# Innovative Nano-Based Delivery System of Ethyl Formate For Active Packing Applications


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## INTRODUCTION

- Ethyl formate (EF) is an FDA-approved food-flavoring agent with a GRAS status.
- It is a potent insecticide and antimicrobial promising as an alternative to the fumigant, methyl bromide.
- However, EF is highly volatile, flammable, and susceptibility to hydrolytic degradation, make its end-use application very challenging.

## OBJECTIVES

- Development of EF precursor with enhanced storage stability.
- Encapsulation of EF precursor in electrospun fibers.
- Controlled release of EF for active packaging application.

## METHOD

- Precursor was synthesized, which can be hydrolyzed to activate the release of EF vapor.

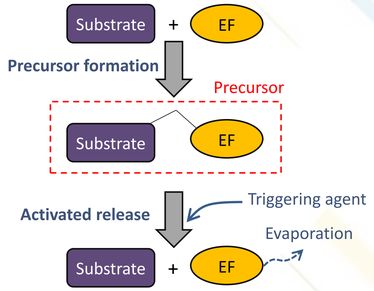


**Fig. 1**: Formation of precursor of EF and its release through cleavage of covalent bonds by a triggering agent.

- Scanning electron microscopy was used to study the morphologies of the fibers, which were correlated with the rheological properties of the spin dope solutions.
- EF release was triggered using 0.1 N citric acid. The release kinetic of EF from the fiber was studied using gas chromatography at 5, 10, 15, and 25°C (Fig. 3).

- The precursor was encapsulated in ethyl cellulose/ poly(ethylene oxide) (EC-PEO) nonwoven by electrospinning (Fig 2).

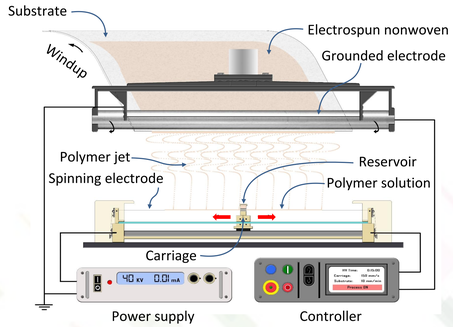


**Fig. 2**: Schematic of free surface wire electrospinner

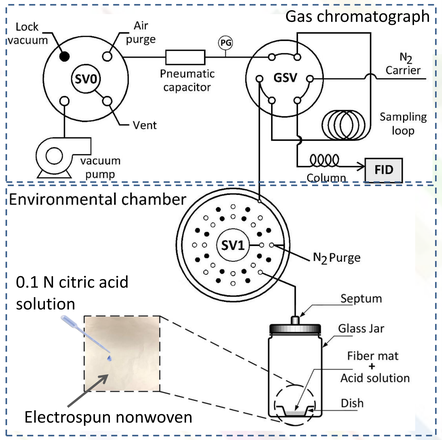


**Fig. 3**: Schematic representation of the automatic headspace analysis system used for studying the EF release.

## RESULTS

- All spin dope solutions exhibited shear-thinning behaviors.
- The addition of EF precursor caused an increase in the solution apparent viscosity (Fig. 4), which correlated with the larger fiber diameter for precursor-loaded nonwovens than the pristine counterpart (Fig. 5).
- Increasing the temperature significantly increased the release of EF from the precursor-loaded fibers (Fig. 6).

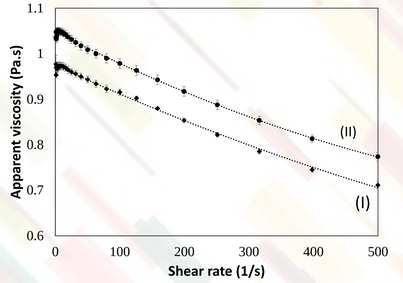


**Fig. 4**: Apparent viscosity of EC-PEO-doped solution (I) and precursor-doped solution (II).

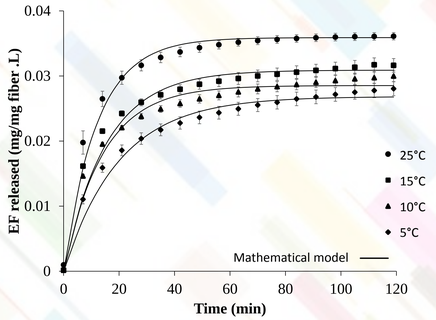


**Fig. 6**: EF released from the precursor-loaded fibers at different temperatures using 0.1 N citric acid solution.

Table 1: EF released from the fiber at different temperatures, and the fitted model parameters.

| Temperature | EF released after 2 h | | $C_e$ | K | $R^2$ |
|---|---|---|---|---|---|
| °C | mg/mg fiber. L | % | mg/mg fiber. L | $min^{-1}$ | |
| 5 | 0.028 | 74 | 0.027 | 0.05 | 0.97 |
| 10 | 0.029 | 79 | 0.029 | 0.07 | 0.97 |
| 15 | 0.31 | 83 | 0.031 | 0.075 | 0.97 |
| 25 | 0.036 | 95 | 0.036 | 0.082 | 0.99 |

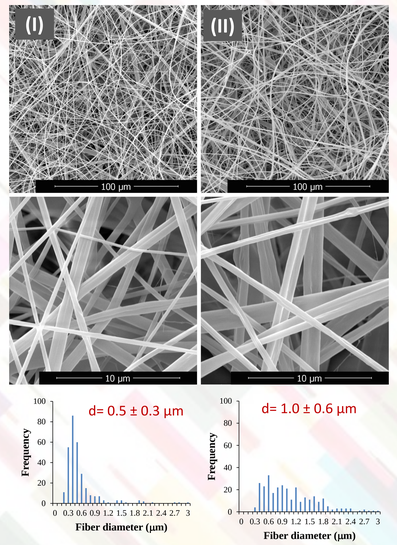


**Fig. 5**: SEM micrographs and histograms of fiber diameter distributions of pristine fiber (I)and precursor-loaded fiber (II).

## CONCLUSIONS

- EF precursor was synthesized for activated release of EF vapor.
- Electrospun EC-PEO nonwoven was developed as a carrier for the EF precursor.
- 95 % of EF was released from the nonwoven after 2 h at 25°C.
- The approach of converting the highly volatile EF into a solid-state precursor can be useful for in-package fumigation of fresh produce to destroy insect pests, as well as to inhibit the proliferation of spoilage microorganisms.

## ACKNOWLEDGEMENTS


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