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Essential oil loaded electrospun membrane - A potential sprout supressant

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Abstract

Quality of the potato tubers during storage could be retained by efficient sprout controlling. Recently it has become important to use natural anti-sprouting agents such as essential oils (EO) as well as pure compounds derived from essential oils. Therefore, in the present work we have attempted to explore the anti-sprouting efficiency of peppermint essential oil (Peppermint EO) loaded Polyurethane (PU)/ Polymethylmethacrylate (PMMA) ultra-thin fibrous mats during the post harvest storage of potato tubers. PU/PMMA blend fibers were produced by electrospinning technique. The electrospun fiber mats were loaded with 2 wt% peppermint essential oil. Essential oil loaded and unloaded fibers were characterised for its chemical composition, surface morphology and controlled release of Peppermint EO using Fourier Transform Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM), and UV-Vis spectrophotometer. The SEM results revealed the change in fiber diameter before and after loading. *In-vitro* release of Peppermint EO in ethanol was approximately found to be 84.8%. Storage life of potato tubers in the presence of peppermint oil was assessed. Storage life study concluded that tubers stored with peppermint EO loaded fibers showed no sprout development for 30 days due to controlled release of EO whereas the tubers with unloaded mats sprouted in 10 days. Thus, the fabricated peppermint EO loaded PU/PMMA fibrous membrane having an excellent anti-sprouting property would be a potential candidate for the post harvest storage of potatoes.

Key words: Electrospinning, Peppermint essential oil, Controlled release, Anti-sprouting agent, Potatoes

Introduction

Growing potatoes is as much important as it occupies a major percentage in the global food system (1). Being a seasonal crop, it is impossible to harvest throughout the year. Therefore, storage of potatoes with no loss in their nutritional value is essential. Sprouting of tubers is the prime drawback during the post harvest storage resulting in the reduction of weight and quality; softening, shrinkage of skin, and raise of bruising vulnerability (2). Production of carcinogenic glycoalkaloids makes the sprouted potatoes unfit for consuming. Conventionally, chemical sprout inhibitor such as carvone, maleic hydrazaide and CIPC, chloropham (isopropyl 3-chlorocarbanilate) have been used which have numerous negative impact on the environment and human health (3) by interfering in the cell division during sprouting (4,5). Sprout formation on tubers is resisted and prevented by the methods like cold-temperature storage, low energy electron and gamma irradiation treatment and application of H_2O_2 formulation. Cold storage below 2-4℃ increases starch to sugar conversion resulting in the formation of primary glucose (6,7). As irradiations are too expensive and unsafe, it remains restricted in most of the countries (8). Therefore, safe and new alternative method, that leaves no adverse effect on usage, is the current need.

Essential oils, naturally occurring substances extracted from flowers, peel, leaves and roots can act as a promising anti-sprouting agent by inhibiting sprout development. However, in the presence of air, moisture and elevated temperatures some of the active ingredients in essential oils degrade very rapidly. Therefore, release of compounds in a controlled rate could be achieved by loading essential oils on to the electrospun polymeric fibers (9).

Electrospinning is a versatile technique used in the fabrication of micro to nano-structured materials. When the polymer solution is subject to high voltage, due to electrostatic force of attraction the solution stretches, developing into a fibrous network membrane. Due to its high surface area and porosity these polymeric electrospun structures are utilised in controlled release of drugs delivery systems (10), food packaging (11), tissue engineering and sensors whereas the conventional wick volatilisation method results in quick evaporation of essential oil. In the present work, we have tried to investigate the controlled release of peppermint essential oil and (Peppermint EO) from the electrospun polyurethane (PU) / Polymethylmethacrylate (PMMA) membrane for extending the post- harvest storage period and the anti-sprouting activity at room temperature.

Materials and Methods

Materials

Polyurethane and Polymethylmethacrylate were purchased from Sigma Aldrich, India. Dimethylformamide was purchased from Fisher Scientific, India. Peppermint essential oil was kindly gifted from Anglo French Aromatics Pvt.Ltd, India.

Preparation of PU/PMMA blend solution

Polymeric blend containing 4 wt% of PU and 6 wt/% of PMMA was dissolved in 3mL of DMF solution. The mixture was stirred continuously for 4h to yield a clear homogenous solution.

Electrospinning of PU/PMMA blend solution

The polymer solutions were electrospun using optimised spinning factors. The polymer solution was fed from a syringe with a steel needle. The electrospun fibers were deposited using a drum collector covered with an aluminium foil. The tip to collector distance was maintained at 10 cm throughout the experiment. The beadless fibers were removed from the collector after electrospinning and stored in a desiccator.

Characterisation of PU/PMMA fibers

The structural characterisation of the chemical blend was carried out using BRUKER 66V Fourier Transform Infrared spectrometer (FT-IR). Surface morphology of the fibers before and after loading of EO was studied with the help of HITACHI S-3400N, high-resolution scanning electron microscope (HR-SEM) was used in conjugation with a HITACHI E-1010 high-resolution ion sputter. The controlled release of essential oil from the fibers is analysed with the aid of UV-Vis Spectrophotometer, Perkin Elmer.

Shelf life analysis

Shelf life assesment on the post-harvest storage of potatoes was conducted for 30 days at a room temperture of 35±2°C. The electrospun PU/PMMA fiber membrane with a dimension of 2 x 1 cm was taken and 2 mg of peppermint EO was loaded by imbibition techinque. The loaded mat was placed in an air tight box containing potatoes taken for study.

In-vitro release study

Peppermint EO loaded PU/PMMA mat was placed in a 2ml vial containing absolute ethanol at room temperature. At regular time intervals, the mat was transferred to fresh vials with same amount of ethanol. The amount of peppermint EO released was determined using UV–vis spectrophotometer at the absorption

wavelength of 236 nm.

Results and discussion

A broad peak at 1733 cm^{-1} is due to C=O stretching of PU and PMMA. Absorption peak at 1437 cm^{-1} and 1204 cm^{-1} is due to CH_3 stretching and –O-CH_3 stretching of PMMA respectively as shown in Fig 1a. The characteristic peaks of –NH wagging and C-O-C stretching of PU was found at 815 cm^{-1} and 1230 cm^{-1} (12, 13) as shown in Fig 1b. The shift in the value of –NH to a higher wave number confirms the interaction between PU and PMMA. Peaks 1718 cm^{-1} and 1134 cm^{-1} respectively were found to become intense and sharp due to the additional interaction of –OH in menthol and C=O in menthone present in peppermint essential oil (14) with the blend.

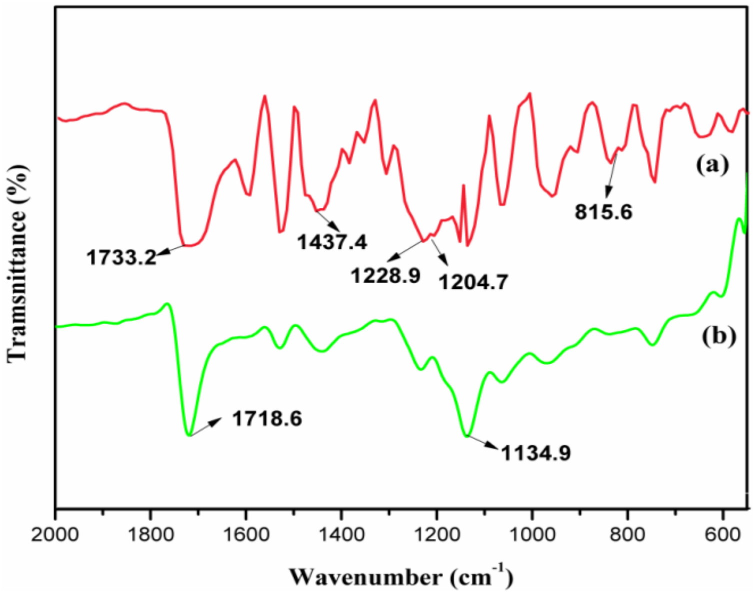

Figure 1 FT-IR spectrum of a) PU/PMMA blend b) PEPPERMINT EO incorporated PU/PMMA blend

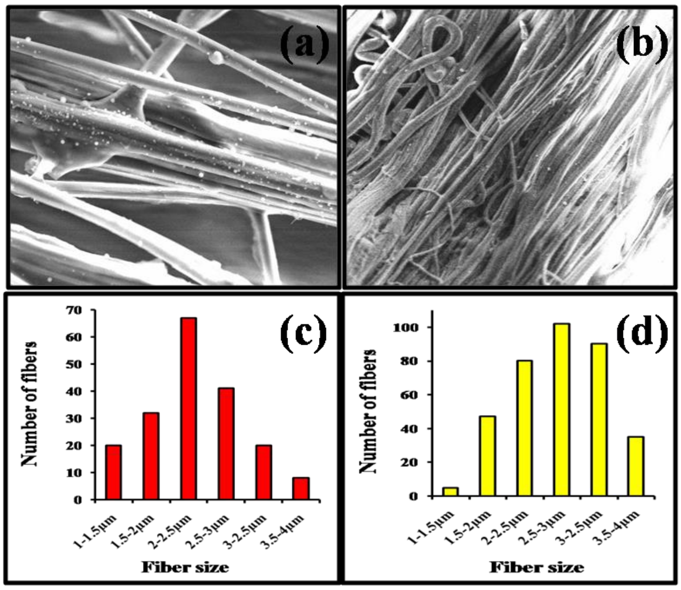

Figure 2 SEM image and the histogram bar chart of (a) and (c) PU/PMMA blend (b) and (d) PEPPERMINT EO incorporated PU/PMMA blend respectively

The fiber morphology of unloaded PU/PMMA fibers was smooth and bead free with an average diameter of 1.3 µm to 2.4 µm as shown in Fig 2a. The peppermint oil loaded blend fibers exhibited a merged appearance and the diameter of the fibers slightly increased to 1.5 µm to 3.5 µm respectively (Fig. 2b) when compared with the unloaded blend.

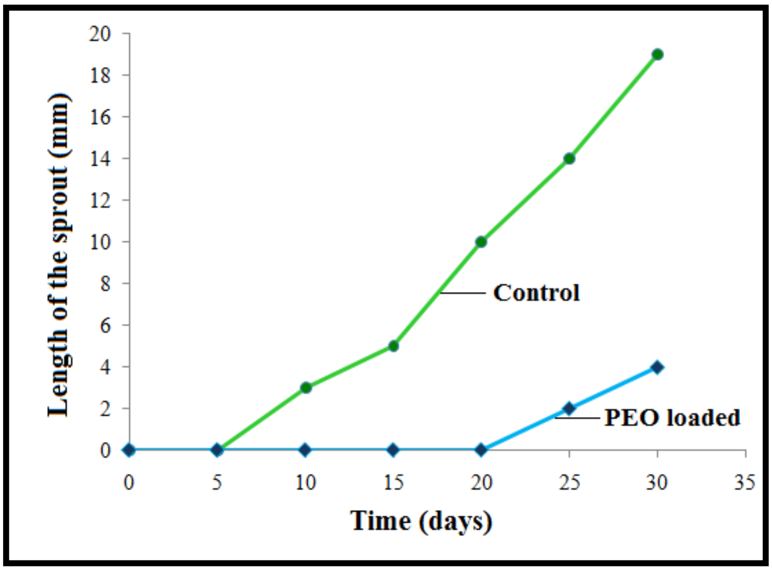

Figure 3 shows the average length of the sprout on Control and PEPPERMINT EO treated potatoes

Fig.3 explains the comparitive study on the length of the sprout grown on the control and peppermint EO treated potatoes.Length of the sprout grown on potatoes were measured at regular intervels. Sprouts with an average size of approximately 19 mm on the control and peppermint EO loaded fibers, with a minimum growth of 4 mm were found at the end of 30 days on the control. This proves the strong sprout inhibiting efficiency of peppermint EO.

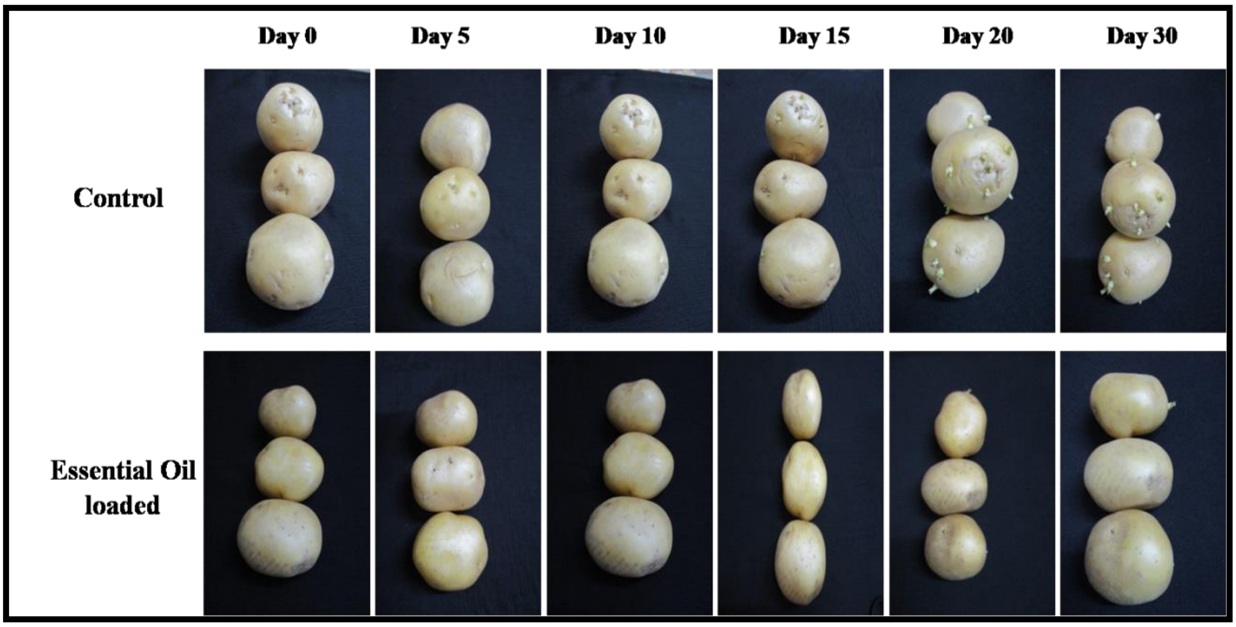

Figure 4 Post harvest shelf life study of potatoes

The release of oil inhibits the sprout development and also prevents it from peel bruising. On the 10th day sprouts started appearing on the potatoes and by the end of day 30 there was a significant sprout growth on the potatoes taken as controls. Peppermint oil treated potatoes showed a high resistance to sprout formation till 28 days. Fig. 4 shows the photographs taken during the post harvest storage period and explains change in the appearance of potatoes.

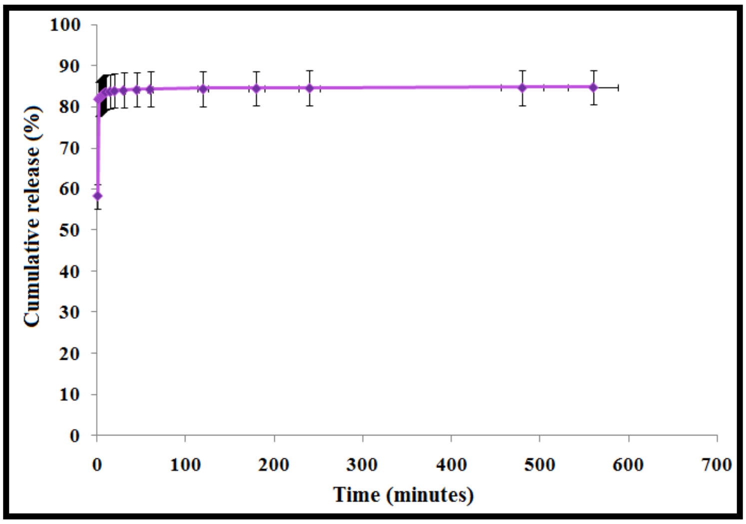

Fig. 5 In- vitro release of Peppermint EO from PU/PMMA fibers

The *in-vitro* release of peppermint EO loaded fibers in ethanol was found to be ~ 85%. Fig.5 shows the % cumulative release of peppermint EO from the blend fibers. Initially there was a burst release up to 60 minutes, which may be attributed to the presence of essential oil on the surface of the polymer membrane. Thereafter, there was a controlled release of essential oil which was evident from the values obtained.

Conclusion

PU/PMMA blend fibers were produced by electrospinning technique. The IR spectrum showed the strong interaction of the blend and the essential oil. SEM analysis gave the change in morphology of fibers before and after loading of essential oil. From the shelf life study at room temperature, the ability of peppermint EO to act as a good anti-sprouting agent has been confirmed. The *in-vitro* release study showed the releasing trend of peppermint EO from the blend fibers. Therefore, the results confirm the applicability of peppermint EO loaded PU/PMMA blend electrospun fibers as a potential sprout suppressant.

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Conflict of Interest

The authors have no conflict of interest.

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