ECP 2024 Conference

The 3rd International Electronic Conference on Processes

29–31 May 2024 | Online

The biodegradation behavior of the siloxane/polycaprolactone composite

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INTRODUCTION & AIM

Polymers are increasing interest in biomedical applications due to their excellent biocompatibility and ease of modification. Nonetheless, a considerable percentage of polymers are not environmentally friendly or biodegradable. It is well acknowledged that natural polymers are environmentally friendly and biodegradable, whereas synthetic polymers have superior mechanical and thermal characteristics. Thus, by combining the advantages of synthetic and natural polymers, hybrid materials have the potential for environmental and biomedical applications.

Poly(dimethylsiloxane) (PDMS) is a popular material due to its biocompatibility, hydrophobicity, chemical inertness, thermal stability, low viscosity, and other advantageous features. [1] Changes in the polydimethylsiloxane chain's end groups have an impact on its properties. [2] Ɛ-caprolactone (CL) is a hydrophobic polymer with a semi-crystalline structure, and the degree of crystallinity and molecular weight of PCL influence its biodegradability and appropriateness for use in biomedical applications. PCL may be destroyed by living organisms such as bacteria and fungi, making it biodegradable in a variety of biotic conditions. [3]

The present research used an aminopropyl polydimethylsiloxane (APDMS) oligomer to polymerize ε-caprolactone (CL), resulting in a siloxane/polycaprolactone hybrid copolymer. The effects of this compound on the evolution of tomato plants (Lypercosium esculentum) were studied, as well as its biological stability, by identifying microorganisms that grew on the surface due to its vulnerability to biodegradation.

METHOD

The FTIR spectra were obtained using a Bruker Vertex 70 Fourier Transform Infrared Spectrophotometer. A Bruker NMR spectrometer was used to obtain nuclear magnetic resonance (^{1}H-NMR) spectra. The morphology and content of materials were investigated with scanning electron microscopy/energy dispersive X-ray spectroscopy (SEM/EDX). Gel permeation chromatography (GPC) was performed using a WGE SEC/GPC chromatograph with four in-line detectors (RI, VI, UV, and MALS) and two Agilent PL gel columns (MIXED D and MIXED C). Surface images were captured using an NTEGRA scanning probe microscope (NT-MDT Spectrum Instruments, Russia) in AFM mode.

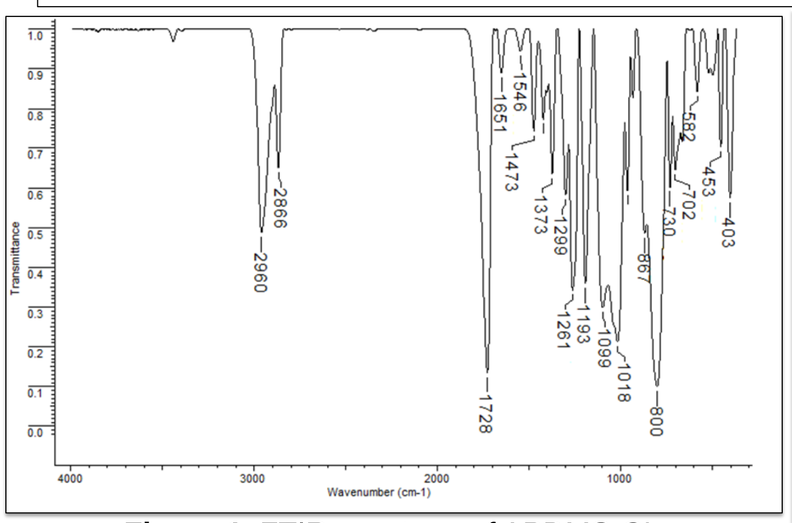

Figure 1. FTIR spectrum of APDMS-CL

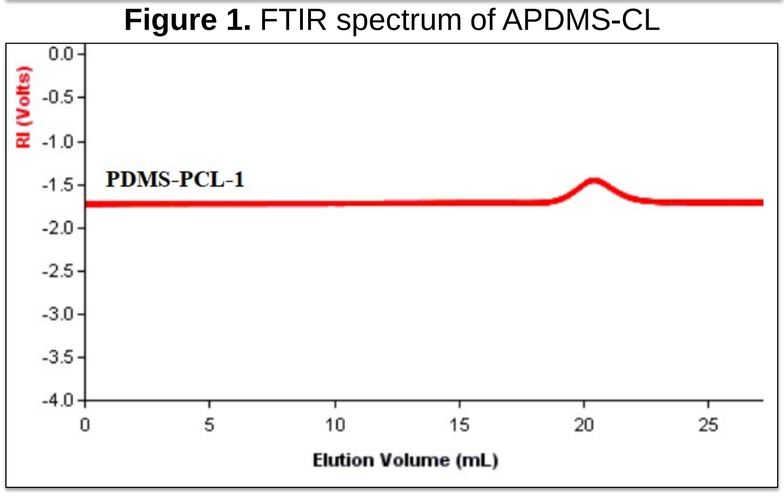

Figure 2. GPC curve of APDMS-CL copolymer

The presence of an absorption band at 1099 cm^{-1}, which corresponds to the stretching vibration of Si-O bonds in APDMS polymer, and a very strong stretching vibration of carbonyl groups at 1728 cm^{-1}, which corresponds to the ester group in CL, confirm the APDMS-CL structure. The 1018-1099 cm^{-1} region corresponds to Si-O-Si bands, the 1261 cm^{-1} band to Si-CH_3, and the 800 cm^{-1} band to CH_2-Si-O vibration.

RESULTS & DISCUSSION

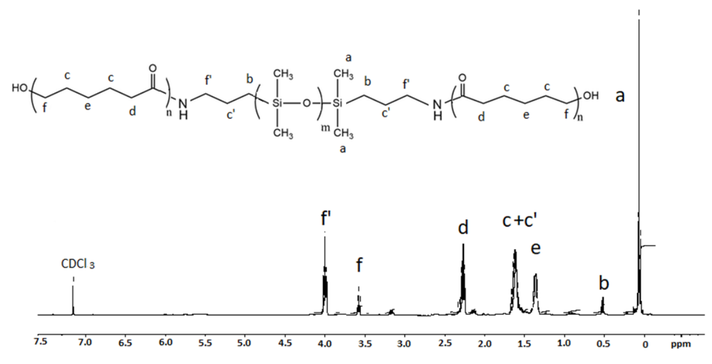

Figure 3. NMR spectrum for APDMS-CL synthesized

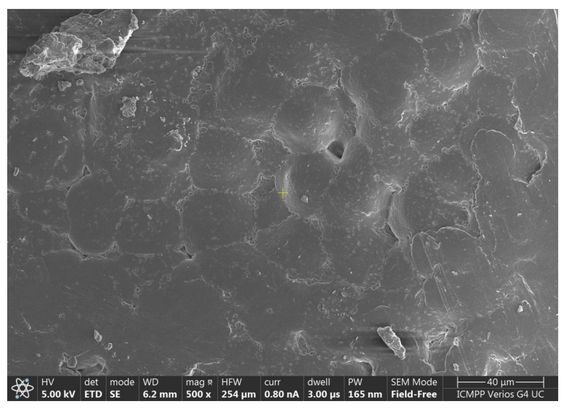

Figure 4. SEM images of APDMS-CL

CH_2-H (3.6 ppm); -CH_2-NH- (4.03 ppm), -CH_2-CH_2-CH_2-NH- (1.61 ppm); -CO-CH_2-CH_2-CH_2- (1.4 ppm); -CO-CH_2-CH_2- (1.61 ppm); -CO-CH_2- (2.34 ppm); -Si(CH_3)$_2$- (0.07 ppm); -Si-CH_2- (0.5 ppm); -CH_2-CH_2-CH_2-(1.46).

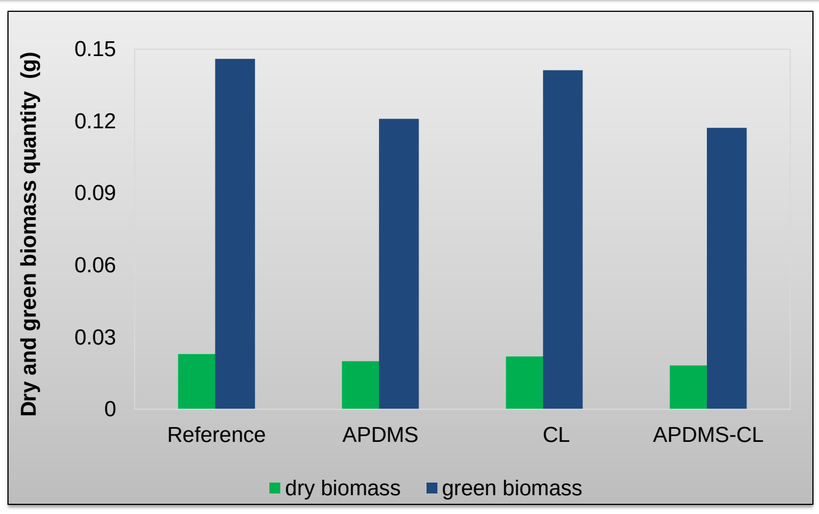

Figure 5. Tomato plant biomass quantity (dry and green)

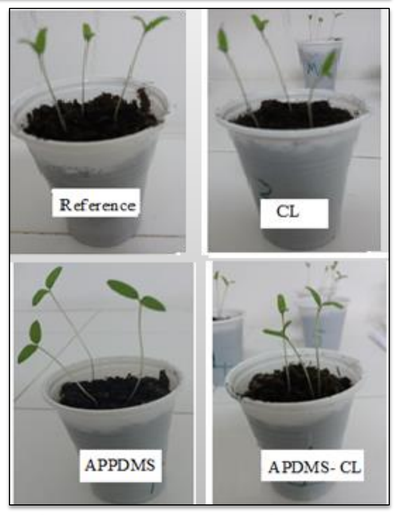

Figure 6. Tomato plants after 7 days from planting

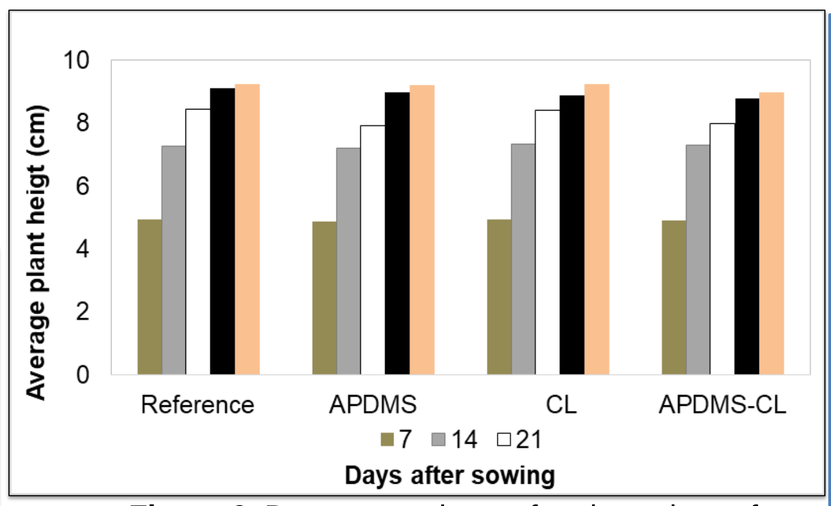

Figure 6. Dry tomato plants after three days of harvesting

Table 2. Total nitrogen after plant removal

Samples	Total nitrogen (N_t), %			
	Reference	CL-APDMS-CL	CL	APDMS
	0,81	1,23	0,91	1,43

After 14 days, the size of the plants in APDMS-CL is identical to that of the reference sample, which can be attributed to the absence of biodegradation initiation. After 21, 28, and 35 days, plant size is less evolutionary for APDMS-CL and CL than the reference sample, confirming the start of biodegradation, but higher than in APDMS, which had a faster contact with the soil due to its liquid condition.

CONCLUSION

APDMS-PCL copolymer was obtained via the ring-opening polymerization of ε-caprolactone (CL) by using aminopropyl-terminated polydimethylsiloxane macroinitiator (APDMS).

The development of microorganisms, specifically Lypercosium esculentum, which originally was found on polycaprolactone-based hybrid polymeric materials, demonstrates that these products exhibit appropriate environmental susceptibility and do not significantly alter soil composition or plant evolution.

Furthermore, without impairing soil bioremediation, the investigated hybrid can be a solution in the future because of its better performance when compared to the individual materials and the ability to model the properties according to the field of usage.

1. Fortună, M.E.; Ignat, M.; Asandulesa, M.; Rotaru, R.; Pricop, L.; Harabagiu, V. J. Inorg Organomet Polym Mater. 2018, **28**, 2275-2287.
2. Fortună, M.E., Ungureanu, E.; Jitareanu, D.C.; Țopa, D.C.; Harabagiu, V. Material. 2023, 16, **5**,1904.
3.Yilgor, E.; Isik, M.; Soz, C. K.; Yilgor, I. Polym. 2016, **83**, 138-153.