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Fabrication and Characterization of Air-jet-Spun Nanofibers and Thin Films from Corn Zein Protein for the Delivery of Therapeutic Molecules

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Abstract:
Corn zein protein is a cheap, widely available biopolymer that is easily extracted from corn and processed into useful forms. In this study, zein was dissolved along with several model drugs or sodium citrate, which was then cast into thin films or air-spun into nanofibers. The molecular weight, solubility and charge of the selected model drugs are different, and the weight percentage of citrate also varies (1-30%). The integrity of the loaded biomaterials were characterized through FTIR, SEM, DSC, and TGA analysis. FTIR analysis showed that the therapeutics interacted strongly with the protein structure of zein nanofibers, transforming their structure from a random coil network to an alpha helical structure. Zein films did not show this shift. This structural change reflects the results of the drug release study, where nanofibers showed a slower, sustained release of therapeutics compared to their film counterparts. Statistical analysis by T-Test proved a significant difference in release between fibers andfilms ($P<0.01$). The structural integration also improved the thermal properties of the biomaterial, where fibers did not degrade until temperatures reached 160°C, but films degrade earlier at 130°C. Finally, the biocompatibility of zein was confirmed by culturing HEK293 cells on zein films and fibers for 72 hours. An MTT assay confirmed good biocompatibility and an improved density of fibers and films compared to a blank control.

Keywords: biomaterial; corn zein protein; drug release; nanofiber; film

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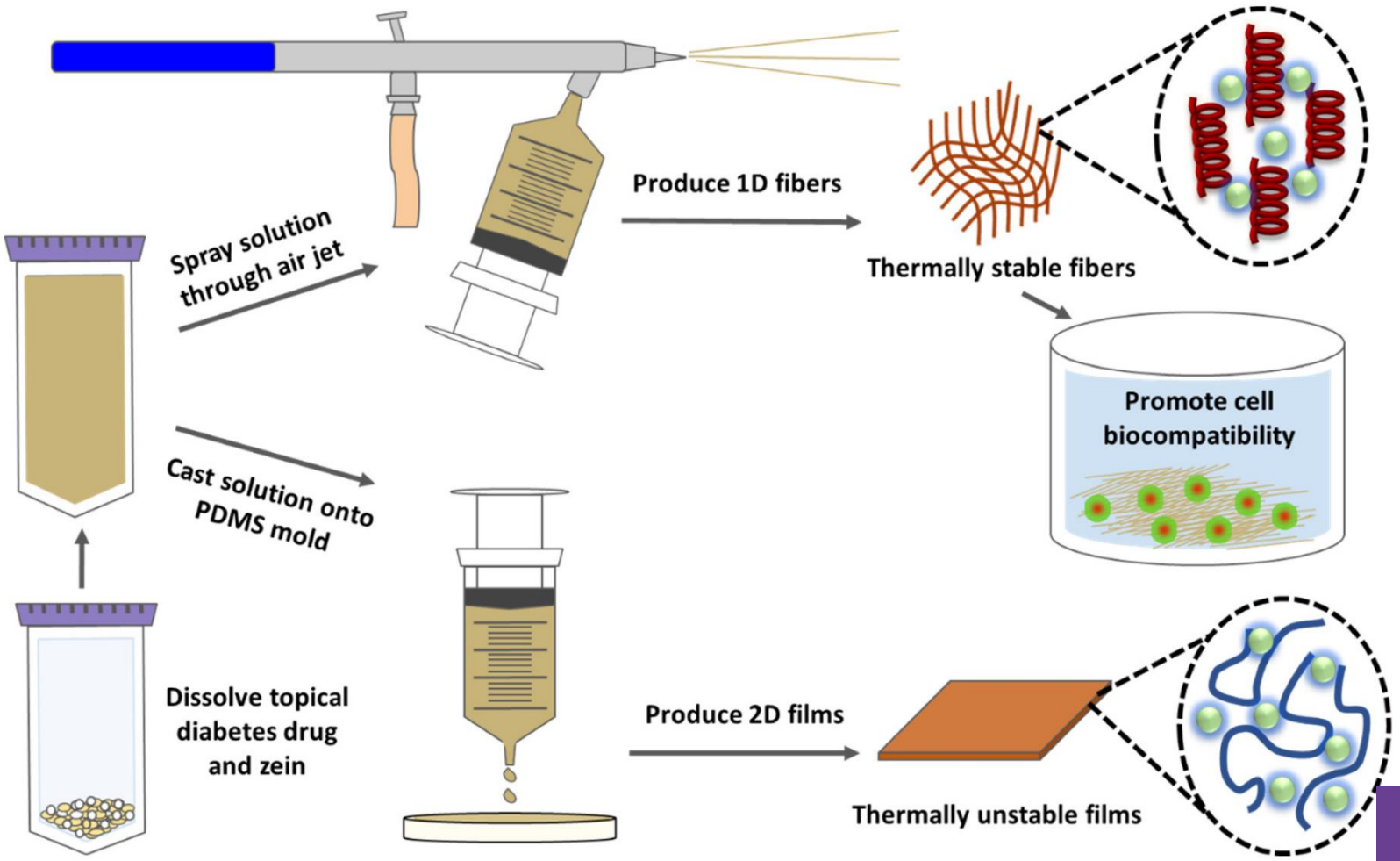
Graphical Abstract



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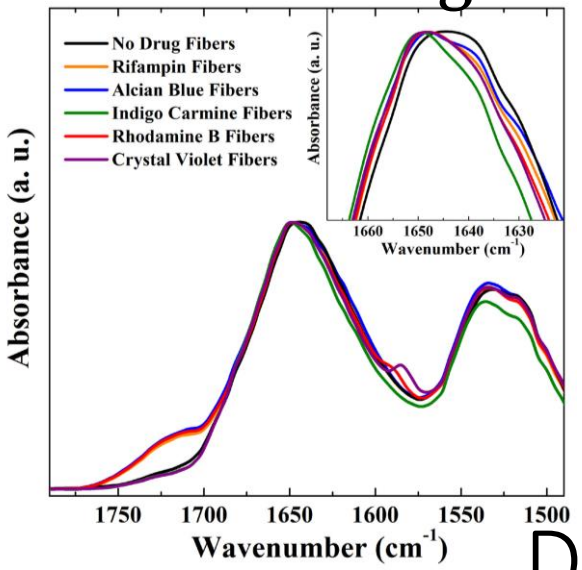
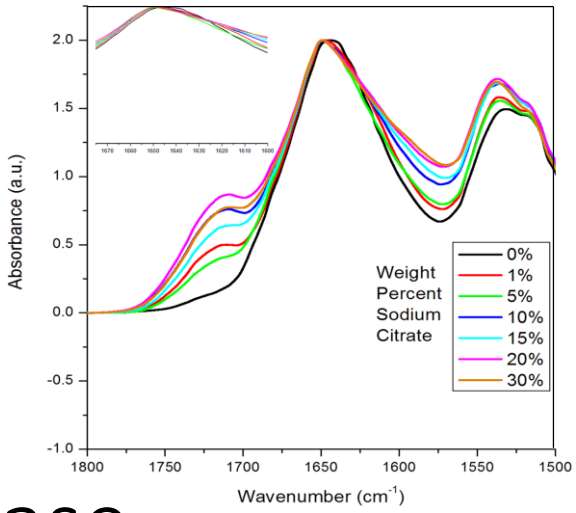
Morphology Analysis – FTIR on Nanofibers

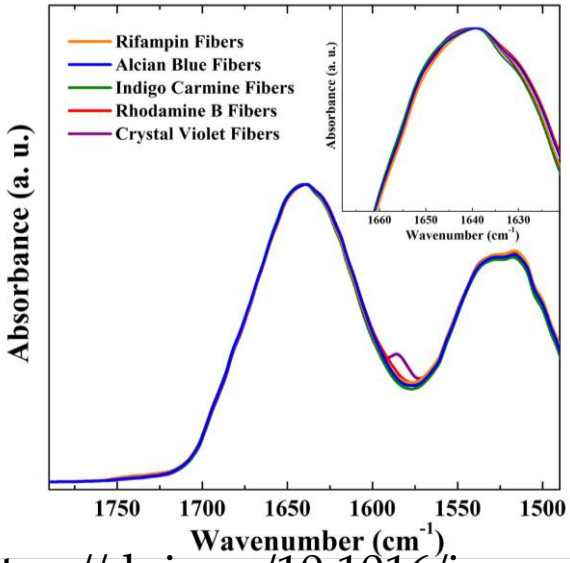
Model Drugs

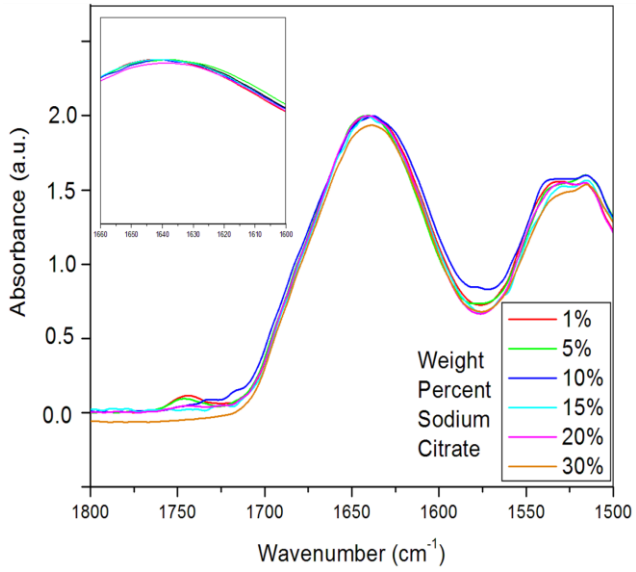


Sodium Citrate



Drug Release





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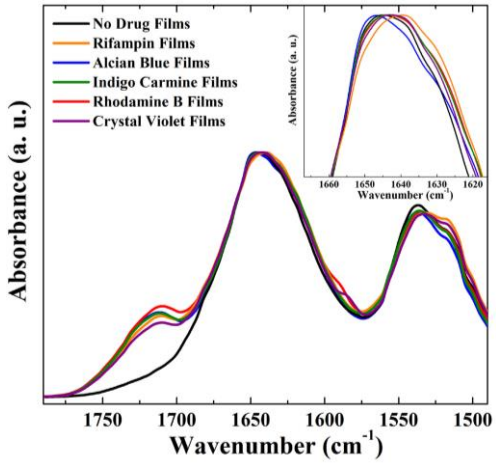
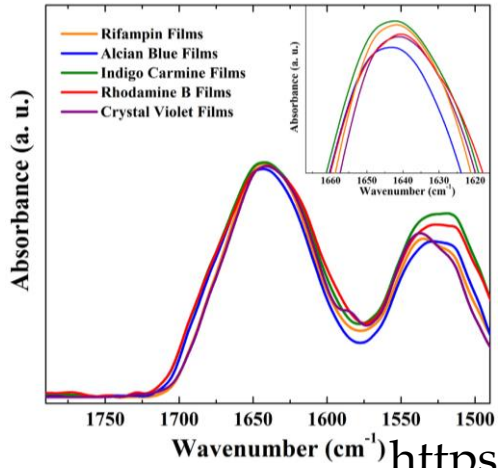
Morphology Analysis – FTIR on Films

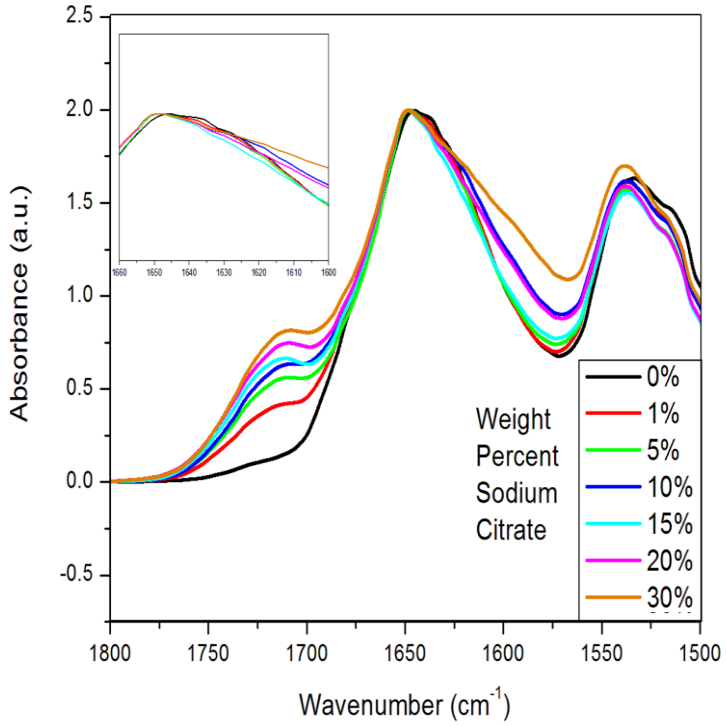
Model Drugs



Drug Release



Sodium Citrate



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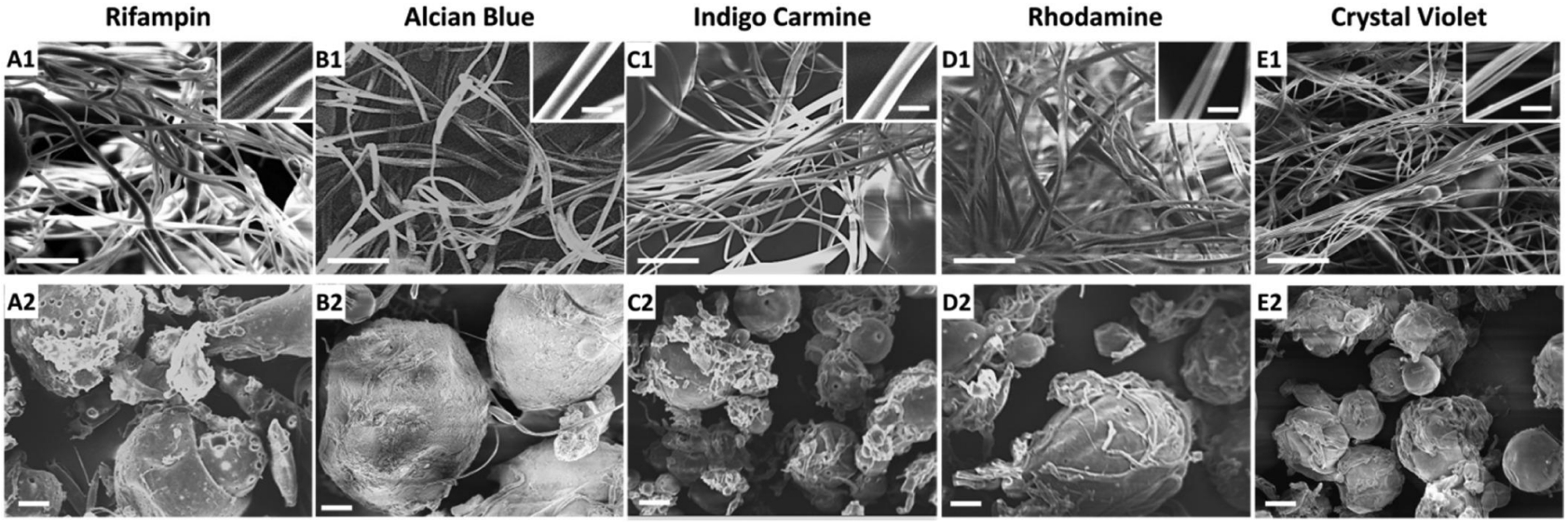
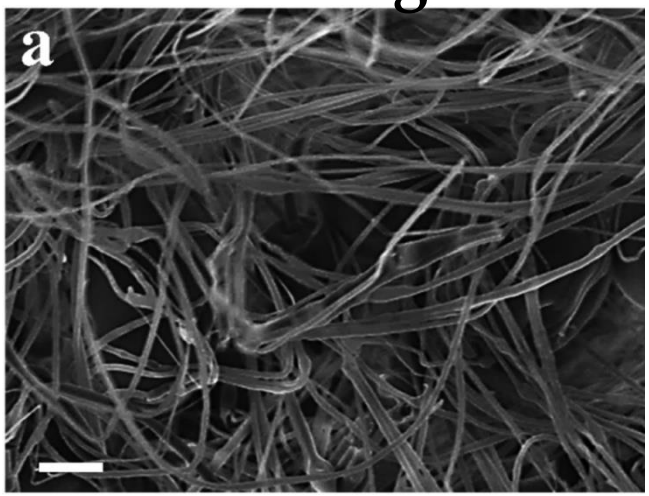
Morphology Analysis- SEM of Nanofibers



No drugs



Sodium citrate

https://doi.org/10.1016/j.msec.2020.111419

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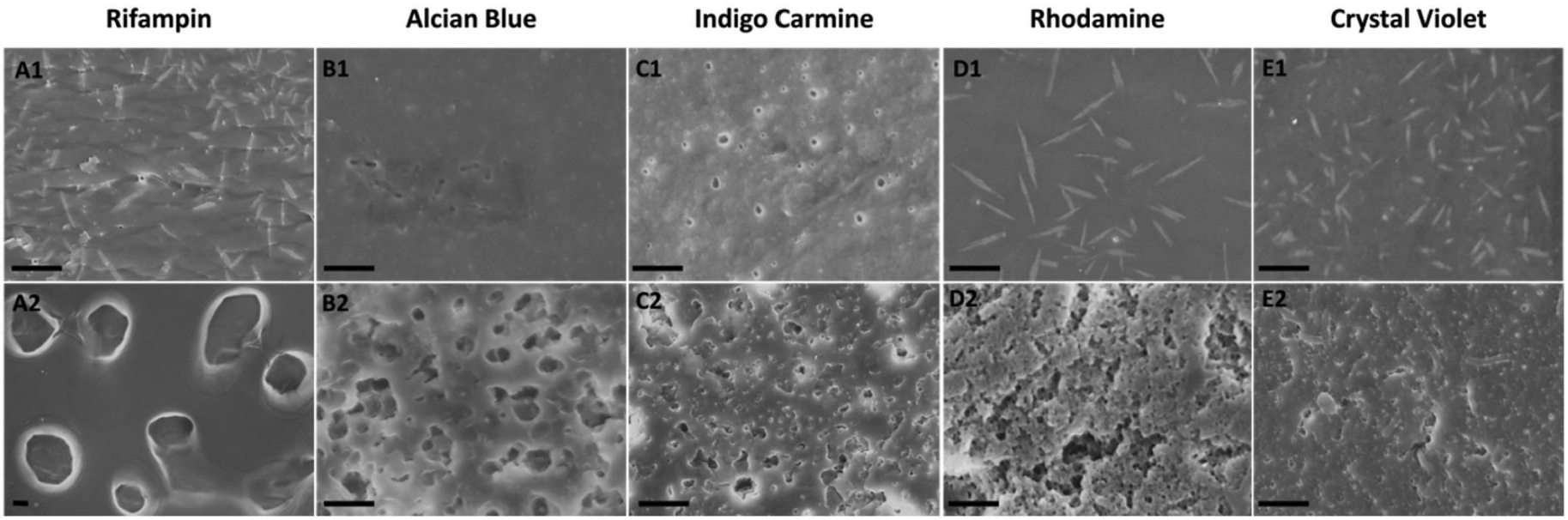
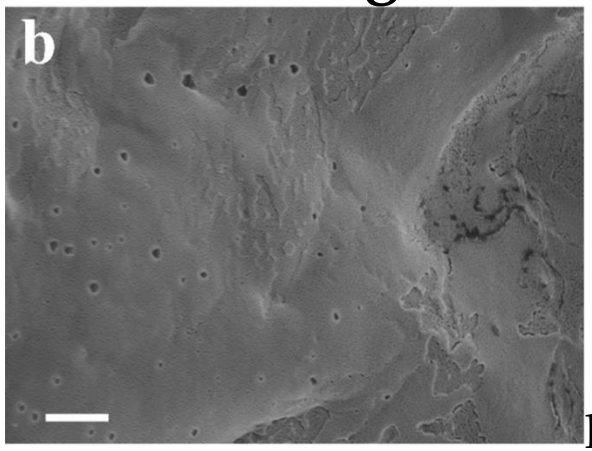
Morphology Analysis- SEM of Films



No drugs



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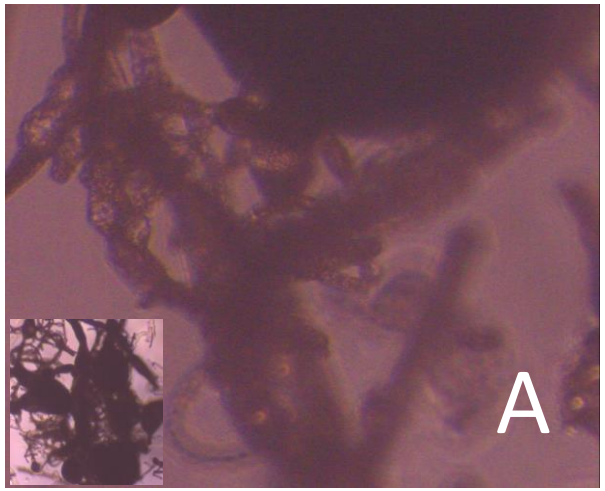
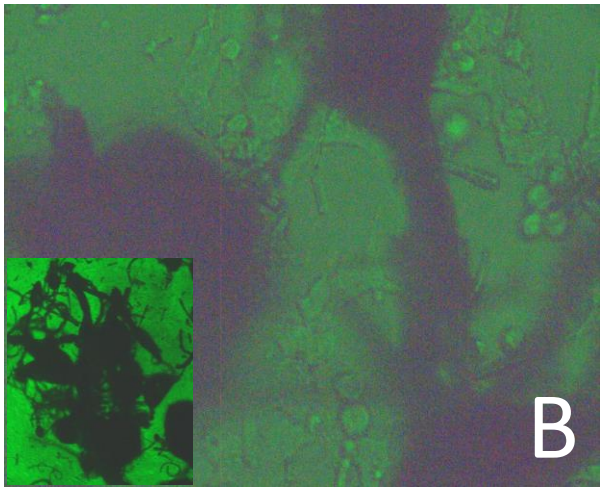
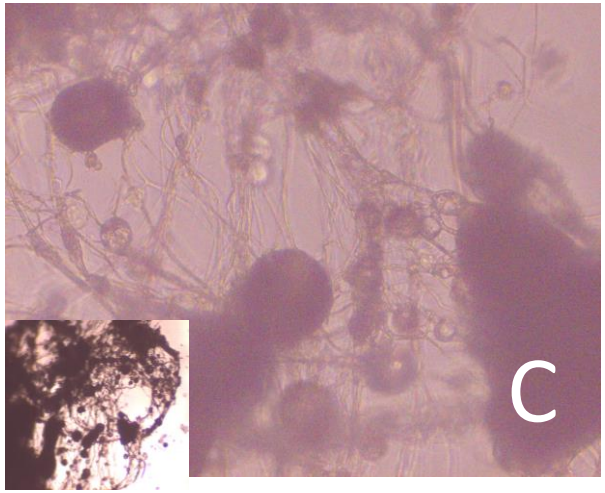
Biocompatibility- Microscopy

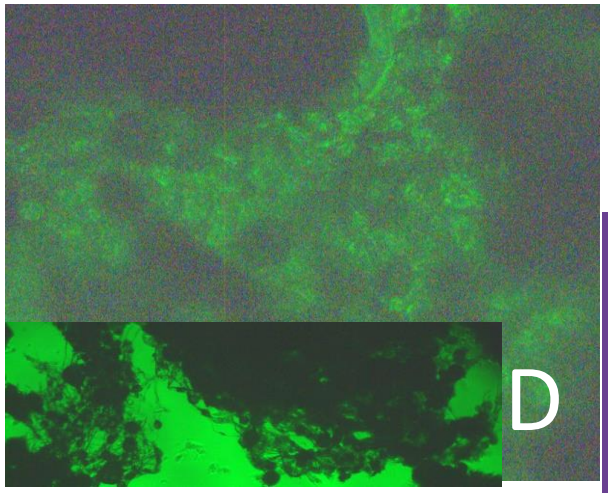


With Citrate





Without



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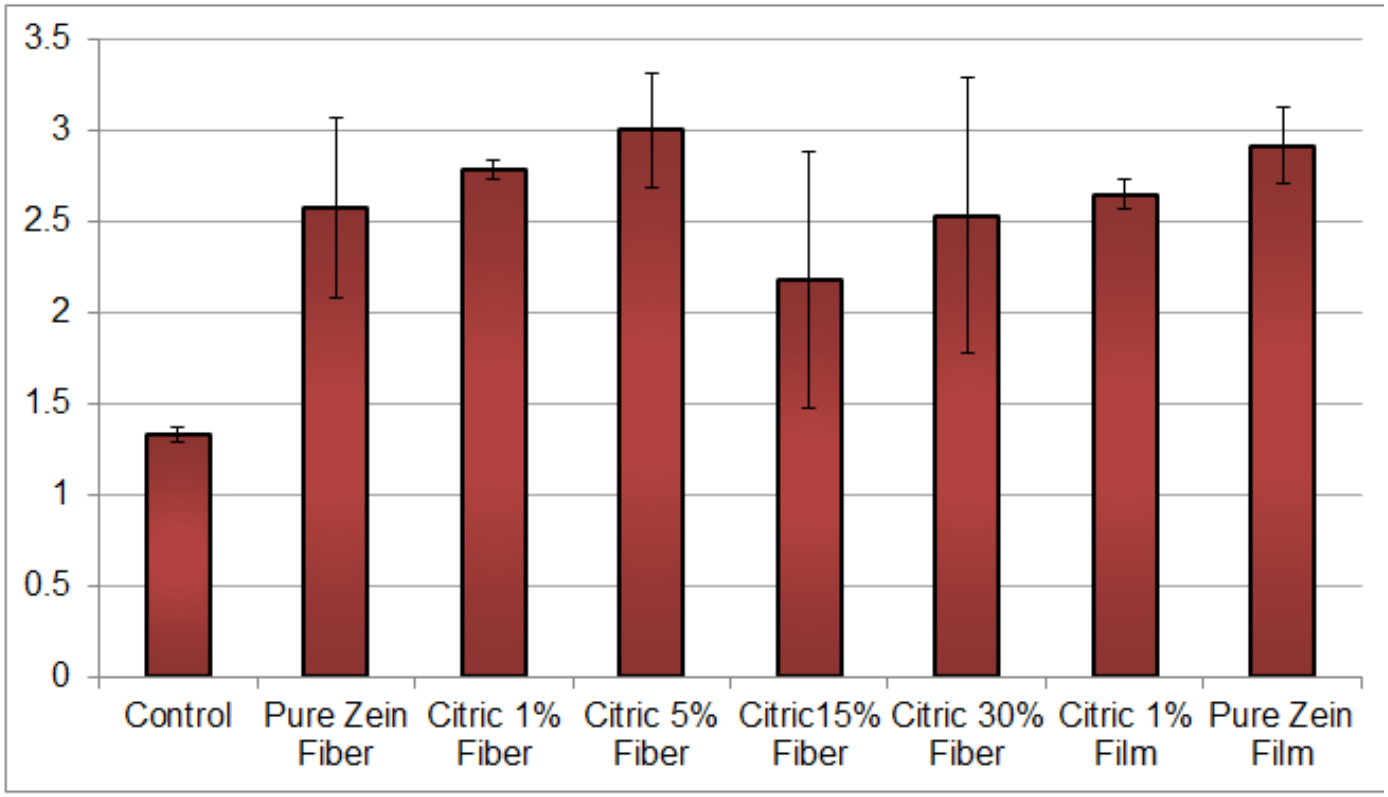
Biocompatibility – MTT Assay



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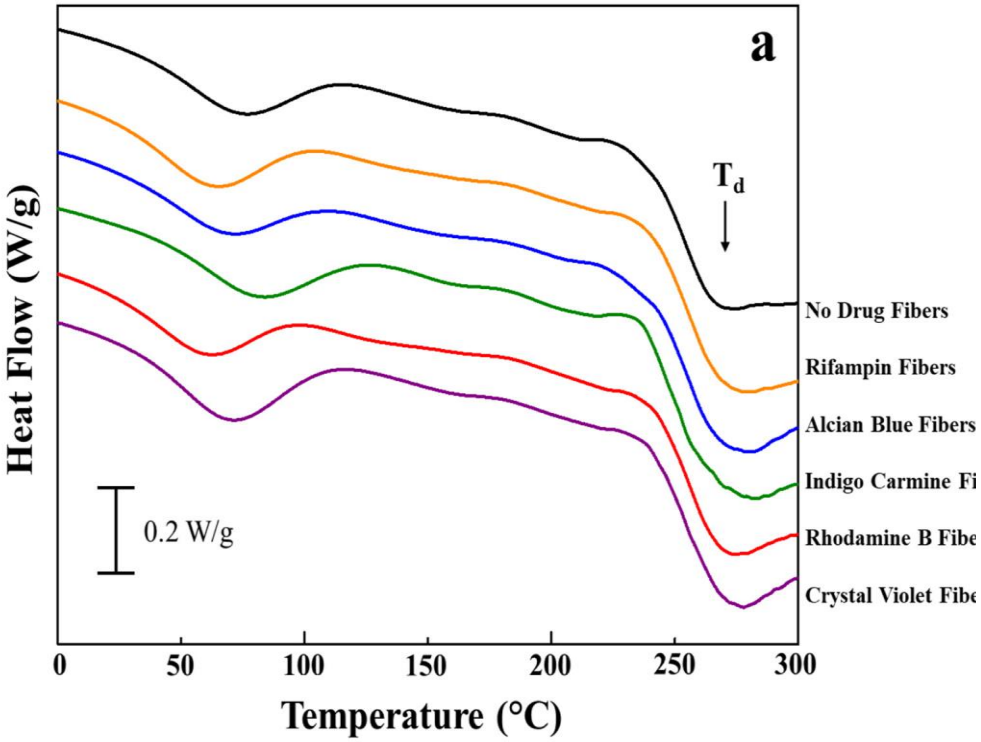
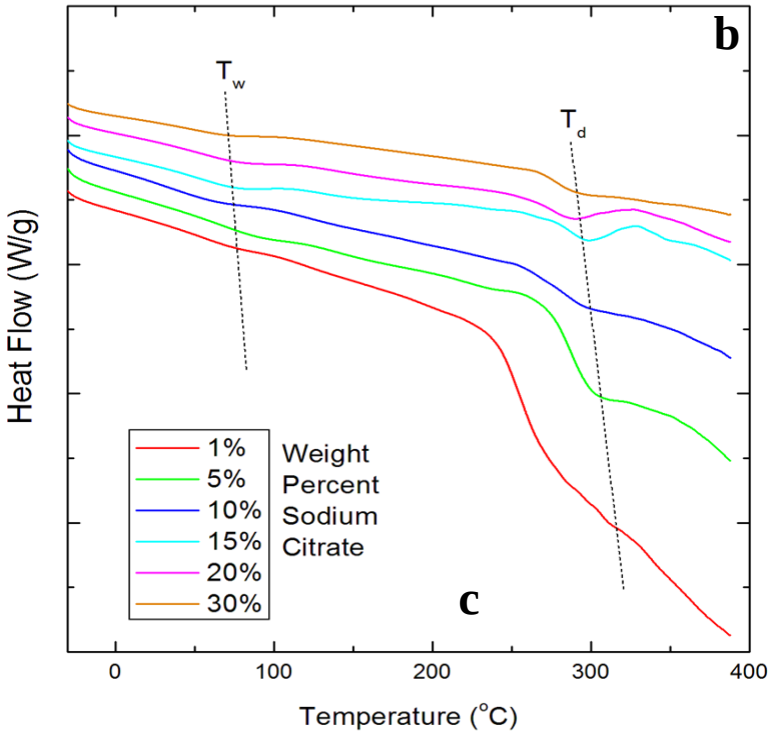
Thermal Analysis – DSC on Nanofibers



Model Drugs



Sodium Citrate

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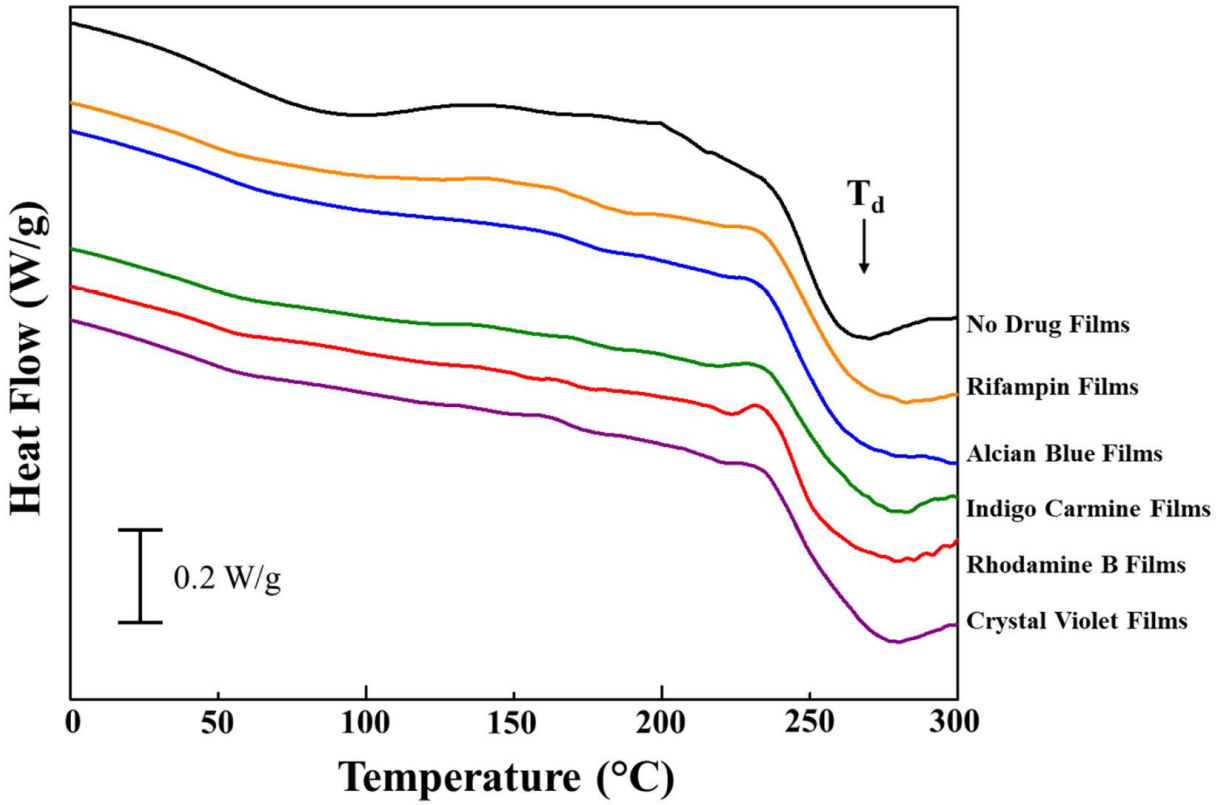
Thermal Analysis – DSC on Films



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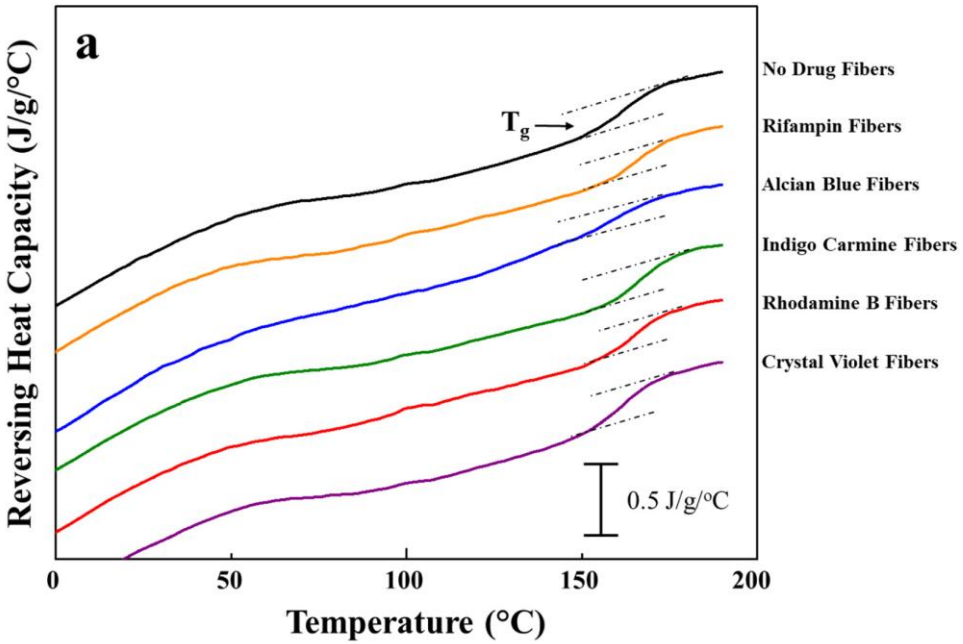
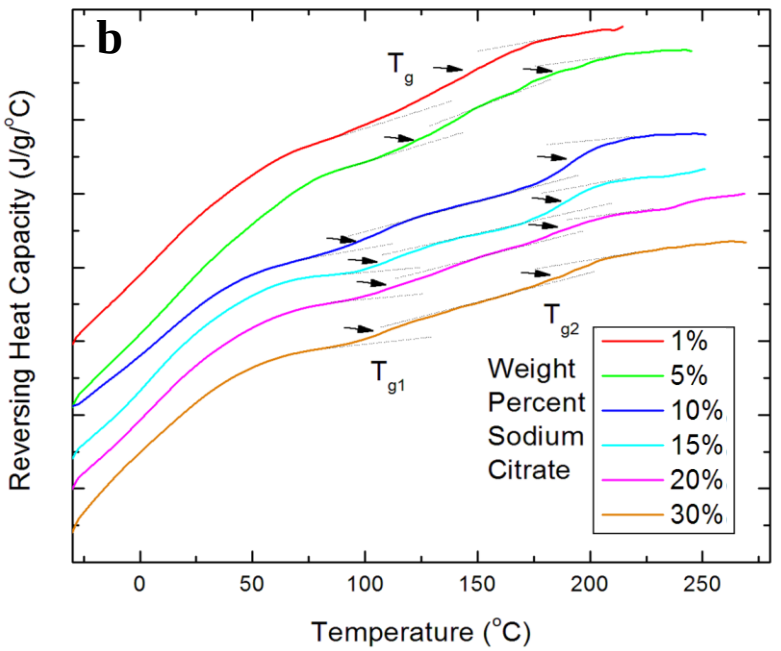
Thermal Analysis – DSC on Nanofibers



Model Drugs



Sodium Citrate

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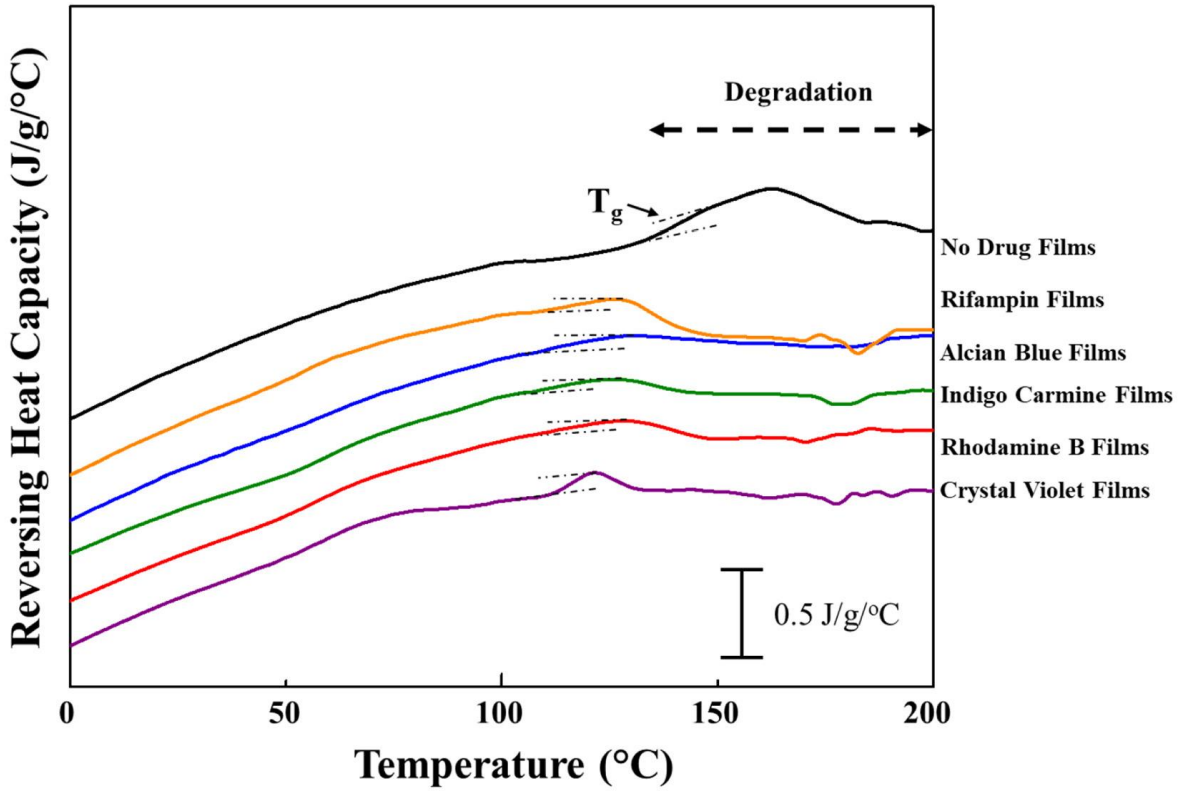
Thermal Analysis – DSC on Films



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Thermal Analysis – Model Drugs

Model Drug	Fiber		Film	
	Glass Transition T_g/°C	Degradation T_d/°C	Glass Transition T_g/°C	Degradation T_d/°C
No drug	162.3	267.1	146.2	268.5
Rifampin	166.8	272.0	121.6	282.1
Alcian Blue	158.2	276.9	120.1	282.9
Indigo Carmine	166.2	275.6	120.4	280.9
Crystal Violet	162.4	273.8	115.3	278.5
Rhodamine B	164.1	272.6	122.3	279.2

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Thermal Analysis – Sodium Citrate

Sodium Citrate wt%	Fiber		Film	
	Water evaporation T_W (°C)	Degradation T_d (°C)	Glass Transition 1 T_{g1} (°C)	Glass Transition 2 T_{g2} (°C)
1	81	311	139	N/A
5	83	305	128	189
10	73	297	104	190
15	78	297	109	188
20	75	290	116	187
30	69	289	105	186

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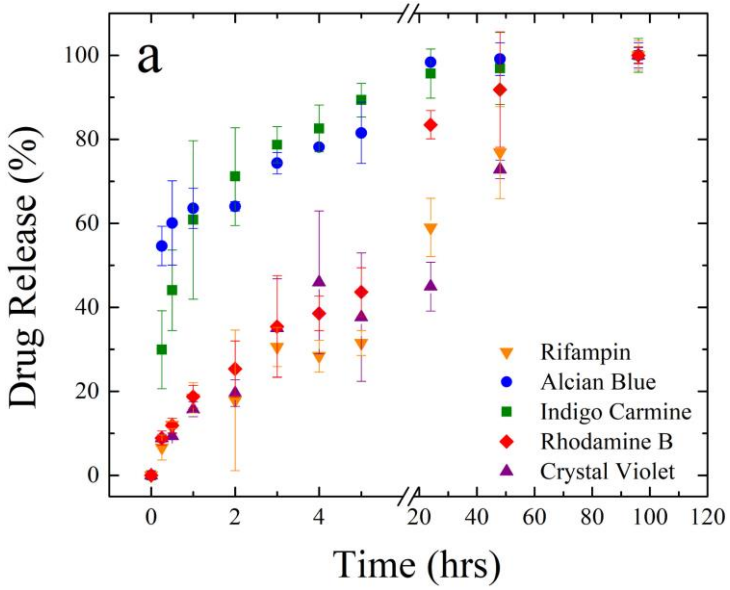
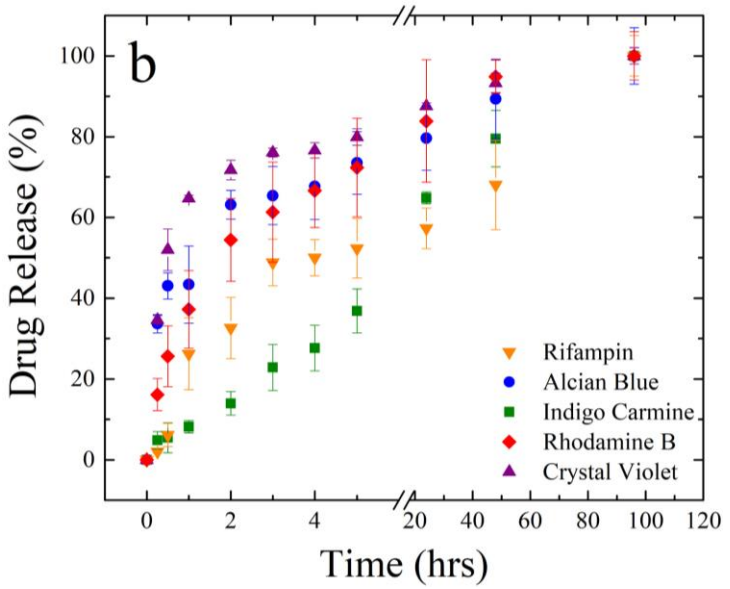
Drug Release – Model Drugs

Model Drug	Fiber		Film	
	n	R^2	n	R^2
Rifampin	0.392	0.99	0.284	0.87
Alcian Blue	0.111	0.97	0.151	0.96
Indigo Carmine	0.132	0.88	0.430	0.98
Crystal Violet	0.353	0.93	0.118	0.93
Rhodamine B	0.337	0.95	0.203	0.91





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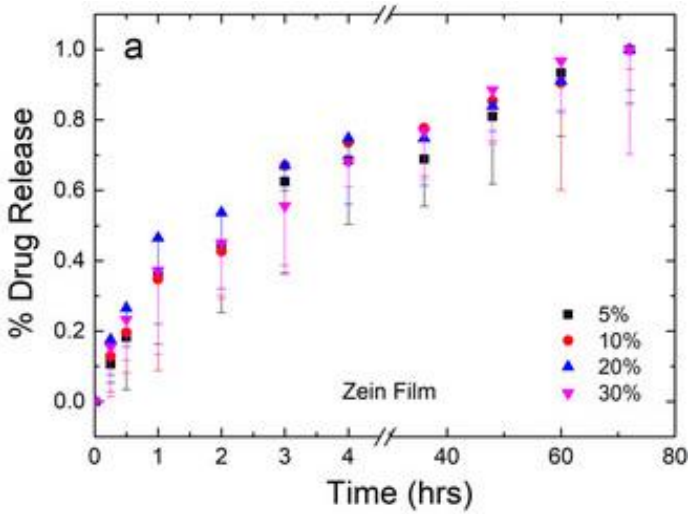
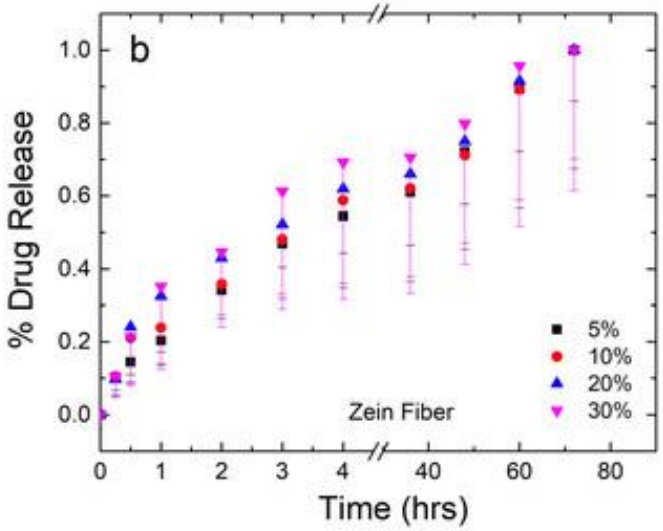
Drug Release - Citrate

Citrate wt%	Pearson Correlation	T-Stat	p(T≤t)
5	0.983	3.948	0.003
10	0.977	3.363	0.007
20	0.984	4.128	0.002
30	0.993	1.464	0.174





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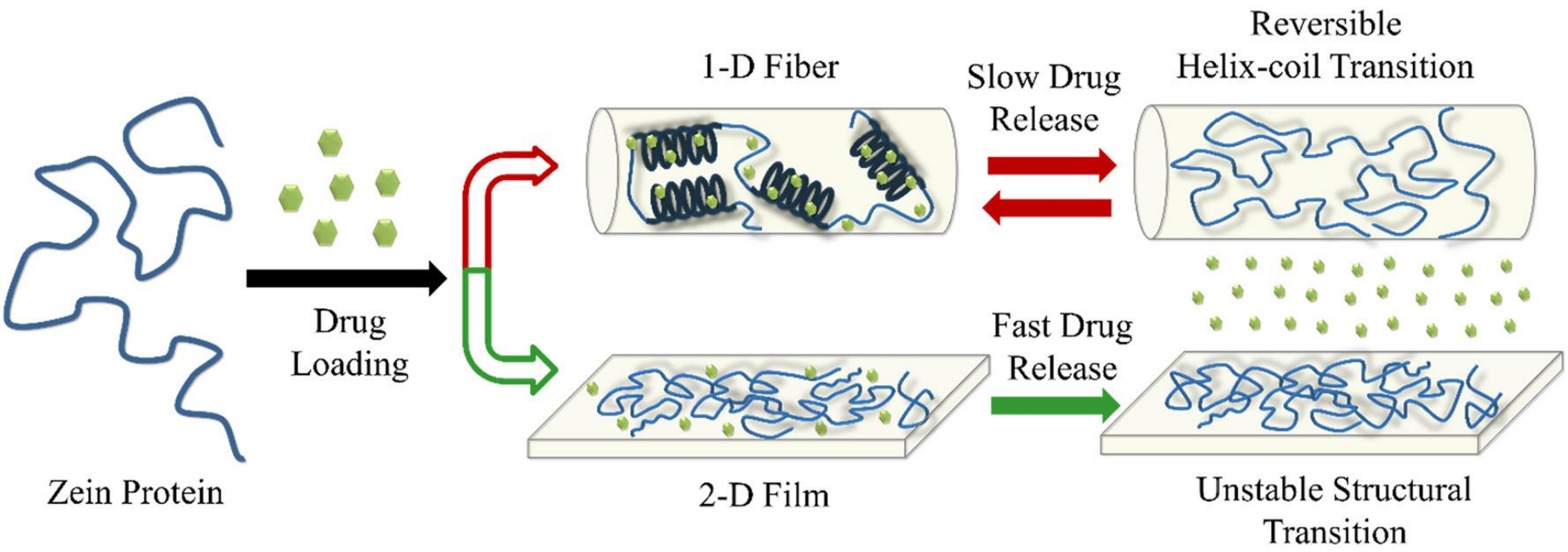
Mechanism



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Conclusions

- Corn zein is a biocompatible, easy to work with biopolymer for fabricating effective drug delivery vehicles
- Nanofibers provide a more thermally stable biopolymer
- Nanofibers interact with therapeutic molecules to better control the release of therapeutics

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Acknowledgments

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