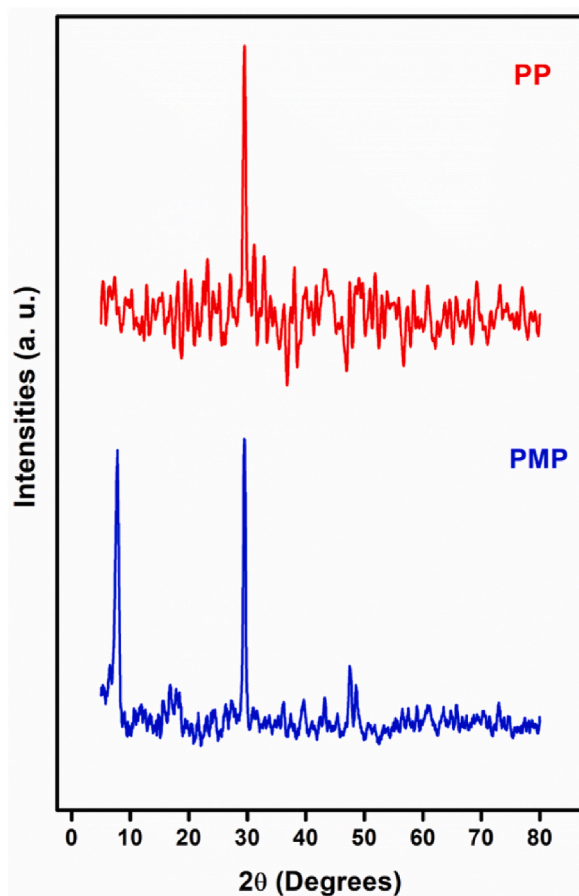
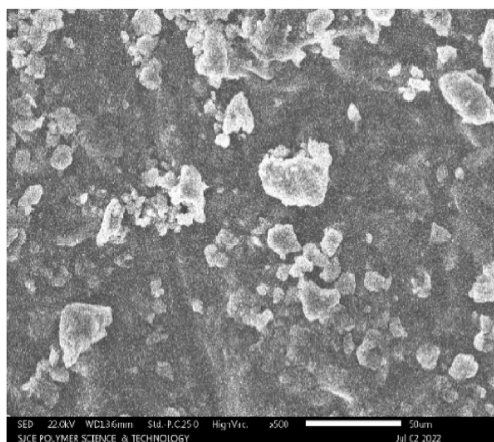
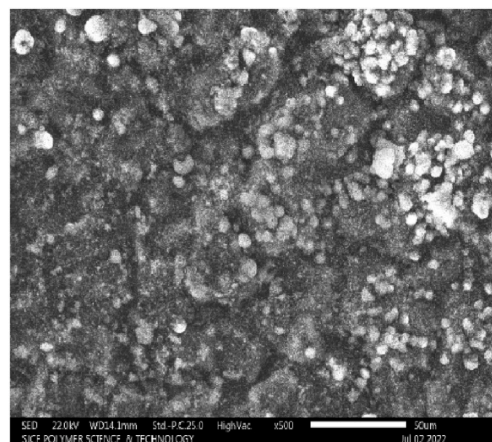


Fig. 7. The powder XRD spectra of PP and PMP films.



(a)



(b)

Fig. 8. The SEM micrographs of (a) PP and (b) PMP films.

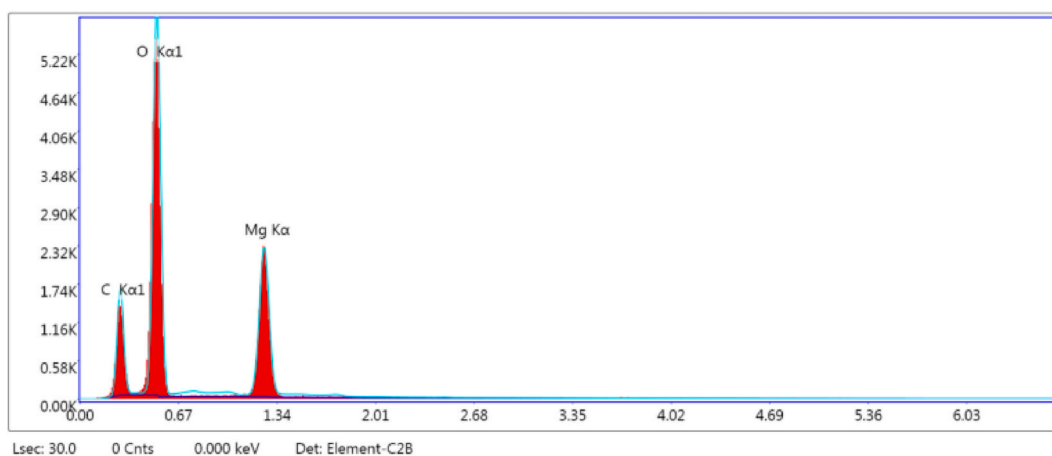


Fig. 9. EDAX spectrum of PMP film.

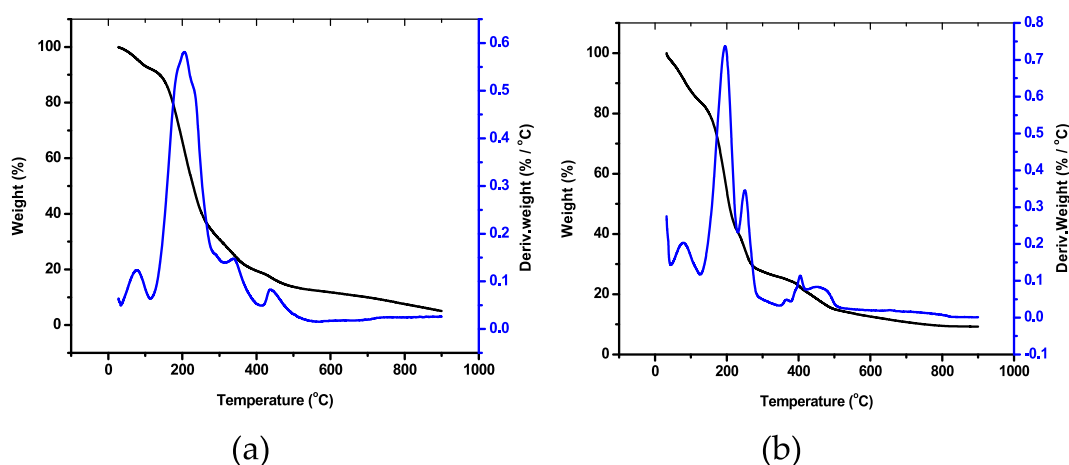


Fig. 10. (a) TGA profile of PP and (b) PMP film.

however the tensile strength needs to be improved.

### 3.3. Spectral characterization of prepared PP and PMP films

#### 3.3.1. FTIR analysis of PP and PMP films

The FTIR spectra of PP and PMP films were recorded in the range 400–4000  $\text{cm}^{-1}$  as shown in Fig. 6. In the IR spectrum of the PP film, the absorption band obtained at 3292.97  $\text{cm}^{-1}$  corresponds to the stretching vibrations of the O–H group. The band at 2930.68  $\text{cm}^{-1}$  to C–H stretching and absorption. The C=O stretching of the ester group at 1737  $\text{cm}^{-1}$  and symmetric stretching of  $\text{COO}^-$  group at 1417  $\text{cm}^{-1}$  of pectin is observed in both the films for citrus pectin [38].

#### 3.3.2. XRD analysis of PP and PMP films

The X-ray diffraction spectra of prepared films were recorded in the  $2\theta$  range of 5–80° as shown in Fig. 7. In the XRD spectrum of PP film, the characteristic peaks centred at  $2\theta$  values of 19.2°, 22° and 29.5° can be assigned to semicrystalline nature of PVA and the peaks at  $2\theta$  values of 21.6°, 33.6°, 38.8° corresponds to pectin. In the XRD spectrum of PMP film, along with characteristic peaks of pectin and PVP, additional peaks at  $2\theta$  values of 36.9°, 38.1°, 43.2°, 62.4° and 74.6° were found, which corresponds to the presence of MgO nanoparticles. The results are in par with the studies reported previously [23]. It is also noted that the percentage crystallinity of PP and PMP films was 60.21% and 86.40% as specified by the XRD results. The increase in crystallinity of PMP film confirms that there is a good dispersion of nanoparticles in the polymer matrix.

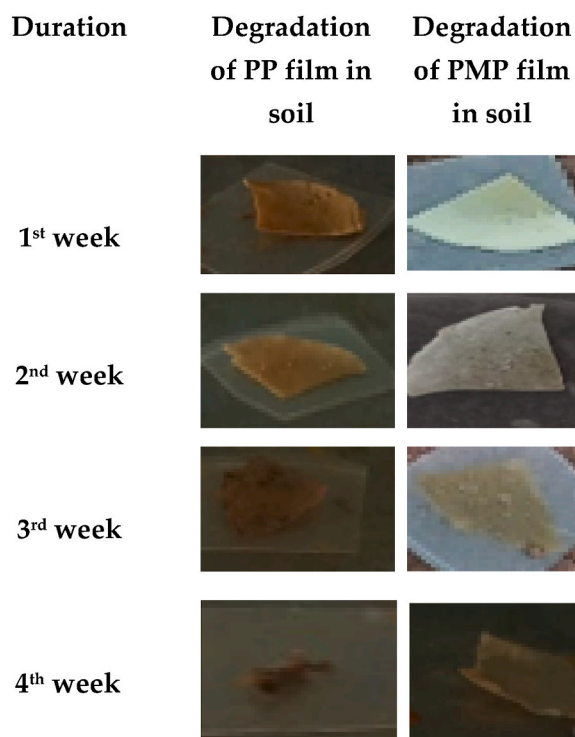
#### 3.3.3. SEM analysis of PP and PMP films

The surface morphology of prepared films was studied using SEM analysis. The surface morphology of pectin/PVA film appears to be rather smooth and homogeneous due to the fine entanglement of PVA chains with pectin chains, as shown in Fig. 8(a). Whereas the



**Table 3**  
Biodegradation test results of films in soil.

Time period	% Weight loss of PP film	% Weight loss of PMP film
1st week	21.5	13.6
2nd week	38.0	28.9
3rd week	71.7	34.4
4th week	89.3	55.8



**Fig. 11.** Photographs of biodegraded PP and PMP films in soil.

SEM image of PMP film as shown in Fig. 8(b), the white spherical spots on the surface shows that pectin/PVA is embedded with MgO nanoparticles. The change in the morphology of the films clearly indicates the incorporation of MgO nanoparticles into the polymer matrix. The similar biphasic microstructure was reported by Fishman and Coffin [39] for the citrus pectin and PVA blend.

### 3.3.4. Energy dispersive X-ray analysis (EDAX) of PMP films

The chemical composition of prepared PMP films was confirmed using the EDAX spectrum. The MgO NPs compositional purity was verified in the PMP film. Magnesium (Mg), oxygen (O) and carbon (C) are three primary peaks that characterize the purity of the MgO NPs (Fig. 9).

### 3.3.5. Thermogravimetric analysis of PP and PMP films

Thermal analysis can be used to evaluate the thermal stability of the prepared films. For pectin/PVA film, the TGA-DTA thermogram profile is shown in Fig. 10(a), indicating four stages of weight loss. The first stage of degradation occurs in the range of 27.62–112.15 °C with a weight loss of 7.69% due to the evaporation of water. The second stage of degradation takes place in the range of 112.15–306.39 °C with a weight loss of 62.37%, corresponding to the thermal degradation of pectin and glycerol. The third stage of degradation takes place in the range of 306.39–412.34 °C with a weight loss of 11.06%, which can be attributed to PVA degradation. During the depolymerization process, the polysaccharide linkages and major chain structure might have been destroyed. Thus, products such as CO<sub>2</sub>, CO, CH<sub>4</sub> and volatile compounds were released in the fourth stage of degradation around 412–561 °C, leading to further weight loss of 6.4%. The similar four stage weight degradation is reported by Lal et al. [12] for the pectin/PVA blend system. The residue of 5% can be attributed to any inorganic matter present in the casted film.

The TGA-DTA thermogram of pectin-MgO/PVA film is shown in Fig. 10(b), indicating four stages of weight loss. The first stage of degradation was noticed in the range of 32.19–124.76 °C with a weight loss of 15.96% due to the removal of moisture and other low molecular weight volatiles. The second stage of degradation takes place in the range of 124.76–230.71 °C with a weight loss of 43.39%.

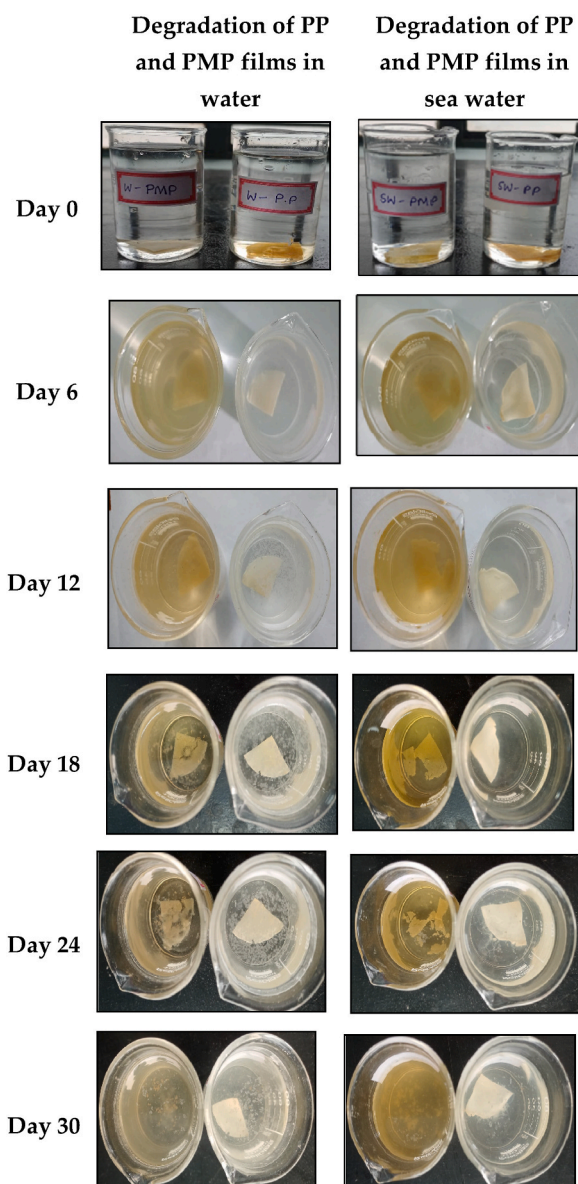


Fig. 12. Biodegradation of PP and PMP films in water and seawater.

This corresponds to the disintegration of pectin, which involves the depolymerization of polymer chain. The third and fourth stage of degradation occurs in the range of 230.7–542.2 °C with a total weight loss of 26.79%. This is due to the breakdown of PVA and the charred residue to lower molecular weight gaseous products. It was observed that the percentage of weight loss in the second stage is less in the pectin-MgO/PVA film compared to pectin/PVA film because of the intense interaction of MgO with the pectin matrix, which retards the degradation of the chain to some extent. The final residue of around 9.25% at 900 °C can be attributed to the inorganic moieties of pectin and MgO.

### 3.4. Biodegradation studies of PP and PMP films

#### 3.4.1. Biodegradation in soil

The biodegradation studies in soil showed no change in the weight of the sample for the initial 24 h. After one week, there was 21.5% reduction in the weight of PP film and 13.6% reduction in the weight of PMP film. The subsequent reduction in the weight of both films is shown in Table 3. One factor that contributes to this degradation is the activity of soil-resident bacteria. According to Shah et al. [40], bacteria and fungi are the microorganisms responsible for biodegradation in soil. Present study findings were consistent with the research [41], wherein cassava starch films began showing evidence of biodegradation after two weeks. The decomposition

rate of the films was faster after 12 days. The water presence assisted the films' initial deterioration. Depolymerization of films then occurs wherein the extracellular enzymes from the microorganisms can break down the polymer to produce short chains or smaller molecules, such as oligomers, dimers and monomers, which are small enough to pass through the semipermeable outer bacterial membranes. The biodegradation end products of these short-chain molecules, including CO<sub>2</sub>, H<sub>2</sub>O, and biomass are finally produced [42]. The progress of degradation of the films in the soil is shown in Fig. 11.

### 3.4.2. Biodegradation in water and seawater

The biodegradation studies carried out in plain water and sea water showed similar changes as shown in Fig. 12. In the initial days, there were no many changes observed. Near to 6th day, there was a colour change of PP film in water and seawater, but no such changes were observed with PMP film. On the 12th day, there were changes in the film's appearance, PP film started to fragment slowly, and the PMP film started to decolourize. After the 24th day, the degradation rate in PP film was faster than PMP film. The PP film got degraded into small pieces, losing its original shape and showing a flaky appearance. In the PMP film, degradation was very slow. Whereas, on the 30th day, the PP film started to dissolve, but in PMP film, no such changes were observed. Various aspects, like agitation of media, the presence of microorganisms in water, the water-to-film weight ratio and oxygenation of media will affect the rate of degradation of polymers in water [43]. On the 22nd day, the seawater-immersed sample began to show signs of clouding, especially for the film with MgO. After 30 days, it was found that both films were quite fragmented, presenting a flaky appearance and completely lost their initial shape and consequently most of their initial structure/physical integrity.

## 4. Conclusion

The extraction of pectin from citrus fruit peel was carried out using the solvent precipitation method. The yield of the citrus pectin extracted was around 12 wt%. The extracted pectin was tested for its purity and chemical confirmation. The extracted citrus pectin found to have an equivalent weight of about 166.7 g/mol, a degree of esterification of 66.6% and a methoxy content of 9.92%. The pectin/PVA (PP) and pectin-MgO/PVA (PMP) films were prepared by casting method. The presence of MgO nanoparticles and their distribution was confirmed by SEM and EDAX. The developed films exhibited good mechanical strength and thermal stability (up to 200 °C). The tensile strength of PP and PMP films at peak load were found to be 0.21 MPa and 0.38 MPa respectively. The mechanical and thermal properties were better for PMP film compared to PP film because of the presence of MgO nanoparticles. The biodegradation rate of PMP film was slightly retarded compared to that of PP film. Overall, the developed films can be used as better alternate to existing synthetic food packaging materials.

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## Author contribution statement

Suhasini M R: Conceived and designed the experiments; Performed the experiments. Rajeshwari K M: Conceived and designed the experiments; Analyzed and interpreted the data; Bindya S: Conceived and designed the experiments. Hemavathi A B: Conceived and designed the experiments; Performed the experiments; Wrote the paper. Prashant M Vishwanath, Rajalakshmanan Eswaramoorthy: Contributed reagents, materials, analysis tools or data. Asad Syed, Sanjay S Majani: Performed the experiments. Vijay Kumar Chattu, Shiva Prasad Kollur: Contributed reagents, materials, analysis tools or data; Wrote the paper. Raghavendra G Amachawadi: Analyzed and interpreted the data; Wrote the paper. Chandan Shivamallu: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

## 5. Data availability statement

Data will be made available on request.

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