Project Notes:

Project Title: A Machine Learning Approach to Optimizing the Tensile Strength of Starch-Based Bioplastics
Name: Sriaditya Vaddadi

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
What Materials should be used to create the strongest and most cost-efficient bioplastic?	Reading articles with #Bioplastics tag.	Project Notes: Check all article notes with #Bioplastics tag.	10-11-24
What methods should be used to create the strongest and most cost-efficient bioplastic?	Reading articles with #Bioplastics tag.	Project Notes: Check all article notes with #Bioplastics tag.	10-11-24
Can simulations be used to test out different bioplastics without having to separately fabricate them each time?			

Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google	“Micropatterns”/”Biomimicry”	Check Articles with #Micropatterns tag
Google	“Starch-Based", “Bioplastics”	Check Articles with #Bioplastics tag
USPTO	“Starch-Based”, “Bioplastics”	Check Patents with #Bioplastics tag

Tags:

Tag Name	
#ChemEng	#BioChem
#Bacteriology	#BioEng
#Micropatterns	#Bioplastics
#ML	

Article #0 Notes: Title

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

Article #1 Notes: Persistent glucose consumption under antibiotic treatment protects bacterial community

Source Title	*Persistent glucose consumption under antibiotic treatment protects bacterial community*
Source citation (APA Format)	Zhang, Y., Cai, Y., Jin, X., Wu, Q., Bai, F., & Liu, J. (2024). Persistent glucose consumption under antibiotic treatment protects bacterial community. *Nature Chemical Biology*. https://doi.org/10.1038/s41589-024-01708-z
Original URL	Persistent glucose consumption under antibiotic treatment protects bacterial community | Nature Chemical Biology
Source type	Journal Article
Keywords	*Bacteria, Lipids, Membranes, Metabolism, Proteomics*
#Tags	#ChemEng, #BioChem, #Bacteriology
Summary of key points + notes (include methodology)	**Although antibiotics were previously known to reduce the rate at which bacteria grow, these antibiotics do not have the same effect regarding glucose consumption. Instead, in a specific area known as the community periphery, glucose consumption does not change due to antibiotics. This notably stops the glucose from diffusing into the community's interior, thereby stopping the spread of antibiotics.**
Research Question/Problem/ Need	**Do bacteria in communities suffer from a slower nutrient (specifically glucose) consumption when antibiotics are present?**
Important Figures	
VOCAB: (w/definition)	Proteomics: The study of proteins, specifically how they operate on a cellular level within an organism. Membrane Potential: A measure of the difference of electric charge from the outside and inside of the cell (i. E. both sides of the membrane)
Cited references to follow up on	Lobritz, M. A. et al. Antibiotic efficacy is linked to bacterial cellular respiration. *Proc. Natl Acad. Sci. USA* 112, 8173–8180 (2015).

	Peng, B. et al. Exogenous alanine and/or glucose plus kanamycin kills antibiotic-resistant bacteria. *Cell Metab.* 21, 249–262 (2015).
Follow up Questions	**Can certain antibiotics be made to increase the membrane potential of bacterial communities' peripheries (causing nutrient consumption to decline)?** **Can planktonic bacteria develop a resistance to certain antibiotics even with a diminished nutrient consumption?** **Is this strategy the only way that bacteria can develop a resistance to antibiotics, or are there other ways?**

Article #2 Notes: Nature-inspired Micropatterns

Source Title	Nature Reviews Methods Primers
Source citation (APA Format)	Wang, Y., Zheng, G., Jiang, N., Ying, G., Li, Y., Cai, X., Meng, J., Mai, L., Guo, M., Zhang, L., & Zhang, X. (2023). Nature-inspired Micropatterns. *Nature Reviews Methods Primers*, *3*(68). https://doi.org/10.1038/s43586-023-00251-w.
Original URL	https://www.nature.com/articles/s43586-023-00251-w
Source type	Journal Article
Keywords	None listed; Some may be “Micropatterns”, “Biomimicry”
#Tags	#BioEng, #BioChem, #Micropatterns
Summary of key points + notes (include methodology)	When solving engineering problems, the best solutions can sometimes be found in nature. The idea of nature-inspired micropatterns is to utilize this fact and harness the power of pre-existing organic mechanisms in our everyday world. This primer details specific methods used in the field of micropatterning (such as photolithography, soft lithography, 2D/3D printing, etc.) as well as materials used to create micropatterns and how those materials are decided on. Materials used to create micropatterns include inorganic materials such as metals, glass, and silicon, and organic materials such as PDMS, Ecoflex, and PUA. The primer concludes by stating its belief that though nature-inspired micropatterns may have many uses in the future, current issues such as difficulty in selecting materials as well as mass production being impossible must be addressed in further research regarding these micropatterns.
Research Question/Problem/ Need	How can micropatterning techniques be used to create nature-inspired solutions to engineering problems; and what are the benefits of using these solutions?

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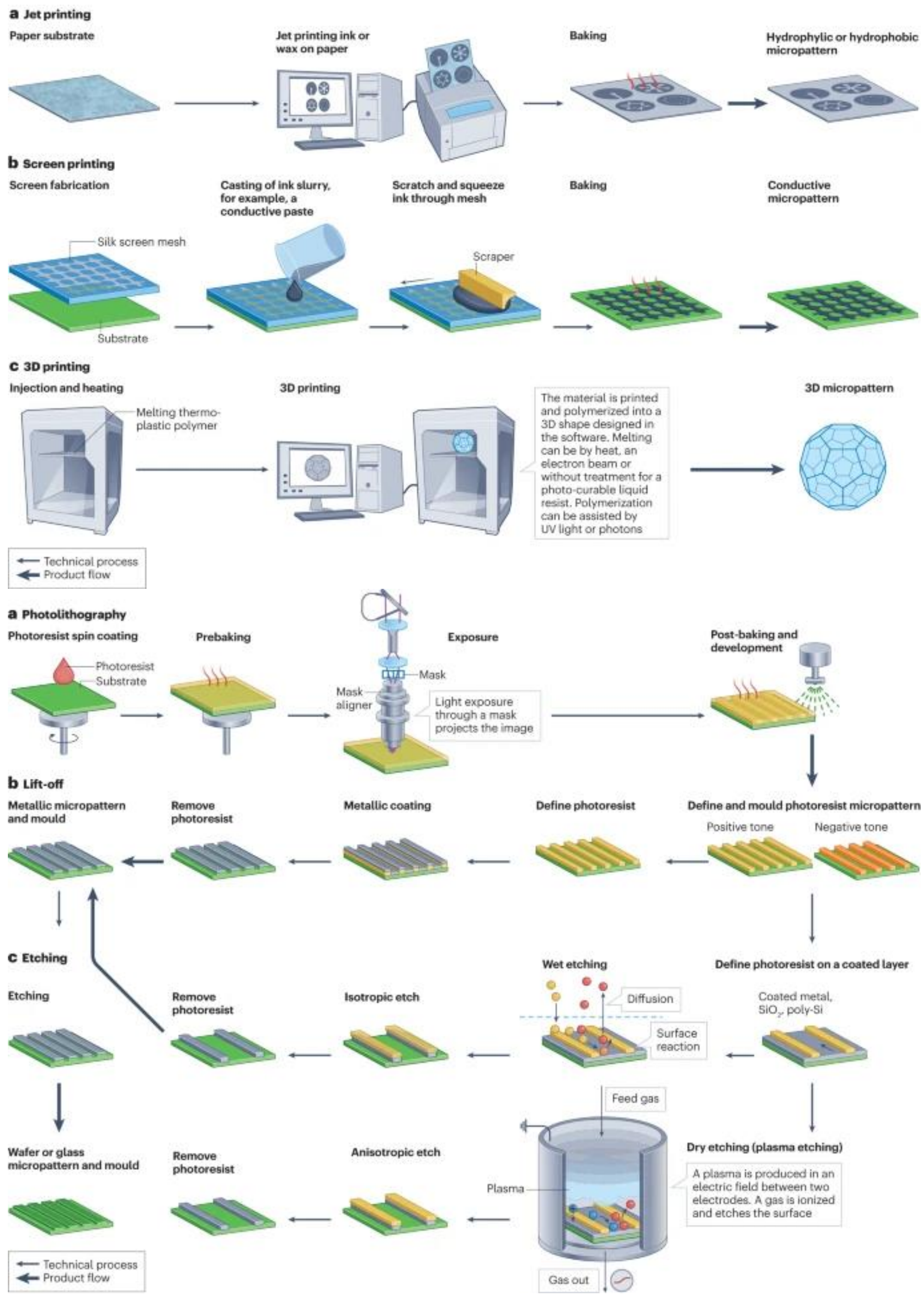
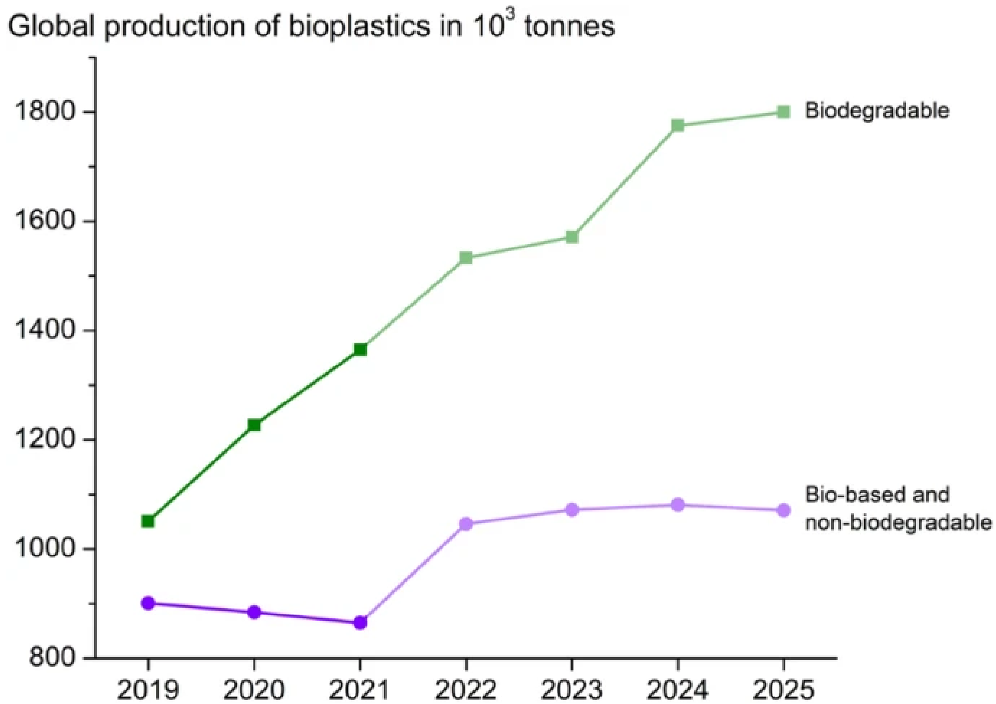
<tr><td>Important Figures</td><td>
</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Micropatterning: A technique that allows for small-scale patterns which are then used to simulate and solve real-world problems.

Biomimicry: A strategy in which mechanisms found in organisms are tweaked and applied to engineering problems.</td></tr>
<tr><td>Cited references to follow</td><td>Zhang, B. et al. Advanced bio-inspired structural materials:</td></tr>
</table>

up on	local properties determine overall performance. *Mater. Today* 41, 177–199 (2020). Houten, F. et al. Bio-based design methodologies for products, processes, machine tools and production systems. *CIRP J. Manuf. Sci. Technol.* 32, 46–60 (2021).
Follow up Questions	Can micropatterns be used to create a sustainable, cost-effective bioplastic? How can the problem of mass production not being readily available for micropatterns be addressed in the future? Are micropatterns expensive to fabricate, and how long are the final micropatterns usable for?

Article #3 Notes: Innovation in applications and prospects of bioplastics and biopolymers: a review

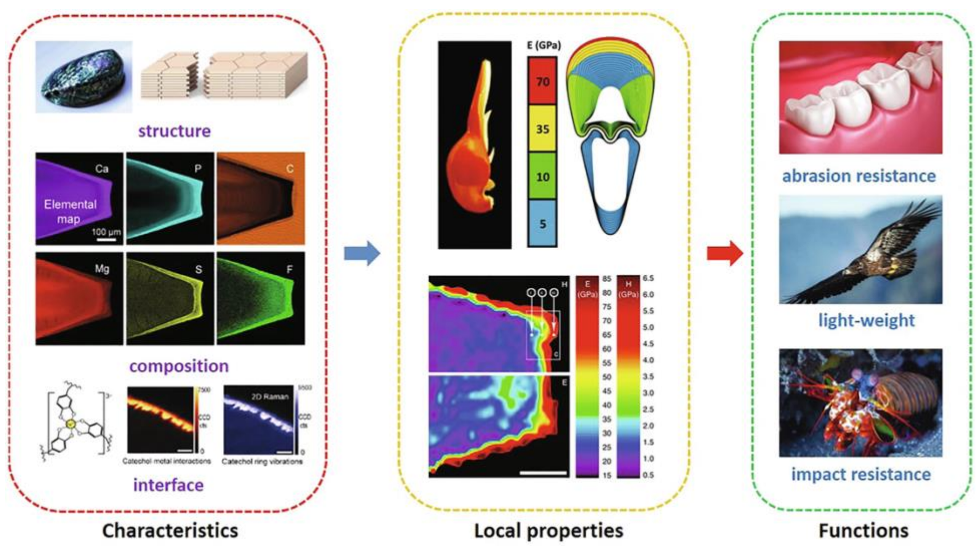
Source Title	Environmental Chemistry Letters
Source citation (APA Format)	Nanda, S., Patra, B. R., Patel, R., Bakos, J., & Dalai, A. K. (2022). Innovation in applications and prospects of bioplastics and biopolymers: a review. *Environmental Chemistry Letters, 20*(1), 379-395. 10.1007/s10311-021-01334-4.
Original URL	https://link.springer.com/article/10.1007/s10311-021-01334-4
Source type	Journal Article
Keywords	Bioplastics, Biopolymer, Biodegradability, Carbon footprint, Sustainability, Bioeconomy
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	Bioplastics, being mostly carbon neutral and biodegradable (there are later examples that are not biodegradable), are generally considered to be much more environmentally friendly than “regular” (synthetic) plastics. The article talks about the financial aspect of bioplastics/biopolymers before speaking on specific applications of these bioplastics. The article’s main methodology is to analyze pre-existing data to reach a consensus on what the future may hold for the bioplastic industry. For example, the article shows that biodegradable bioplastics are growing at a rate much faster than their non-biodegradable counterparts (see Important Figures), indicating that focusing on biodegradability will be much better for my project. The article also looks at different types of biopolymers and their uses, before concluding with their expressed belief that although bioplastics have many benefits over synthetic plastics (such as CO2 emissions and biodegradability), further work will have to be done regarding some persisting challenges of bioplastics.
Research Question/Problem/ Need	Are bioplastics better for humanity than synthetic plastics, and what specifically do we have to learn to reach a conclusion on this?

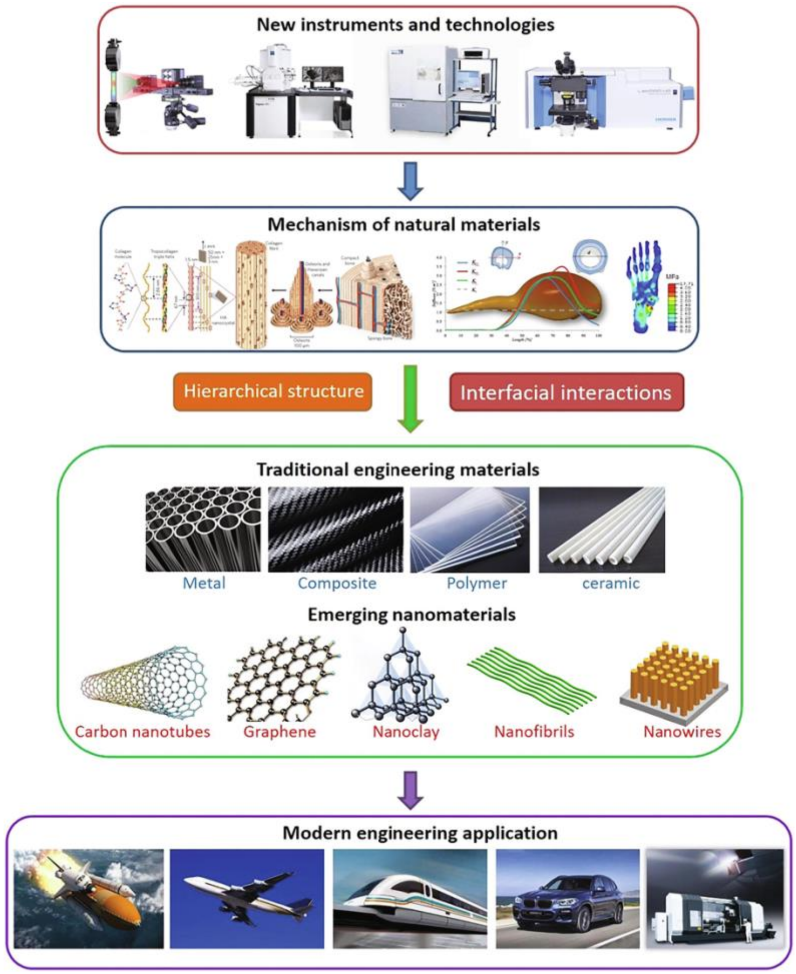
Important Figures	
VOCAB: (w/definition)	Bioplastics: A type of plastic produced with organic materials rather than petroleum used to make synthetic plastic. Carbon neutral: A situation in which the CO2 emitted by the production or usage of something is equally balanced out by the CO2 removed in these processes.
Cited references to follow up on	de Amorim JDP, de Souza KC, Duarte CR, da Silva DI, de Assis Sales Ribeiro F, Silva GS, de Farias PMA, Stingl A, Costa AFS, Vinhas GM, Sarubbo LA, (2020) Plant and bacterial nanocellulose: production, properties and applications in medicine, food, cosmetics, electronics and engineering. a review. Environ Chem Lett 18:851–869. https://doi.org/10.1007/s10311-020-00989-9 European Bioplastics (2021) Bioplastics market data. https://www.european-bioplastics.org/market/ (accessed on 2 August 2021) Miao S, Wang P, Su Z, Zhang S (2014) Vegetable-oil-based polymers as future polymeric biomaterials. Acta Biomater 10:1692–1704. https://doi.org/10.1016/j.actbio.2013.08.040

Follow up Questions	How can the cost-efficiency of bioplastics be properly addressed? Are there currently efforts being made to mass produce bioplastics, and how are these efforts faring regarding production as well as CO_2 emissions? Why might one use non-biodegradable bio-based plastics?

Article #4 Notes: Advanced bio-inspired structural materials: Local properties determine overall performance

Source Title	Materials Today
Source citation (APA Format)	Zhang, B., Han, Q., Zhang, J., Han, Z., Niu, S., & Ren, L. (2020). Advanced bio-inspired structural materials: local properties determine overall performance. *Materials Today, 41*, 177-199. https://doi.org/10.1016/j.mattod.2020.04.009.
Original URL	https://www.sciencedirect.com/science/article/pii/S1369702120301127#f0030
Source type	Journal
Keywords	Bio-inspired structural materials; local properties; overall performance; multiple characteristics; manufacturing technologies; strategies
#Tags	#BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	The article itself is a summary of the methods and strategies used to create biomaterials rather than a test of how to make these materials, but I will be looking into papers that do the latter starting from now. The authors start off by talking about how specific properties can be targeted for biomaterials by looking at where the properties are found in nature. Specifically, the article says that specific chemicals found in natural materials can be tweaked to fit the needs of a given biomaterial. The article also states that factors such as strength, hardness, and elasticity can be used to determine what nature materials should be used as the base for the biomaterial. The article then goes into further detail on what specific "levels" of the factors could be used for (e.g. when it comes to hardness, a harder material may be used on the exterior of a biomaterial to handle the brunt of the impact, whereas softer materials may be found inside the biomaterial). The article then touches upon what methods are currently being used to fabricate biomaterials, including freeze casting (which allows for specific properties of natural materials to be used in making biomaterials) and self-assembly (a much more precise method of utilizing natural properties). The

	authors conclude the article by stating their belief that (and forgive me if I sound like a broken record here with how many times I have written this previously) biomaterials look to be an interesting choice for the future if the many hurdles regarding their fabrication can be crossed. The article also notes that there are many advances currently being made to cross these hurdles.
Research Question/Problem/ Need	What materials and methodologies should be used to create specificbiomaterials?
Important Figures	

	
VOCAB: (w/definition)	Biomaterials: Materials that can be safely used in conjunction with biological systems to benefit the user (usually in a medical sense).
Cited references to follow up on	T.N. Sullivan, *et al.* Materials Today, 20 (2017), pp. 377-391 (this is Extreme lightweight structures: avian feathers and bones)
Follow up Questions	What are some specific uses of biomaterials (other than prosthetics)? Is the cost of fabricating biomaterials currently an issue, and if so, how can it be meaningfully reduced? In the four years that this paper has been out, have biomaterials become more popular in the field of prosthetics?

Article #5 Notes: Development of Starch-Based Bioplastic from Jackfruit Seed

Source Title	Advances in Polymer Technology

Source citation (APA Format)	Nguyen, T. K., That, N. T. T., Nguyen, N. T., & Nguyen, H. T. (2022). Development of Starch-Based Bioplastic from Jackfruit Seed. *Advances in Polymer Technology.* https://doi.org/10.1155/2022/6547461.
Original URL	https://onlinelibrary.wiley.com/doi/10.1155/2022/6547461
Source type	Journal Article
Keywords	None provided, see #Tags for important terms.
#Tags	#BioEng, #ChemEng, #Bioplastics, #MaterialsScience
Summary of key points + notes (include methodology)	Due to the high levels of starch present in jackfruit seeds (the article claims that 30% jackfruit seeds are starch), the authors believed that jackfruit seeds would be a good material to fabricate a bioplastic. The authors specifically focused on jackfruit seeds as they are from Vietnam, a country that is abundant with jackfruit. This is good to consider for my project (i. E. look at fruits/vegetables with high levels of starch that are local to my area). The authors also used glycerol, citric acid, and baking soda to further strengthen and facilitate the fabrication of the bioplastic. In order to create said bioplastic, the authors first extracted the starch from the jackfruit seeds before mixing said starch with glycerol, citric acid, and baking soda. They then continued mixing (with a magnetic stirrer) until the mixture was ready to be dried in the oven which would create the final product. The authors tested this process with different ratios of starch to glycerol, and found that the less glycerol used (the higher the ratio), the stronger the plastic. The authors claimed that the tensile strength of their bioplastic was relatively high compared to other bioplastics, but that the strength was still low compared to synthetic plastics.
Research Question/Problem/ Need	Can the starch found in jackfruit seeds be used to create a sustainable bioplastic that is as strong as pre-existing bio and synthetic plastics?

Important Figures

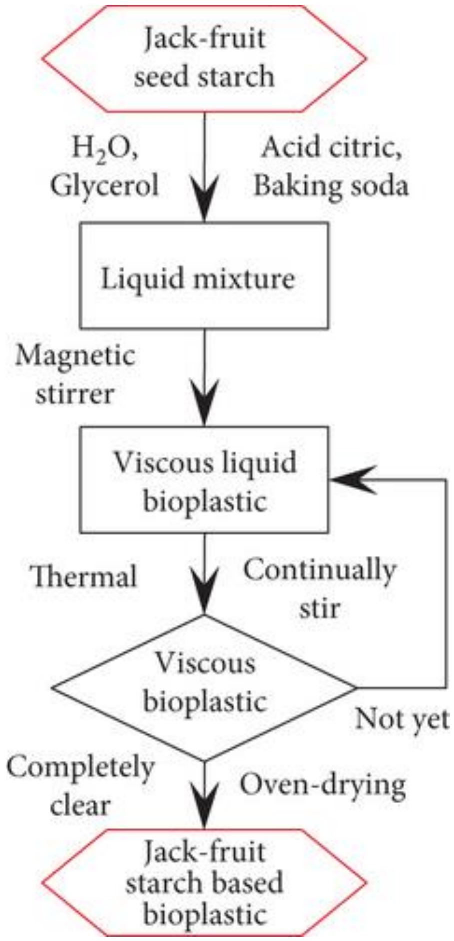
1. The ratio of the raw material composition of plastic specimens.

Ingredients	Starch : glycerol	Citric acid : (starch+glycerol)	Baking soda : (starch+glycerol)	Starch : water
Ratio	3.50 : 1	1 : 100	5 : 100	12.5 : 100
	3.00 : 1			
	2.75 : 1			
	2.50 : 1			

2. The specific weight of each material.

Specimens	Ingredients				
	Starch (g)	Glycerol (g)	Citric acid (g)	Baking soda (g)	Water (g)
Ratio 3.5 : 1	20	5.71	0.25	1.28	160
Ratio 3.0 : 1	20	6.67	0.26	1.33	160
Ratio 2.75 : 1	20	7.27	0.27	1.36	160
Ratio 2.5 : 1	20	8.00	0.28	1.40	160

(Tables 1 and 2)

	
VOCAB: (w/definition)	Plasticizer: An additive used to make materials easier to fabricate.
Cited references to follow up on	18 Niu X., Ma Q., Li S., Wang W., Ma Y., Zhao H., Sun J., and Wang J., Preparation and characterization of biodegradable composited films based on potato starch/glycerol/gelatin, *Journal of Food Quality*. (2021) **2021**, 6633711. 23 Abdullah A. H. D., Pudjiraharti S., Karina M., Putri O. D., and Fauziyyah R. H., Fabrication and characterization of sweet potato starch-based bioplastics plasticized with glycerol, *Journal of Biological Sciences*. (2019) **19**, 57–64. 27 Lubis M., Harahap M. B., Ginting M. H. S., Sartika M., and Azmi H., Production of bioplastic from avocado seed starch reinforced with microcrystalline cellulose from sugar palm fibers, *Journal of Engineering Science and Technology*. (2018) **13**, 381–393.
Follow up Questions	How high can the starch:glycerol ratio go before diminishing returns?

	Can this optimal ratio be calculated, or are there any linear regression models being used to calculate it? Can this fairly easy model of fabricating jackfruit seed-based bioplastics be used to fabricate other starch-based bioplastics?

Article #6 Notes: Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials

Source Title	Fibers
Source citation (APA Format)	Marichelvam, M. K., Jawaid, M., & Asim, M. (2019). Corn and Rice Starch-Based Bio-Plastics as Alternative Packaging Materials. *Fibers, 7*(4). **https://doi.org/10.3390/fib7040032.**
Original URL	https://www.mdpi.com/2079-6439/7/4/32

Source type	Journal Article
Keywords	Corn Starch, Rice Starch, Thermoplastic Starch, Polymers, Biodegradability, Hydrophilicity
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	The main goal of this paper was to create a bioplastic out of the starch found in corn and rice. The reason this is so important is that current synthetic plastics are very unsafe for the environment, and the field of bioplastics seems to be what the future holds. The reason that the authors of this paper chose corn and rice starches specifically was because of their high amylose content (28 and 35% respectively). In order to create the bioplastic itself, Marichelvam and team first had to extract the starch from the corn and rice. They accomplished this by boiling, grinding, and filtering a solution of corn/rice and water. Eventually, the starch was extracted. Now that the authors had obtained starch, they were able to mix water, glycerol, gelatin, and citric acid with the starch, and after heating this mixture at 100 Celsius, the bioplastic was fabricated. After testing their bioplastic samples, the authors noted that their fifth sample (which had the highest rice starch to cornstarch ratio of 7:3) had a great tensile strength of 12.5 MPa. The authors concluded by stating their belief that their bioplastics could be used as a packing material.
Research Question/Problem/ Need	Can rice and corn starch-based bioplastics be used as an environmentally safe replacement for the current synthetic plastics in packing materials?
Important Figures	(see below)

×

Table 4. Tensile properties of different samples.

Samples	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation (in %)
S1	6.11	0.09	3.38
S2	7.3	0.11	5.1
S3	10.6	0.15	5.3
S4	11.38	0.17	6.19
S5	12.5	0.183	6.8

	Table 2. Physical and chemical properties of corn and rice starch.

Properties	Corn Starch	Rice Starch
Moisture content (in %)	10.82	11.24
Ash content (in %)	0.32	0.29
Protein (in %)	0.38	0.43
Fat (in %)	0.32	0.34
Fiber (in %)	0.10	0.12
Amylose (in %)	29.4	33.6
Density (g/ml)	1.356	1.282
pH	6.72	6.82

Table 3. Composition of prepared bioplastics.

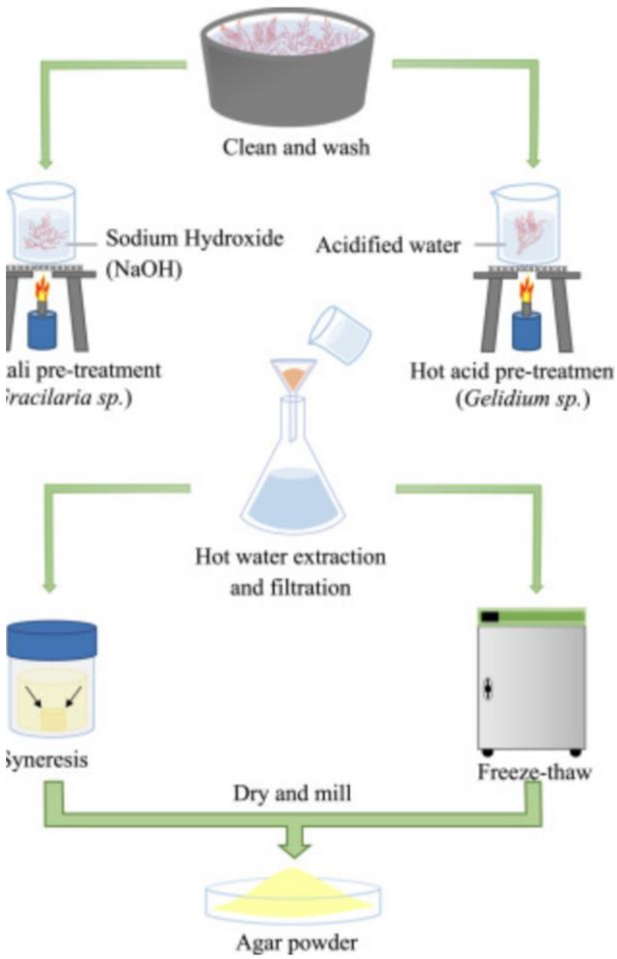
Sample	Rice Starch	Corn Starch	Glycerol	Citric Acid	Gelatin	Water
	Weight (in Grams)					
S1	5	5	3	1	2	100
S2	5.5	4.5	3	1	2	100
S3	6	4	3	1	2	100
S4	6.5	3.5	3	1	2	100
S5	7	3	3	1	2	100

VOCAB: (w/definition)	Amylose + Amylopectin: The two polysaccharides that starch is made from.
Cited references to follow up on	Edhirej, A.; Sapuan, S.M.; Jawaid, M.; Zahari, N.I. Effect of various plasticizers and concentration on the physical, thermal, mechanical, and structural properties of cassava-starch-based films. *Starch-Stärke* **2017**, *69*, 1500366. Muscat, D.; Adhikari, B.; Adhikari, R.; Chaudhary, D. Comparative study of film forming behaviour of low and high amylose starches using glycerol and xylitol as plasticizers. *J. Food Eng.* **2012**, *109*, 189–201.
Follow up Questions	What would the ideal rice starch to corn starch ratio be? (Is 7:3 the perfect ratio, or can it go even higher?) Can these bioplastics be used to make other things than just packaging materials, or would there have to be specific changes to accommodate these other needs? Was the rice:corn starch ratio of 7:3 the best due to rice's high amylose content compared to corn?

Article #7 Notes: Bioplastic made from seaweed polysaccharides with green production methods

Source Title	Journal of Environmental Chemical Engineering
Source citation (APA Format)	Lim, C., Yusoff, S., Ng, C. G., Lim, P. E., & Ching, Y. C. (2021). Bioplastic made

	from seaweed polysaccharides with green production methods. *Journal of Environmental Chemical Engineering, 9*(5). https://doi.org/10.1016/j.jece.2021.105895.
Original URL	https://www.sciencedirect.com/science/article/pii/S2213343721008721
Source type	Journal Article
Keywords	Bioplastic, Seaweeds Polysaccharides, Green production methods
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	The authors of this article wished to make a bioplastic out of seaweed since normal synthetic plastics have many problems regarding their usage. The reason they chose seaweed was due to the polysaccharides produced by seaweed being very utile for bioplastic fabrication. The first step that the authors took to make their bioplastic was to differentiate between different types of seaweed and their purposes. For example, the authors explained that red seaweed (such as Gelidium sp. and Gracilaria sp.) have high agarose contents, meaning agar can be retrieved from these seaweeds. In this case, a base (NaOH) was used for Gracilaria sp. and an acid was used for Gelidium sp. to extract the agar powder. The authors now compared the bioplastic films they had fabricated with pre-existing synthetic plastics, and discovered that the tensile strengths of their bioplastics were high enough to be used commercially (such as for packaging), but that work has to be done towards making these bioplastics eco-friendlier and easier to mass produce.
Research Question/Problem/ Need	Can seaweed itself be used to fabricate a bioplastic that is comparable to similar synthetic plastics?

Important Figures	
VOCAB: (w/definition)	None
Cited references to follow up on	S.N. Goyanes, N.B. D'Accorso Industrial applications of renewable biomass products Ind. Appl. Renew. Biomass Prod. Present Future (2017), 10.1007/978-3-319-61288-1
Follow up Questions	The paper talks about how different seaweeds have different uses. Is this true for other materials used to make bioplastics (such as different types of potatoes or rice)? What is the difference between Gracilaria sp. and Gelidium sp. that makes acid work well for one and a base work well for the other? What are the pHs of these (Gracilaria/Gelidium sp.)?

Article #8 Notes: Effect of various plasticizers and concentration on the physical, thermal, mechanical, and structural properties of cassava-starch-based films

Source Title	Starch-Based Films and Reviews
Source citation (APA Format)	Edhirej, A., Sapuan, S. H., Jawaid, M., & Zahari, N. I. (2016). Effect of various plasticizers and concentration of the physical thermal, mechanical, and structural properties of cassava-starch-based films. *Starch-Based Films and Reviews, 69*(1-2). **https://doi.org/10.1002/star.201500366.**
Original URL	https://onlinelibrary.wiley.com/doi/abs/10.1002/star.201500366
Source type	Journal Article
Keywords	None Provided
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	The authors of this article wanted to see what specific plasticizers bode the best with cassava-starch films. To do this, the authors tested their films with four different plasticizers: Fructose, Urea, Tri-ethyleneglycol, and Triethanolamine. The process of film fabrication was very similar to the articles I mentioned above, with the starch and plasticizers being mixed in with distilled water before being heated and dried. The results showed that Tri-ethyleneglycol and Urea at 45% concentration had the greatest percentage of water absorption, whereas Fructose had the lowest percentage of water absorption. The results also showed that films that had fructose as a plasticizer were the strongest. The authors also noticed that plasticizer concentration and tensile strength were inversely proportional. Finally, the authors concluded by explaining that fructose was the ideal plasticizer for cassava-starch-based film based on the research they did.

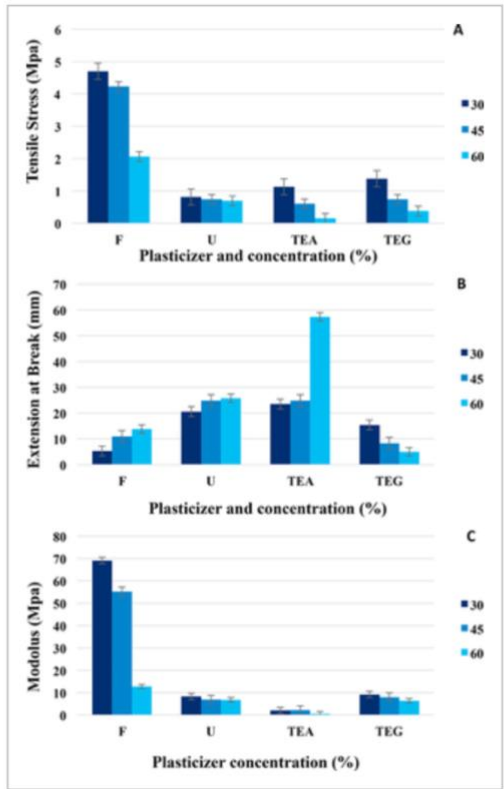
<table>
<tr><td>Research Question/Problem/ Need</td><td>How do different plasticizers affect the properties of starch-based bioplastics?</td></tr>
<tr><td>Important Figures</td><td>


Figure 6 Open in figure viewer | PowerPoint

Mechanical properties of cassava film with different plasticizers type and content.
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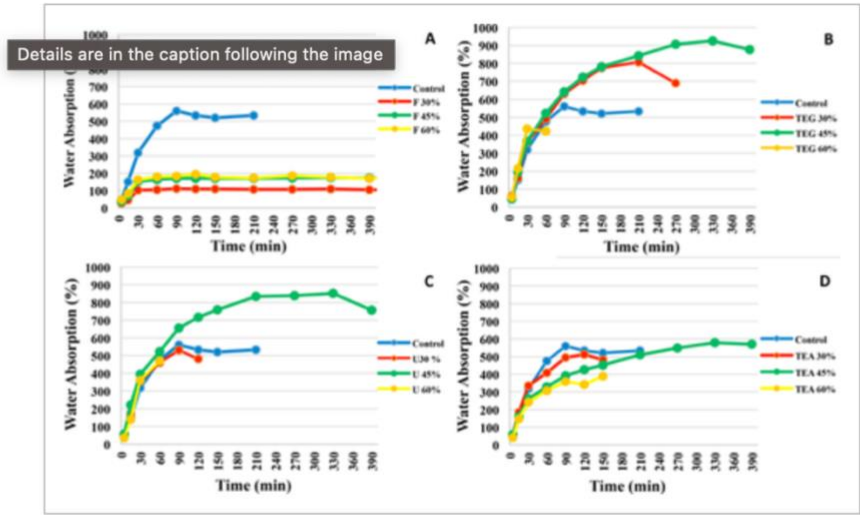

Figure 1 Open in figure viewer | PowerPoint

Water absorption of cassava films with different plasticizers type and content.
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<td>VOCAB: (w/definition)</td>
<td>No new Vocab (I have already mentioned terms like “plasticizer")</td>
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<tr>
<td>Cited references to follow up on</td>
<td>Cao, N., Yang, X., Fu, Y., Effects of various plasticizers on mechanical and water vapor barrier properties of gelatin films. Food Hydrocolloids 2009, 23, 729–735.

Bertuzzi, M., Armada, M., Gottifredi, J., Physicochemical characterization of starch based films. J. Food Eng. 2007, 82, 17–25.</td>
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<tr>
<td>Follow up Questions</td>
<td>Is fructose still the best plasticizer for starch-based bioplastics such as corn or potato starch-based bioplastics?

If this is not true, then what about fructose works so well for cassava starch-based bioplastics?

Are there other plasticizers that were not mentioned in this paper that could be better than fructose for some specific bioplastics?</td>
</tr>
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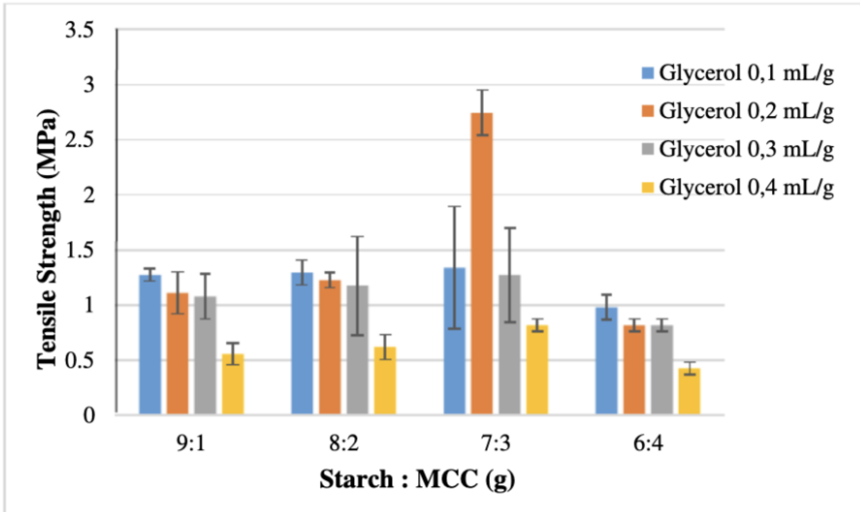
Article #9 Notes: Production of bioplastic from avocado seed starch reinforced with microcrystalline cellulose from sugar palm fibers

Source Title	Journal of Engineering Science and Technology
Source citation (APA Format)	Lubis, M., Harahap, M. B., Ginting, M. H. S., Sartika, M., & Azmi, H. (2018). Production of bioplastic from avocado seed starch reinforced with microcrystalline cellulose from sugar palm fibers. *Journal of Engineering Science and Technology, 13*(2), 381-393.
Original URL	https://www.researchgate.net/publication/323276614_Production_of_bioplastic_from_avocado_seed_starch_reinforced_with_microcrystalline_cellulose_from_sugar_palm_fibers
Source type	Journal Article

Keywords	Avocado Seed, Glycerol, Microcrystalline Cellulose, Sugar Palm Fibers
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	The authors of this article looked at bioplastics created from avocado seed starch as a replacement for synthetic starches (which are bad for the environment). The authors expressed their reasoning for using avocado, saying that the high levels of starch in avocado seeds would be good for fabricating bioplastics. Other than avocado seeds, the authors used microcrystalline cellulose and glycerol to boost the strength of the bioplastic. Their process of bioplastic fabrication began by using a similar process to those I have previously mentioned. First, to extract the starch, the authors of the paper soaked ground up avocado seeds in water and then heated and dried the solution to get the starch. After extracting starch, the authors of the paper had to also extract microcrystalline cellulose from sugar palm fibers. This process required α-cellulose to be extracted first, and then the microcrystalline cellulose would be extracted. Once microcrystalline cellulose and starch were extracted, the authors tried making bioplastics with different ratios of starch:cellulose. Once the bioplastics were fabricated, the authors began analyzing the bioplastic. It should be noted that the tensile strength of their bioplastic was at maximum 2.74 MPa, which is not that high compared to other bioplastics and most definitely, synthetic plastics. The authors of the article themselves never talked about how their bioplastic compared to other plastics, but it can be inferred that the low tensile strength means that this may not be the best direction to go to make a bioplastic.
Research Question/ Problem/ Need	Can avocado seed starch be used to create a usable and sustainable bioplastic?

Important Figures	 **Fig. 1. The effect of MCC from sugar palm fibers and glycerol addition on tensile strength of bioplastics.**
VOCAB: (w/definition)	None
Cited references to follow up on	Bertuzzi, M.A. (2012). Mechanical properties of a high amylose content corn starch based film, gelatinized at low temperature. Brazilian Journal of Food Technology, 15(3), 219-227
Follow up Questions	Are there specific properties in avocado seed starch that specifically make microcrystalline cellulose a good additive? Are there better additives/plasticizers for avocado seed starch than those presented in this study (because from what I've seen here, the strength of the bioplastic itself is really small)? Why was the 7:3 ratio (specifically with glycerol 0.2 mL/g) so much better than every other bioplastic in terms of tensile strength?

Article #10 Notes: Recent Advances in Starch-Based Blends and Composites for Bioplastics Applications

Source Title	Polymers (Basel)
Source citation (APA Format)	Jayarathna, S., Andersson, M., & Andersson, R. (2022). Recent Advances in Starch-Based Blends and Composites for Bioplastics Applications. *Polymers (Basel), 14*(21). 10.3390/polym14214557.
Original URL	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9657003/
Source type	Journal Article

Keywords	Starch, Bioplastics, Plasticizer, Filler, Thermoplastic, Polymer, Blend, Composite
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	As a preface to this summary, I wanted to point out that as this article is a recap of how the field of starch-based polymers has been growing, a lot of the methodology of the specific advancements aren't highlighted in the paper. Now then, to start things off, I wanted to look at what advancements have been made regarding what starch-based polymers have recently been bioplastics. I mainly want to focus on this section, since this is mainly what I will be focusing on for my project. One of these advancements is the usage of elastomers in Starch-PLA compounds to help strengthen the compound. One of these elastomers that has been used in research is Polyethylene Octane. The article notes that making starch-based polymers is becoming increasingly popular in the field of food packaging, since these polymers are naturally non-toxic. This, in turn, caused many scientists to look into how this specific function of starch-based polymers could be bettered. Studies such as those done by Bie et al., Ali et al., Dhumal et al., Muller et al., Tran et al., Perazzo et al., Nisa et al., Baek et al., Souza et al., Piñero-Hernandez et al., Costa et al., Mehdizadeh et al., and Sganzerla et al. have worked with antimicrobial agents and antioxidants in starch-based polymers for food packaging, which would make the food being stored much less prone to spoiling. The article concludes with the authors' beliefs that the current issues of starch-based polymers (such as their relatively miniscule strength) should be touched upon in further research regarding this field, something that I will hope to do in my project.
Research Question/Problem/ Need	What are some of the current advancements being made in the field of starch-based polymers?

Important Figures

Target Property	Example	Important Results	Reference
Antimicrobial action	Chitosan in PLA/starch blend	PLA and starch were a slow-release matrix of chitosan. Chitosan release was fast at the beginning and slowed down later which imparted long residual antimicrobial properties to the blend. Showed effectiveness in preserving food with high water activity such as fresh meat.	[115]
	Peel particles of pomegranate in starch-based films	Pomegranate peel acted both as an antimicrobial agent and a reinforcing agent. The films showed effectiveness for both gram-positive (*S. aureus*) and gram-negative (Salmonella) bacteria. The films showed better mechanical properties (Young's modulus, tensile strength, stiffness) due to the reinforcing action of the pomegranate peel particles	[116]
	Essential oils from oregano (e.g., carvacrol and citral) in sago starch and guar gum-based films	The films showed antimicrobial activity against Bacillus cereus and *Escherichia coli*. Essential oils acted as a plasticizer and contributed to improving mechanical properties and reducing moisture content and water solubility of the films	[117]
	Cinnamaldehyde in cassava starch/PLA bilayer film	Cinnamaldehyde-loaded cassava starch/PLA bilayer films exhibited antimicrobial properties against *E. coli* and *L. innocua*	[118]
	Beetroot powder in starch-based hydrophobic bio-elastomer film	Betanin from beetroot was very effective in scavenging free radicals against 2,2-diphenyl-1-picrylhydrazyl free radical (DPPH) and 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) radical cation (ABTS+). Betanin was released by diffusion without disintegration of the polymer matrix. Beetroot powder incorporation could increase Young's modulus of the bio-elastomers	[119]
	Cassava starch film with green tea extract and palm oil colorant	Antioxidant properties of polyphenols from green tea extract and carotenoid colorant from oil palm added antioxidant properties to the film. High concentrations of green tea extract should be avoided since the high content of polyphenols in green tea extract can be acted as a pro-oxidant agent. The films with antioxidant properties were effective for the storage of fatty foods. The incorporation of colorant and green tea extract could improve the mechanical and water vapor barrier properties of the films.	[120]

Antioxidant action	Green tea extract in potato starch-based films	The films have improved antioxidant, water vapor barrier, mechanical, and thermal properties. The films showed great potential for the development of active antioxidant packaging for fresh beef.	[121]
	Curcumin (from *Curcuma longa* L.) in proso millet starch-based film	The phenolic compounds in curcumin imparted antioxidant properties to the film, but at the expense of film tensile strength. The addition of Curcumin could enhance the water and UV–visible light barrier properties of the films.	[122]
	Mango (*Mangifera indica* L.) and acerola (Malpighia emarginata DC.) pulps in cassava starch-based films	Fruit pulp incorporated into cassava starch-based films makes the films effective for packaging lipid-rich foods. Fruit pulps with high vitamin content should be avoided since vitamin C can act as a pro-oxidant.	[123]
	Rosemary extracts in cassava starch films	The polyphenols from rosemary extracts imparted an increase in their antioxidant activity to the films. The films having a high extract content showed better UV barrier properties. However, the presence of Rosemary extracts inhibited the formation of bonds between glycerol and starch molecules which negatively affected the water vapor permeability and mechanical properties of the films.	[124]
Antioxidant and antimicrobial action	Alcoholic extract of red propolis in cassava starch films plasticized with glycerol and reinforced with cellulose nanocrystals	The films showed effectiveness against coagulase-positive staphylococci in cheese and could slow the oxidation of butter. The antimicrobial and antioxidant properties of alcoholic red propolis were due to the presence of phenolic compounds	[125]
	Thymus kotschyanus essential oil in starch-chitosan composite film	Monoterpene phenols, especially thymol and carvacrol, in *T. kotschyanus* essential oil play a vital role in imparting antibacterial and antioxidant properties. Films show an inhibitory effect against *L. monocytogenes*, *E. coli* O157:H7, *S. aureus*, and *S. typhimurium*, while starch-chitosan films without essential oil show no effectiveness against *S. typhimurium*.	[126]
	Pinhão starch and citric pectin packaging film, functionalized with feijoa peel flour (a byproduct from Acca sellowiana)	The packaging contains bioactive compounds such as phenolics and flavonoids, imparting both antioxidant and antimicrobial properties. The films showed inhibitory effects against *E. coli*, *S. typhimurium*, and *Pseudomonas aeruginosa* and showed effectiveness in maintaining the quality of apples during storage, with no weight loss after 5 days of storage.	[127]

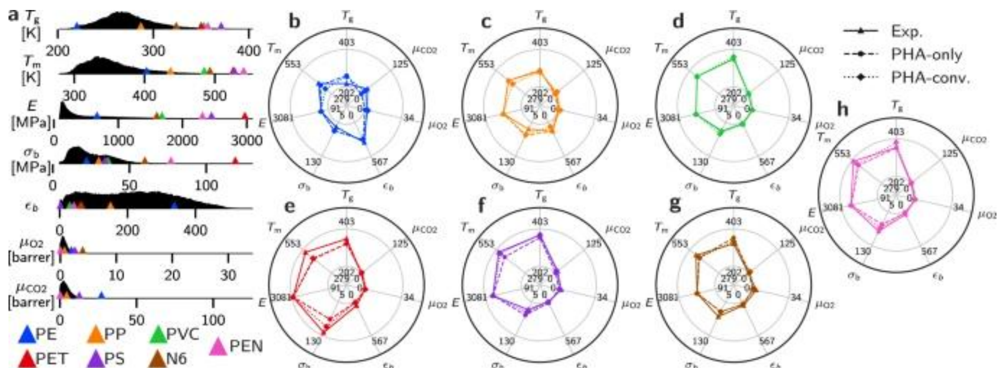
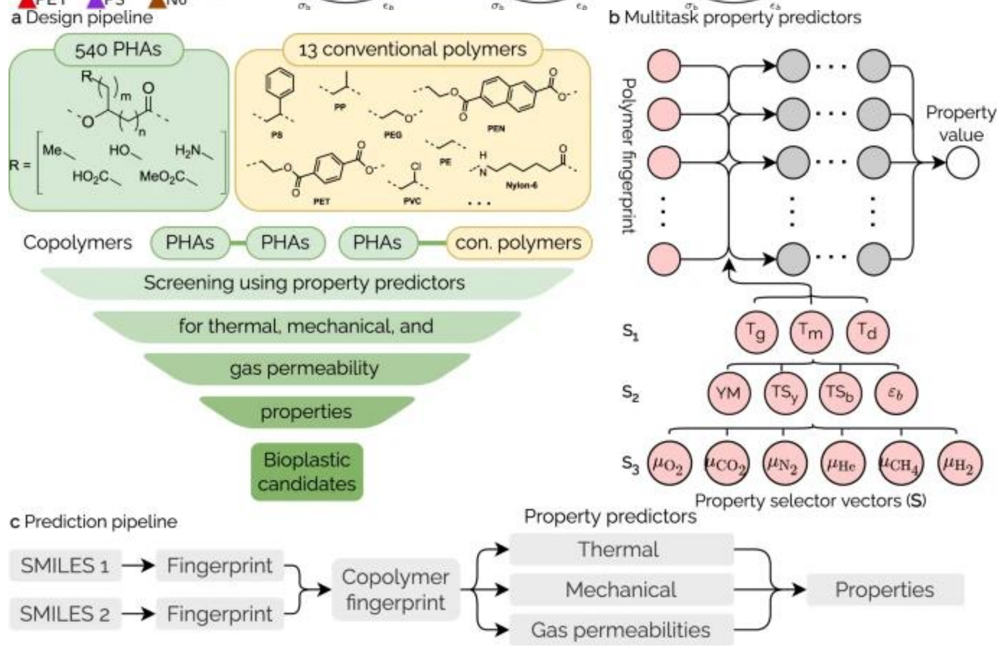
VOCAB: (w/definition)	None
Cited references to follow up on	Sagnelli D., Hebelstrup K.H., Leroy E., Rolland-Sabaté A., Guilois S., Kirkensgaard J.J.K., Mortensen K., Lourdin D., Blennow A. Plant-Crafted Starches for Bioplastics Production. *Carbohydr. Polym.* 2016;152:398–408. Lauer M.K., Smith R.C. Recent Advances in Starch-Based Films toward Food Packaging Applications: Physicochemical,

	Mechanical, and Functional Properties. *Compr. Rev. Food Sci. Food Saf.* 2020;19:3031–3083. doi: 10.1111/1541-4337.12627.
Follow up Questions	I noticed that nowhere in this were simulations mentioned as a strategy to test out materials before fabricating them. Does this mean that such a strategy is not currently feasible, as if so, would it be a good project idea to try and make a simulator that could do so? What other main uses do starch-based polymers have (than their usage in food packaging)? What are the costs of making these bioplastics (and would it be possible to fabricate these on a much larger scale)?

Article #11 Notes: Bioplastic design using multitask deep neural networks

Article notes should be on separate sheets

Source Title	Communications Materials
Source citation (APA Format)	Kuenneth, C., Lalonde, J., Marrone, B. L., Iverson, C. N., Ramprasad, R., & Pilania, G. (2022). Bioplastic design using multitask deep neural networks. *Communications Networks, 3*(96).
Original URL	https://www.nature.com/articles/s43246-022-00319-2
Source type	Journal Article
Keywords	None provided.
#Tags	#Bioplastics, #ChemEng, #BioEng, #BioChem, #ML
Summary of key points + notes (include methodology)	In this article, the authors wanted to create a PHA-based bioplastic using a neural network model that could replace seven current synthetic plastics. The authors decided to train their model on a set of 540 PHAs and 13 copolymers as well as multiple properties that they grouped into three different vectors that were run through three different neural networks. This resulted in over one million different bioplastics. The authors of this paper then used an algorithm to find the five

	bioplastics in this set that most closely resembled each of the seven current synthetic plastics they wanted to replace. Then, they chose one bioplastic from each of those five to physically test, which showed that the properties simulated by the neural network were very similar to the actual properties physically tested.
Research Question/Problem/ Need	Can neural networks be used to efficiently simulate bioplastics with specific properties?
Important Figures	
VOCAB: (w/definition)	PHA (Polyhydroxyalkanoates) - A biodegradable material that can be used to fabricate many things, such as bioplastics.
Cited references to follow up on	Adams, N. & Murray-Rust, P. Engineering polymer informatics: towards the computer-aided design of polymers. *Macromol. Rapid Commun.* 29, 615–632 (2008).
Follow up Questions	Can the same or similar system be used to find the optimal bioplastic rather than just the one that matches the current synthetic plastics we use?

	How easily can these bioplastics be mass produced? Similarly, how cost-efficient is the fabrication of these bioplastics?

Article #12 Notes: Machine learning to enhance sustainable plastics: A review

Article notes should be on separate sheets

Source Title	Journal of Cleaner Production
Source citation (APA Format)	Guardia, C., Caseiro, J., Pires, A. (2024). Machine learning to enhance sustainable plastics: A review. *Journal of Cleaner Production, 474*. https://doi.org/10.1016/j.jclepro.2024.143602.
Original URL	https://www.sciencedirect.com/science/article/pii/S0959652624030518
Source type	Journal Article
Keywords	Machine learning, Sustainable plastics, Life cycle, Neural networks, Random forest
#Tags	#Bioplastics, #BioEng, #ChemEng, #BioChem, #ML
Summary of key points + notes (include methodology)	Since this article is a compilation of multiple different methods to use machine learning in the field of bioplastics, there isn't much methodology to add here. Instead, I will mostly focus on the methods of machine learning I found the most interesting as well as the most useful for my own project. For starters, the paper goes through different types of machine learning models, with the one that I found would work the best for my project to be that of Supervised Learning. The paper explains that Supervised Learning is when the ML model is trained with data that has specific labels so that the model can generate new predictions that adhere to those labels. For example, if I was to look at how the tensile strength of a bioplastic is related to the starch:glycerol ratio, I would use

	this Supervised Learning model to accurately "predict the future" (or make a regression) based on the tensile strength label. One tiny problem is that it is very likely that linear regression models cannot account for the fact that there is most certainly an ideal starch:glycerol ratio, so I would maybe need to try a polynomial regression or something in that vein. Other than this, the article talks about specific scenarios in which machine learning has already been used, and how it was used. One of these scenarios, for example, was, similarly to my own project idea, to try and find the maximum tensile strength of a specific type of biomaterial. Since my project may be similar to this, I wanted to see what strategies this study used. (You can find further information in both the "Important Figures" section as well as the "Cited references to follow up on" section). The aforementioned study's authors, Mishra et al. specifically used a Supervised Learning – Classification model, with logistic regressions, decision trees, gradient boosting, and k-nearest neighbors for the ML process. After carefully looking at specific examples of ML in the field of bioplastics, the authors wanted to talk about if ML is actually useful in the field. The authors bring up the important problem that, with the limited data available in the field currently, the machine learning models might not be easily trainable. Currently, I am not sure how much data is considered good enough to train the model (10,000 data points? 100,000? 1 million?). Interestingly, some of the same problems we are currently looking at in Math Modeling for MTFC are coming back here (since there is a *lot* of statistical and data analysis that needs to be done in order to reach a conclusion). The authors conclude with their belief that ML is definitely the right step for the future of bioplastics, but that there needs to be some more work done on reducing the risk of bad models that may be caused by a lack of usable data.
Research Question/Problem/ Need	Can ML be used to help with the bioplastic fabrication process? If so, has this already been done before, and if it has, what methods of machine learning were used in those studies?

Important Figures

Table 5. Research papers on the use of ML for plastic-product manufacturing.

Goal and scope	Problem Type	ML algorithm(s)	Reference
Monitor extrusion-induced degradation of PLA	SLR	RF, RR, PLS, PCA with LR	Munir et al. (2023)
Predict nozzle temperature of fused deposition modeling 3D printing of recycled PE and PLA	SLR	LR	Hossain et al. (2022)
Analyze and predict the printable bridge length in fused deposition modeling of PLA	SLR	NN	Jiang et al. (2019)
Predict tensile strength of 3D-printed parts of PLA	SLR	XGBoost, GB, AdaBoost, RF, LR	Jayasudha et al. (2022)
Predict the dynamic strength of continuous ramie fiber-reinforced biocomposites printed using different printing conditions	SLR	RF, NN	Cai et al. (2022)
Estimate the ultimate tensile strength of PLA specimens fabricated using the fused deposition modeling process	SLC	LoR, GB, DT, k-NN	Mishra et al. (2023)
Classify the degree of thermal degradation of heat-treated PLA materials	SLC	LoR, RF, NN	Zhang (2020)
Predict the optimum setting of fused filament fabrication for PLA with carbon fiber	SLR	DT	Thakur et al. (2023)
Learn and predict the dominant build parameters to print high-fidelity 3D features of biopolymers	SLR	NN	Bone et al. (2020)
Predict the yield stress of extruded PLA sheets inline during extrusion processing	SLR	RF, Bagging	Mulrennan et al. (2018)
Predict the Young's modulus, ultimate tensile strength, and elongation at break of agar biopolymer films	SLR	NN	Hernández et al. (2022)
Predict the ultimate tensile strength, Young's modulus, and strain at break of PLA and PLA-CF 3D-printed parts	SLR	LR, DT, RR, RF, GB	Ziadia et al. (2023)
Predict the density of PLA foams based on their processing parameters	SLR	RF, GB, KRR, LR, LASSO, k-NN, SVR	Albuquerque et al. (2022)

VOCAB: (w/definition)

Supervised Learning – already defined in my summary

Cited references to follow up on

A. Mishra, V.S. Jatti, E.M. Sefene, A.V. Jatti, A.D. Sisay, N.K. Khedkar, S. Salunkhe, M.Pagáč, E.S.A. Nasr
Machine learning-assisted pattern recognition algorithms for estimating ultimate tensile strength in fused deposition modelled polylactic acid specimens
Mater. Technol., 39 (1) (2023), Article 2295089, 10.1080/10667857.2023.2295089

Follow up Questions

How much data is needed for machine learning models to be able to properly be trained? Similarly, does this depend on the type of data? Thirdly, and in the same vein, can the "quality" of data be specifically measured, and does this factor into how much data is necessary for a machine learning model to make its decision?

Article #13 Notes: Machine-learning assisted pattern recognition algorithms for estimating ultimate tensile strength in fused deposition modelled polylactic acid specimens

Source Title	Materials Technology: Advanced Performance Materials

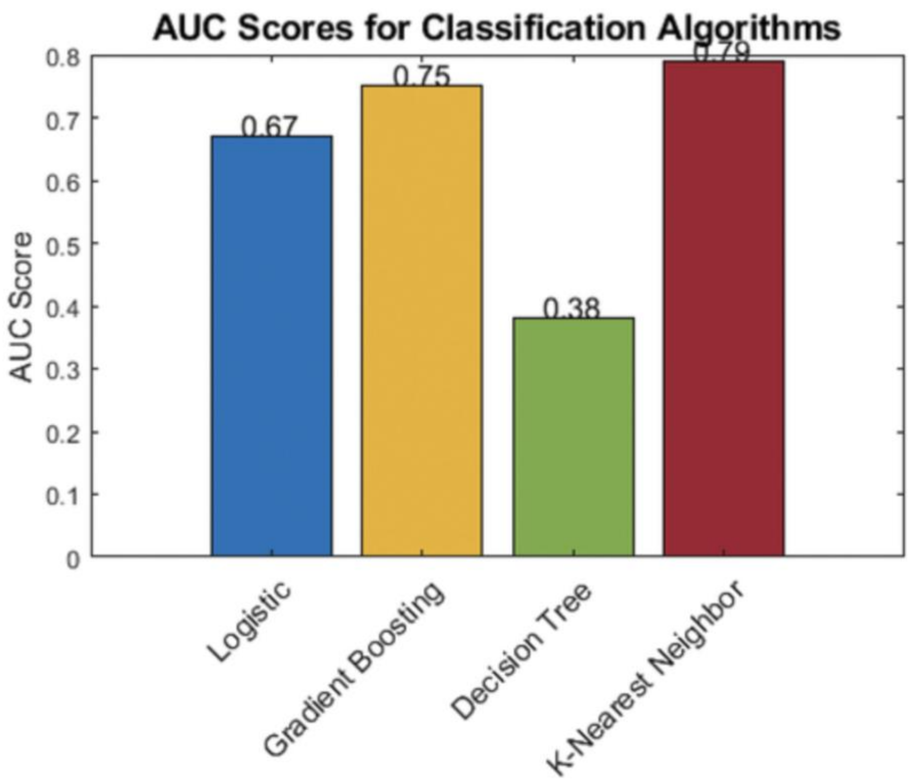
Source citation (APA Format)	Mishra, A., Jatti, V. S., Sefene, E. M., Jatti, A. V., Sisay, A. D., Khedkar, N. K., Salunkhe, S., Pagáč, M., & Abouel Nasr, E. S. (2023). Machine-learning assisted pattern recognition algorithms for estimating ultimate tensile strength in fused deposition modelled polylactic acid specimens. *Materials Technology: Advanced Performance Materials, 39*(1). https://doi.org/10.1080/10667857.2023.2295089.
Original URL	https://www.tandfonline.com/doi/full/10.1080/10667857.2023.2295089#abstract
Source type	Journal Article
Keywords	Additive Manufacturing, Machine Learning, Fused Deposition Modelling, Classification Algorithms
#Tags	#ML, #ChemEng
Summary of key points + notes (include methodology)	The researchers of this study wanted to use machine learning to fabricate the strongest possible PLA specimens. They decided on a Supervised Learning – Classification Model (this model was explained in Article #12, SLC in that article) in order to classify the tensile strengths of specific PLA specimens. Before the researchers could test out their different algorithms, however, they needed to make a data set that they could train the ML models on. Their dataset consisted of multiple different PLA specimens that they had fabricated using the fused deposition modeling method in the past. The data set can be partially seen in the "Important Figures" section. Now that the researches had their dataset, they trained it on four different algorithms. The first of these was a Logistic Classification algorithm. The goal of a logistic classification algorithm is to classify a given data point into different sections by using the specific properties of that data point. After this algorithm, the researchers tried out a Gradient Boosting Classification algorithm, which makes a series of predictions to narrow down the classification of a data point. Thirdly, the researches used a Decision Tree Classification algorithm, which, as the title explains, uses a decision tree to predict the classification of a data point. Lastly, the researchers used a K-nearest neighbors classification method, which finds the k nearest newly created data points to those in the original dataset. In order to decide which of these algorithms was the best, two different metrics were used. The first of these metrics is the AUC-ROC score, which checks the accuracy of the classifications. The other metric used was the F1 score, which checks the new data points for false negatives/positives to find the accuracy of the model. The researchers found that the K-nearest neighbors algorithm had the highest AUC-ROC score of 0.79, with the Gradient Boosting Classification algorithm coming in a close second with 0.75. These two also had the tied highest F1 scores, at 0.7143, meaning that the K-nearest neighbors algorithm was superior. The study concludes with the

researchers' beliefs that their novel work can be further implemented in many other facets of the field.

Research Question/Problem/ Need

How can ML algorithms be used to find the strongest PLA specimen fabricated using fused deposition modeling?

Important Figures



Infill percentage (%)	Layer height (mm)	Print speed (mm/sec)	Extrusion temp ($^{\circ}C$)	Ultimate Tensile Strength (MPa)	Classification Label
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10.5	0.24	50	210	42.78	0
33	0.16	35	220	45.87	0
33	0.32	35	200	41.18	0
33	0.16	65	200	43.59	0
100	0.24	50	210	54.2	1
78	0.16	35	200	51.88	1
33	0.32	65	200	43.19	0
78	0.32	65	200	50.34	1
33	0.16	65	220	45.72	0
78	0.16	35	220	53.35	1

Algorithms	Obtained F1-Score
Logistic Classification	0.7143
Gradient Boosting Classification	0.5714
Decision Tree Classification	0.4286
K-Nearest Neighbours Classification	0.7143

VOCAB: (w/definition)

All models have already been thoroughly defined in the summary.

Cited references to follow up on

Xu P, Ji X, Li M, et al. Small data machine learning in materials science. Npj Comput Mater. 2023;9(open in a new window)(1(open in a new window)):42. doi: 10.1038/s41524-023-01000-z

Follow up Questions	Were new PLA specimens actually fabricated to test out the accuracy of the K-nearest neighbor algorithm? Can the K-nearest neighbor classification algorithm be used for other specimens and fabrication method than those in this study? Would a bigger dataset than the 31 used in the study help improve the accuracy of this study?

Article #14 Notes: Machine intelligence-accelerated discovery of all-natural plastic substitutes

Source Title	Nature Nanotechnology
Source citation (APA Format)	Chen, T., Pang, Z., He, S., Li, Y., Shrestha, S., Little, J. M., Yang, H., Chung, T., Sun, J., Whitley, H. C., Lee, I., Woehl, T. J., Li, T., Hu, L., & Chen, P. (2024). Machine intelligence-accelerated discovery of all-natural plastic substitutes. *Nature Nanotechnology, 19.*
Original URL	https://www.nature.com/articles/s41565-024-01635-z
Source type	Journal Article
Keywords	None provided
#Tags	#Bioplastics, #BioEng, #ChemEng, #ML

<table>
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<td>Summary of key points + notes (include methodology)</td>
<td>
The researchers of this study wished to use ML to help fabricate bioplastics with specific properties in mind. An SVM, or Support-Vector Machine classification model was used in the ML process.
An SVM classification model, as the name suggests, is used to classify data into one of many possible groups. In this case, the researchers wished to classify data based on the mechanical properties of the plastic replacements. They did this because different uses for plastics require different mechanical properties, so in order to find what plastics would be used for specific uses, this classification model would help.
The researchers’ model was sufficiently trained on 286 different nanocomposites that were themselves fabricated for this specific paper. The trained model was then verified and was found to be consistently accurate in its prediction of mechanical properties, meaning that it could be used further in the field.
The authors concluded with their belief that they had a very unique idea regarding how nanocomposites could be fabricated, but more research would be necessary to examine just how useful this process could be.
</td>
</tr>
<tr>
<td>Research Question/Problem/ Need</td>
<td>Can ML help categorize bioplastics with specific properties and then use that data to target those specific properties in new fabricated bioplastics?</td>
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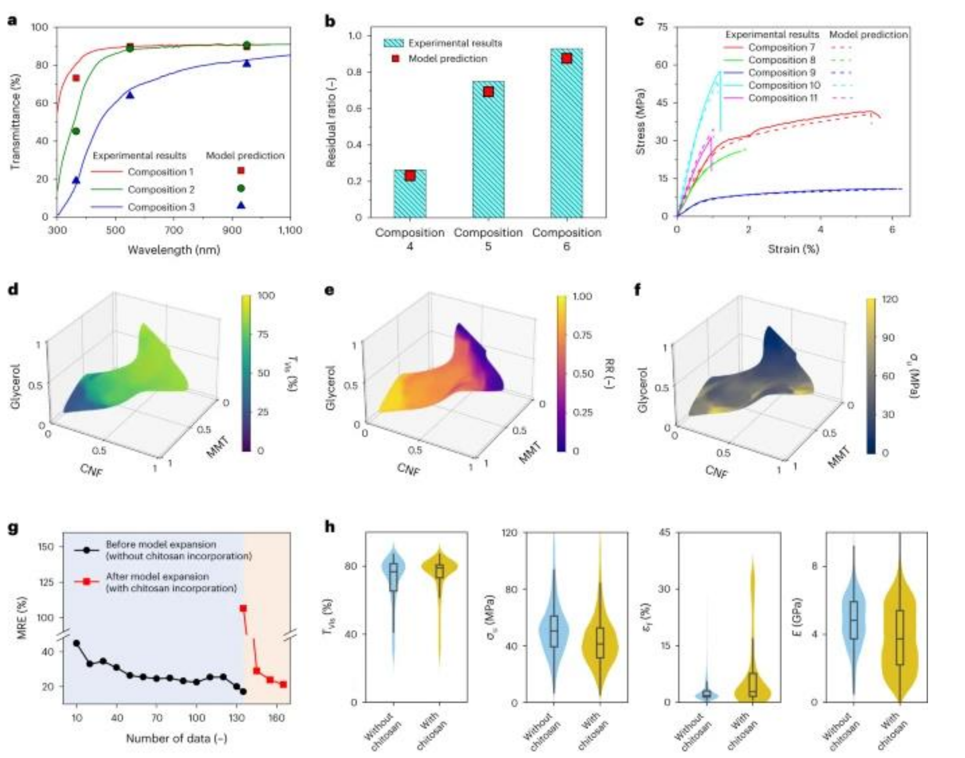
<tr>
<td>Important Figures</td>
<td>


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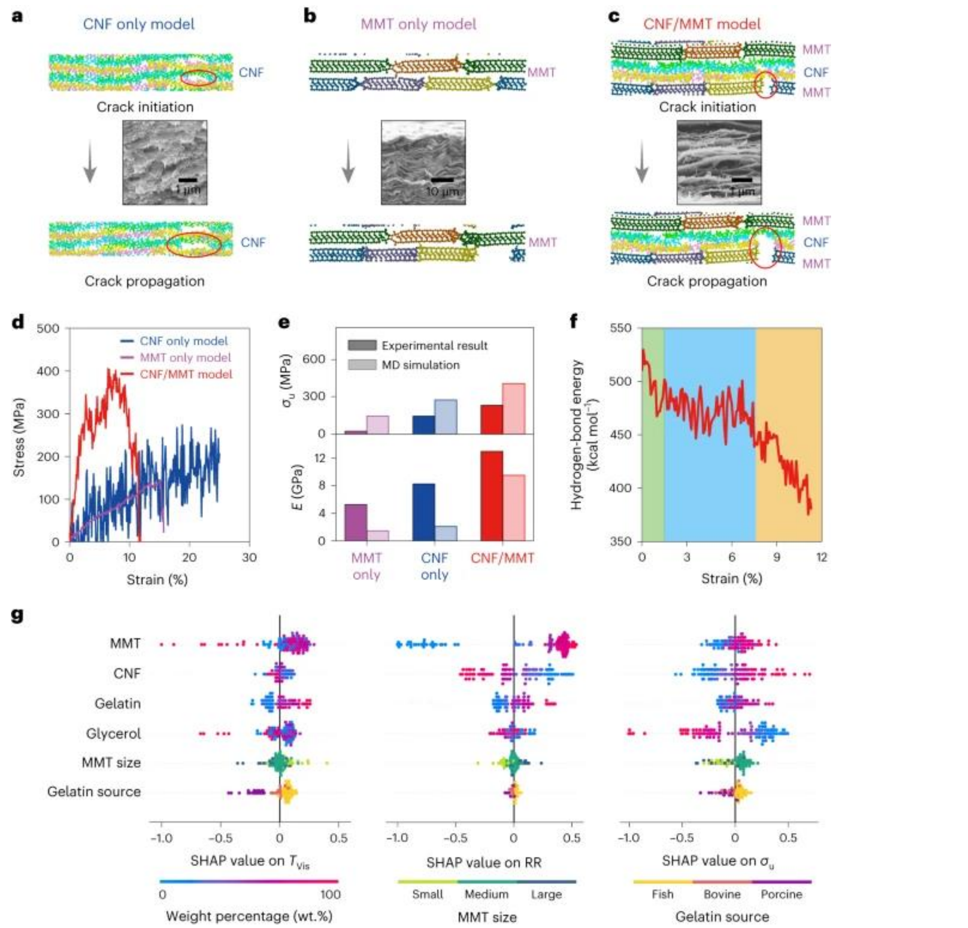
<tr><td></td><td>
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<tr><td>VOCAB: (w/definition)</td><td>Support-Vector Machine: “Definition” in the summary (explanation of this type of classification model)</td></tr>
<tr><td>Cited references to follow up on</td><td>Bayer, I. S. et al. Direct transformation of edible vegetable waste into bioplastics. Macromolecules 47, 5135–5143 (2014).</td></tr>
<tr><td>Follow up Questions</td><td>Would the methods used in this study similarly apply to starch-based bioplastics, or would there be any major differences?

Are there any lingering concerns with this method of fabricating nanocomposites that could be addressed in further research?

How cost-efficient is this method of fabricating nanocomposites?</td></tr>
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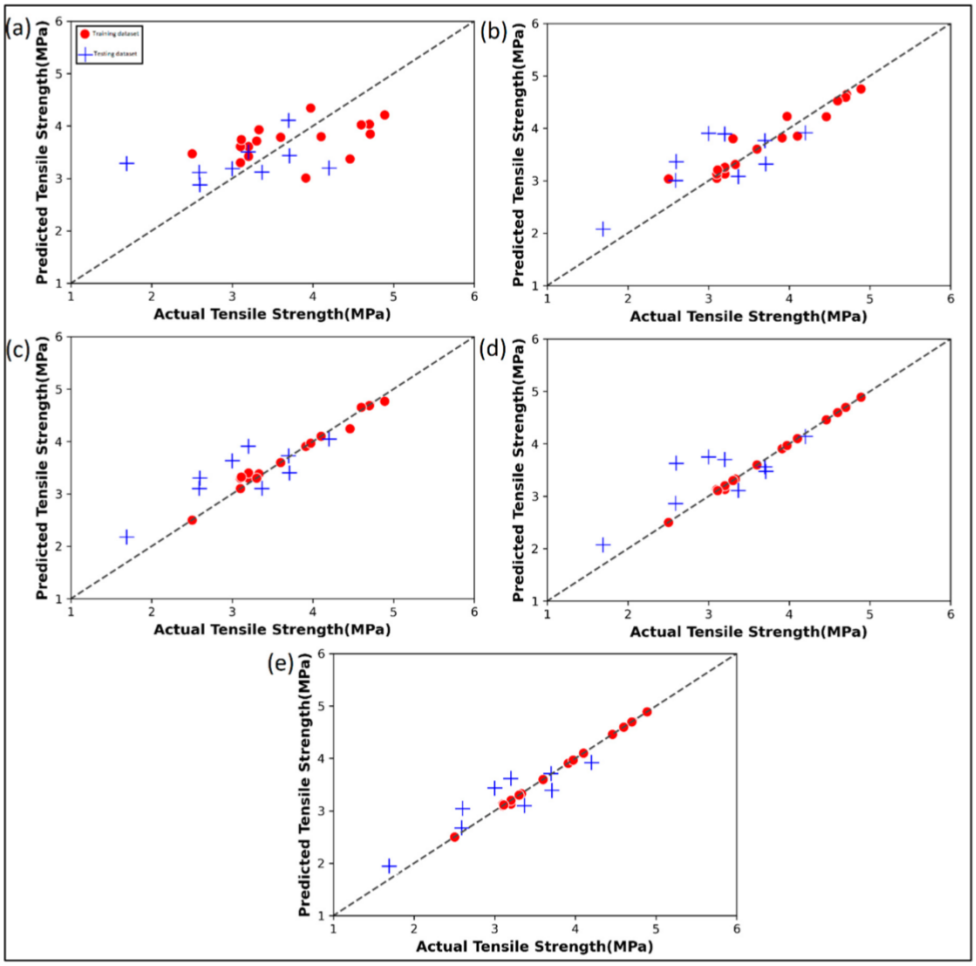
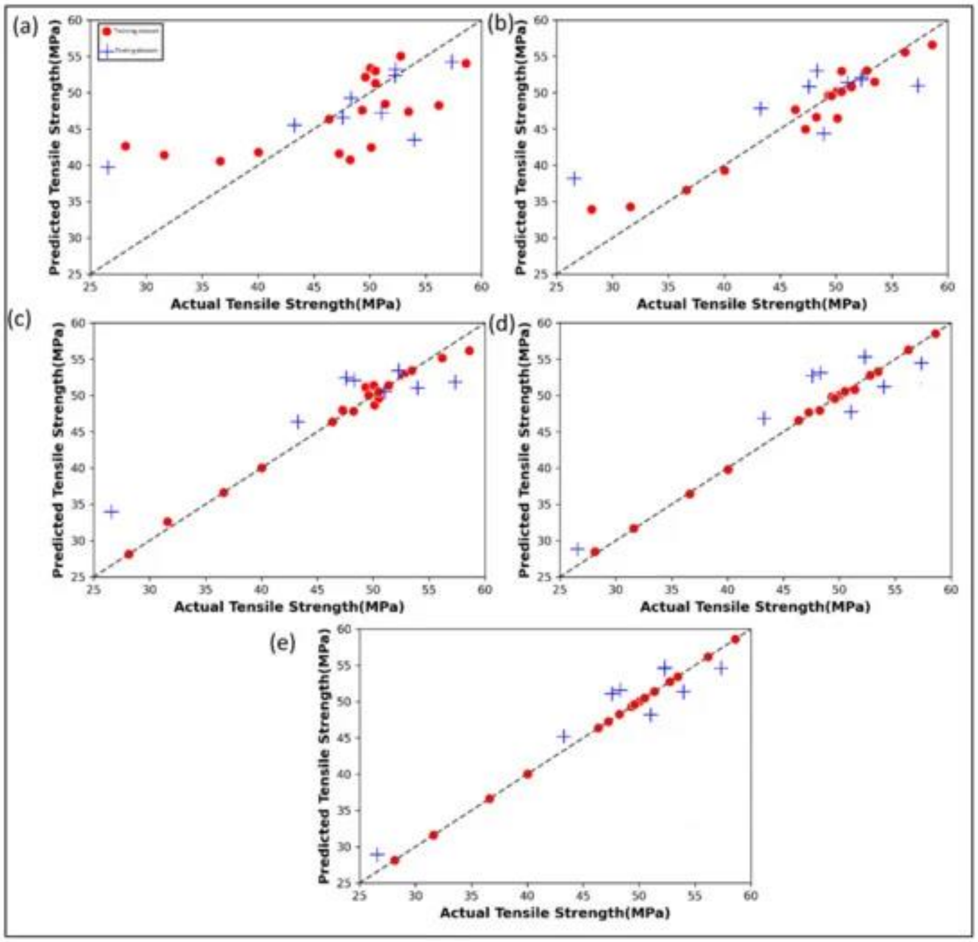
Article #15 Notes: Accurate Estimation of Tensile Strength of 3D Printed Parts Using Machine Learning Algorithms

Source Title	Processes
Source citation (APA Format)	Jayasudha, M., Elangovan, M., Mahdal, M., & Priyadarshini, J. (2022). Accurate Estimation of Tensile Strength of 3D Printed Parts Using Machine Learning Algorithms. *Processes, 10*(6). **https://doi.org/10.3390/pr10061158**
Original URL	https://www.mdpi.com/2227-9717/10/6/1158
Source type	Journal Article
Keywords	Machine Learning, Predictive Models, Regression, 3D Printing, XGBoost
#Tags	#ML, (Doesn't 100% fit the #Bioplastics tag)
Summary of key points + notes (include	The authors of this journal article wished to use ML to make the process of 3D printing much more efficient. The authors also outline some of the current uses of

methodology)	3D printing. In order to use ML in this scenario, the researchers tested out many different types of machine learning algorithms. The first of these, and arguably the most basic machine learning algorithm, was linear regression. This is essentially what Excel does when you ask it to find a line of best fit. For my study, my initial thoughts are that I might use some sort of regression method to find maximum tensile strength. While this will probably not be linear regression (probably some sort of polynomial regression?), it's interesting to see how linear regression fares at estimating tensile strength. The second algorithm that the researchers tested was a Random Forest Regression Algorithm. This algorithm is much more complicated than that of linear regression, but to put it simply, a random forest regression model uses a lot of decision trees (hence the name "forest") and does a few calculations to find the output value. The third algorithm used by the researchers was AdaBoost Regression. This algorithm uses regression like the other two models. The difference with this model is that from what I understood, every new iteration of the regression works to improve upon the previous iteration, which results in a much more accurate output value. The fourth algorithm used was a Gradient Boosting Regression Algorithm. Unlike the other algorithms, this algorithm retrieves an accurate output by adding more and more regressions each time, instead of optimizing the original regression. The fifth and final algorithm used by the researchers was an XGBoost Regression Algorithm. An XGBoost algorithm uses two main functions, an objective function which helps find error, and base learners which are continuously added to the regression to reduce error. This results in a very accurate output value. The researchers tested out the algorithms with two different datasets, and they found that out of these five algorithms, the XGBoost algorithm fared the best, whereas the linear regression algorithm did the worst. The researchers concluded their paper by explaining that although the XGBoost algorithm fared the best out of all the algorithms presented, there are still many algorithms not shown in this paper that could perhaps fare better, so a future step may be to look into other types of machine learning algorithms.
Research Question/Problem/ Need	Can Machine Learning be used to make the production of 3D Prints much more efficient by estimating their tensile strengths?

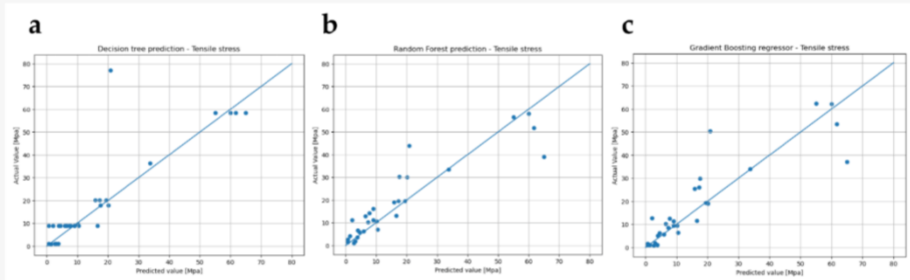
Important Figures	

	
VOCAB: (w/definition)	All Vocab is explained in the summary section
Cited references to follow up on	Mahmood, M.A.; Visan, A.I.; Ristoscu, C.; Mihailescu, I.N. Artificial neural network algorithms for 3D printing. *Materials* **2020**, *14*, 163.
Follow up Questions	Can the same algorithms be applied to starch-based bioplastics rather than just 3D prints? Is it true that XGBoost would be the optimal algorithm for most data sets, or are there a few datasets that some of the other algorithms would provide more accurate data? What other machine learning algorithms should be tested against these five in the future?

Article #16 Notes: Predicting the Composition and Mechanical Properties of Seaweed Bioplastics from the Scientific Literature: A Machine Learning Approach for Modeling Sparse Data

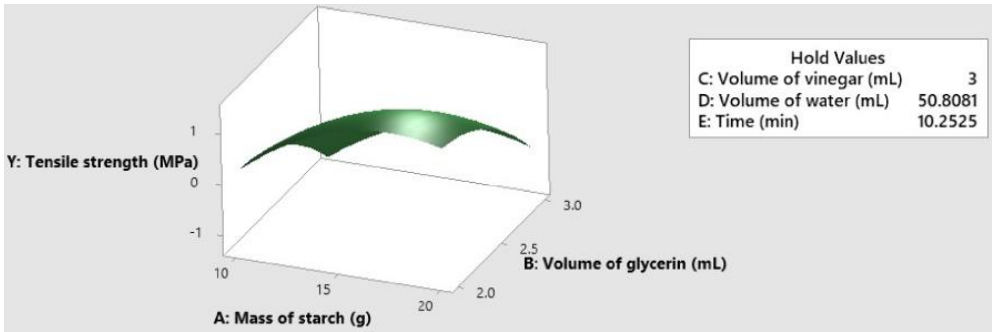
Source Title	Applied Sciences
Source citation (APA Format)	Ibarra-Pérez, D., Faba, S., Hernández-Muñoz, V., Smith, C., Galotto, M. J., & Garmulewicz, A. (2023). Predicting the Composition and Mechanical Properties of Seaweed Bioplastics from the Scientific Literature: A Machine Learning Approach for Modeling Sparse Data. *Applied Science, 13*(21). **https://doi.org/10.3390/app132111841**
Original URL	https://www.mdpi.com/2076-3417/13/21/11841
Source type	Journal Article
Keywords	Bioplastics, Seaweed Bioplastics, Film, Mechanical Properties, Machine Learning
#Tags	#Bioplastics, #BioChem, #ML
Summary of key points + notes (include methodology)	The authors of this journal article wished to use machine learning to estimate the mechanical properties of seaweed-based bioplastics. To do this, the researchers

	used three different regression algorithms on a dataset they found regarding previous seaweed bioplastics. The first regression algorithm that the researchers used was that of a decision tree regression model. The second regression algorithm used by the researchers was a random forest regression model, which is an improved version of the decision tree algorithm. This is because random forest algorithms take the average of many different decision trees (hence the name forest). Finally, the researchers tested a gradient boosting machine learning algorithm. The methodology used by the researchers was to first get usable data for their model to be trained upon. “Usable data” essentially means data that fit their restrictions, which they imposed upon the data to make it more accessible and easier to use regression on. Once they had usable data, they split this data up into training data and testing data (using an 80/20 split). They then trained each of their three algorithms out on the training data, before testing the model with the rest of the data. The accuracy of the model was measured using a few calculations, namely, to find the R-squared value (closer to 1, the better), to find the Mean Squared Error and Root Mean Squared Error (the lower, the better), and a few other calculations (such as Median Absolute Error). The researchers found that, when modeling tensile strength, the random forest regression algorithm performed the best, with a R-squared value of 0.821. Similarly, random forest regression also performed the best with regards to modeling elongation at break, but the R-squared value was relatively low (being only 0.421). This is another reason why modeling tensile strength may be more apt than modeling other mechanical properties of starch-based bioplastics, such as in this case, elongation. The researchers conclude the article by expressing their belief that, when only limited data (such as what was presented here) is available, a random forest regression algorithm is most often the best choice, and that their machine learning model will be a great improvement when it comes to the fabrication of bioplastics.
Research Question/Problem/ Need	Can machine learning be used to estimate the mechanical properties of seaweed-based bioplastics?

Important Figures	**Figure 3.** Tensile stress evaluations for (**a**) decision tree prediction, (**b**) random forest prediction, and (**c**) gradient boosting prediction. 
VOCAB: (w/definition)	Vocab is explained in the text above, and all regression algorithms are either explained here or in a previous article.
Cited references to follow up on	George, A.; Sanjay, M.R.; Srisuk, R.; Parameswaranpillai, J.; Siengchin, S. A comprehensive review on chemical properties and applications of biopolymers and their composites. *Int. J. Biol. Macromol.* **2020**, *154*, 329–338. [**Google Scholar**] [**CrossRef**]
Follow up Questions	Will these regression algorithms perform similarly to how they did here if other types of bioplastics were tested (i.e. corn starch-based bioplastics?) What other regression algorithms could be tested against the three presented in this article, and how would they fare against those presented here? Why were the constraints (in section 2.2) chosen (what I mean by this is why can't a bioplastic break one of these criterion; have these been used in other journal articles before or are they specific to this study)?

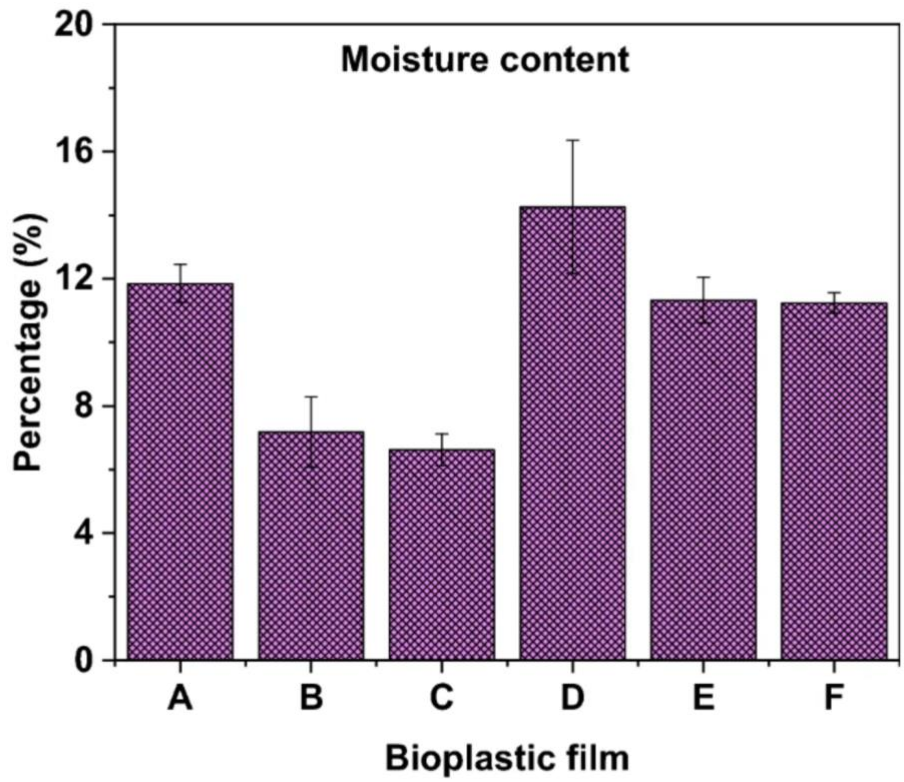
Article #17 Notes: Statistical Modeling and Optimization of Bioplastic Synthesis from Waste Corn Using Polynomial Regression Analysis

Source Title	Green Energy and Environmental Technology
Source citation (APA Format)	Adeyemo, F., Ogunwumi, O. T., Oyedeko, K., & Amodu, O. S. (2024). Statistical Modeling and Optimization of Bioplastic Synthesis from Waste Corn Using Polynomial Regression Analysis. *Green Energy and Environmental Technology.*
Original URL	https://www.intechopen.com/journals/7/articles/439
Source type	Journal Article
Keywords	Bioplastics, Eco-Friendly Synthesis, Response Surface Methodology, Optimal Conditions, Biodegradable Polymer
#Tags	#Bioplastics, #BioChem, #ML
Summary of key points + notes (include methodology)	The authors of this journal article wished to estimate the mechanical properties of bioplastics fabricated from corn starch with the help of a polynomial regression algorithm. However, instead of relying on other data, like most other studies, the authors of this paper fabricated forty-six of their own bioplastics. The authors then ran a polynomial regression on this data, with the goal of optimizing the bioplastic's weight, the tensile strength, the elongation, and the energy consumed by the fabrication of the bioplastic. The independent variables were the starch mass in the bioplastic, and the volumes of glycerin, vinegar, and water. The researchers found that the optimal tensile strength was 1.44 mPa. Overall, the researchers concluded with their belief that their model is very accurate in portraying the mechanical properties of bioplastics.

Research Question/Problem/ Need	Can a polynomial regression algorithm be used to estimate the mechanical properties of a waste corn-based bioplastic?
Important Figures	
VOCAB: (w/definition)	None that were not explained in the summary.
Cited references to follow up on	42. Imoisili PE, Jen TC. Modelling and optimization of the impact strength of plantain (Musa paradisiacal) fibre/MWCNT hybrid nanocomposite using response surface methodology. J Mater Res Technol. July–Aug 2021;13: 1946–1954. doi:10.1016/j.jmrt.2021.05.10.
Follow up Questions	The 1.44 mPa value seems fairly low --- is this just due to the fact that waste corn does not produce strong bioplastics? Can cost of fabrication be added to the model, since mass production is very important for the future of bioplastics? Are there other ways of fabricating bioplastics out of waste corn that may produce better results than those shown here?

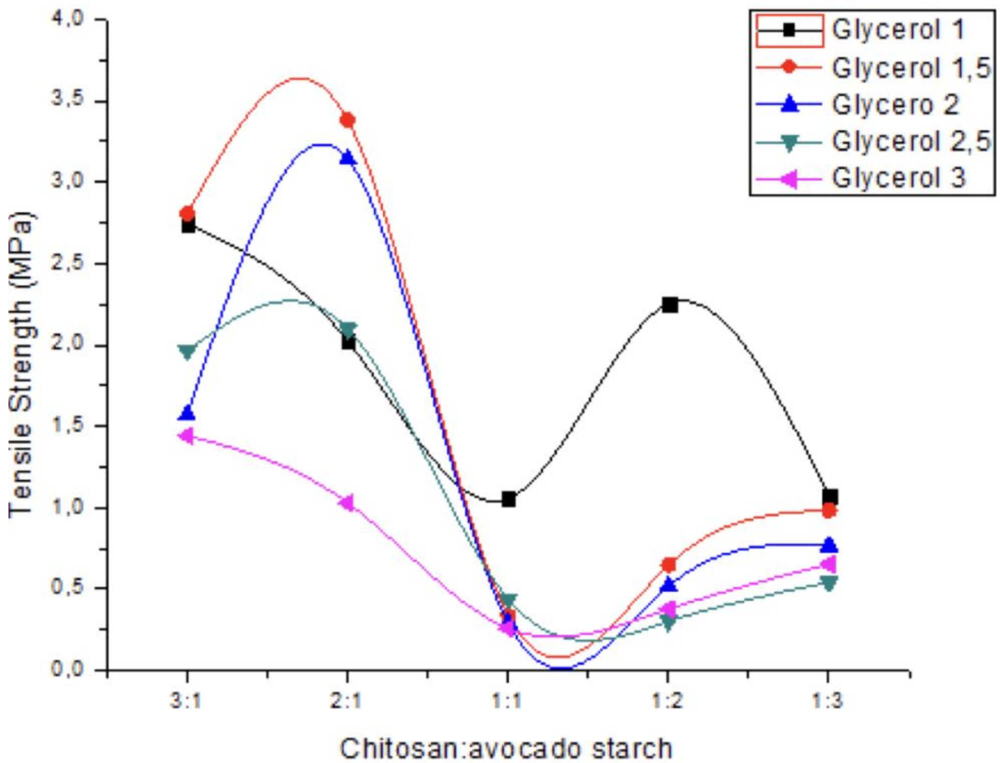
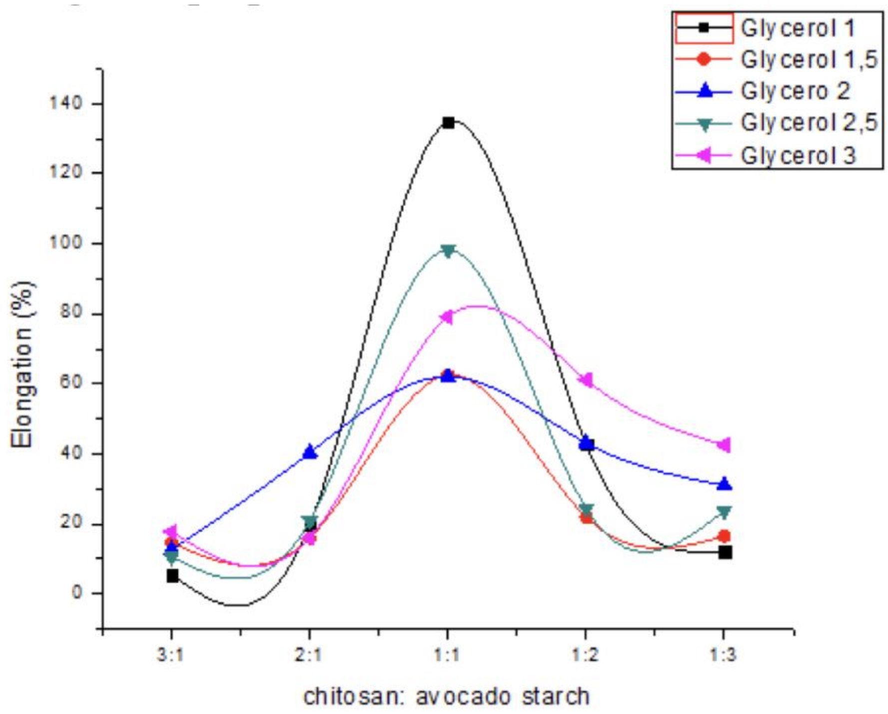
Article #18 Notes: Evaluation of the effects of additives on the properties of starch-based bioplastic film

Source Title	SN Applied Science
Source citation (APA Format)	Oluwasina, O. O., Akinyele, B. P., Olusegun, S. J., Oluwasina, O. O., & Mohallem, N. D. S. (2021). Evaluation of the effects of additives on the properties of starch-based bioplastic film. *SN Applied Science, 3*(421).
Original URL	https://link.springer.com/article/10.1007/s42452-021-04433-7#Tab1
Source type	Journal Article
Keywords	None mentioned in the article.
#Tags	#Bioplastics, #ChemEng
Summary of key points + notes (include methodology)	The authors of this journal article wished to see how the additions of dialdehyde starch and silica affect the mechanical properties of starch-based bioplastics. Specifically, the researchers tested out these two additives on bamboo leaf starch-based and cassava tuber starch-based bioplastics. The researchers tested out multiple concentrations of both dialdehyde starch and silica. Specifically, concentrations of 60, 80, and 100% of both additives were added to the starch. The researchers tested out many different mechanical properties of their bioplastics, including, but not limited to, the tensile strength, the biodegradability, and the moisture content of the bioplastic. Regarding tensile strength, the researchers found that the plastics with the additive of dialdehyde starch fared significantly better (having between 1.63-3.06 mPa tensile strength) than the plastics with the additive of silica (which had between 0.53 - 0.75 mPa). Similarly, the researchers found that the addition of dialdehyde starch meant that the plastics took longer to degrade than the addition of silica. The researchers concluded by explaining some of the pros and cons of dialdehyde starch and silica as additives to the bioplastic and expressed their belief that using dialdehyde starch as an additive is superior to using silica as an additive.
Research Question/Problem/ Need	What are some of the pros and cons of using dialdehyde starch vs. Silica as an additive to starch-based bioplastics?

Important Figures	Fig.1  Percentage moisture content of $Film_{di60}$ **(a)**, $Film_{di80}$ **(b)**, $Film_{di100}$ **(c)**, $Film_{si60}$ **(d)**, $Film_{si80}$ **(e)**, and $Film_{si100}$ **(f)**
VOCAB: (w/definition)	Not any new Vocab that has not already been previously defined.
Cited references to follow up on	Zhang R, Wang X, Cheng M (2018) Preparation and characterization of potato starch film with various size of nano-SiO2. Polymers 10:1–16. https://doi.org/10.3390/polym10101172
Follow up Questions	What other additives may be used in the starch-based bioplastic fabrication process, and what are the pros and cons of these additives? Would the pros and cons of dialdehyde starch and silica stay constant even with different starches? How does the fabrication process affect the utility of dialdehyde starch and silica?

Article #19 Notes: Preliminary Study of Synthesis and Characterization of Biodegradable Avocado Seed Starch-Chitosan Plastic with Glycerol Plasticizer

Source Title	BioResources
Source citation (APA Format)	Perwitasari, D. S., Fauziyah, N. A., Pesra, R. H., & Putu, N. L. (2024). Preliminary Study of Synthesis and Characterization of Biodegradable Avocado Seed Starch-Chitosan Plastic with Glycerol Plasticizer. *BioResources, 19*(4), 8769-8780. 10.15376/biores.19.4.8769-8780
Original URL	https://bioresources.cnr.ncsu.edu/wp-content/uploads/2024/10/BioRes_19_4_8769_Perwitasari_FPP_Biodegrad_Packag_Avocado_Starch_Chitosan_Bioplastic_22985.pdf
Source type	Journal Article
Keywords	Mechanical Properties, Bioplastic, Avocado Seed Starch
#Tags	#Bioplastics, #ChemEng
Summary of key points + notes (include methodology)	The authors of this journal article wished to fabricate a bioplastic using the starch found in avocado seeds. Alongside the starch found in avocado seeds, the authors of this journal article also used chitosan and glycerol to assist in the fabrication of the bioplastic. In order to fabricate the bioplastic, the researchers first needed to actually get the starch from the avocado seeds. Once they had the starch from the seeds, the researchers then combined the starch with chitosan at multiple different chitosan to starch ratios. Finally, glycerol was added to the solution. After roughly a day, the bioplastic was properly formed and fabricated. The researchers then tested out the mechanical properties of these bioplastics that they had fabricated. What we can notice from their results is that a lower glycerol concentration usually correlated to a higher tensile strength. Interestingly, the further away the chitosan to starch ratio was from 1 (on both sides, i.e. a ratio of 2 or a ratio of 0.5), the higher the tensile strength of the bioplastic. On the other hand, a chitosan to starch ratio close to 1 is optimal for the elongation of the bioplastic.
Research Question/Problem/ Need	Can the starch found in the seeds of avocadoes be used to fabricate a starch-based bioplastic with decent mechanical properties?

Important Figures	 
VOCAB: (w/definition)	None.
Cited	Devi, N. L. P. A. P., Pesra, R. H., & Perwitasari, D. S. (2021). The effect of chitosan composition,

references to follow up on	avocado seed starch and the addition of glycerol on the biodegradable ability of bioplastics. *Seminar Nasional Soebardjo Brotohardjono,* 86-91.
Follow up Questions	Are the conclusions presented in the summary section about the chitosan to starch ratios true for any starch, or just for avocado seed starch? Why might a chitosan to starch ratio closer to 1 have a higher elongation? Why might a chitosan to starch ratio further away from 1 have a higher tensile strength?

Article #20 Notes: Environmental impact of bioplastic use: A review

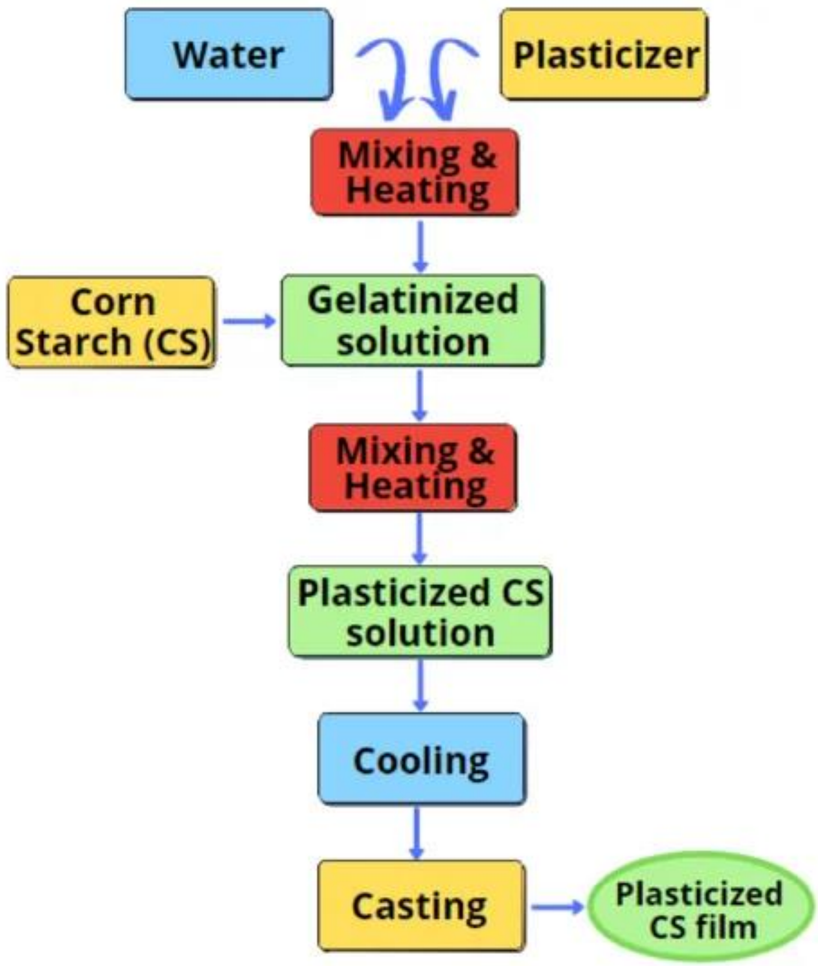
Source Title	Heliyon

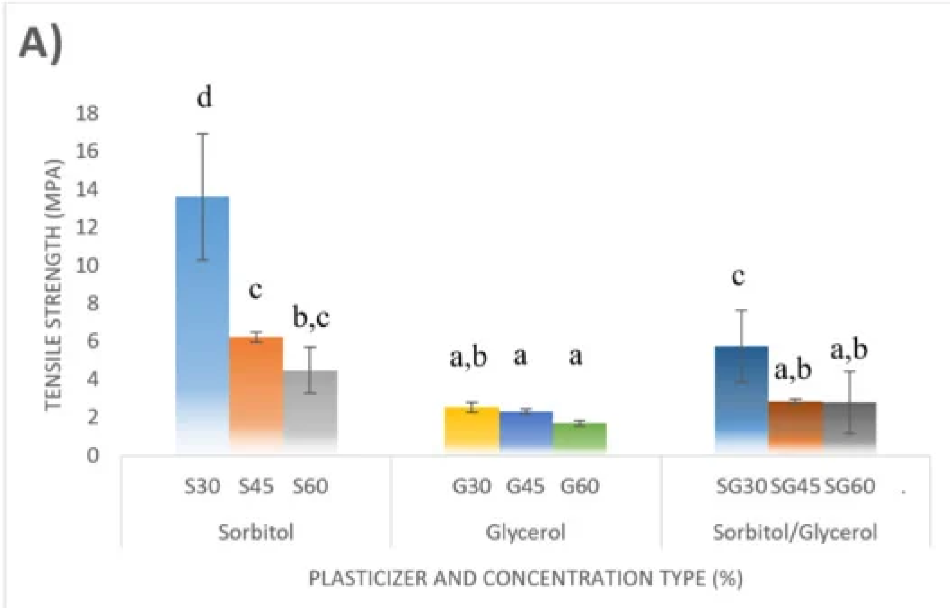
Source citation (APA Format)	Atiwesh, G., Mikhael, A., Parrish, C. C., Banoub, J., Le, T. T. (2021). Environmental impact of bioplastic use: A review. *Heliyon, 7*(9). 10.1016/j.heliyon.2021.e07918
Original URL	https://nam11.safelinks.protection.outlook.com/GetUrlReputation
Source type	Journal Article
Keywords	Bioplastics, Environment, Petroleum-based plastics, Life cycle assessment
#Tags	#BioChem, #ChemEng, #Bioplastics
Summary of key points + notes (include methodology)	The authors of this journal study wanted to take a look at the field of bioplastic, plastics made from organic materials that could replace the currently used synthetic plastics. Specifically, the researchers wanted to specifically consider one of the supposed positives of bioplastics, the fact that they are much more safe for the environment than synthetic plastics (regarding plastic pollutiona nd climate change). In order to compare the environmental impacts of bioplastics versus synthetic plastics, the researchers read through multiple different scientific papers which take a look at the environmental impacts of these two types of plastics (this is a review article). The total conclusions that the researchers found was as such: Firstly, the researchers found that current synthetic plastics are not biodegradable mostly due to the fact that they are fabricated with petroleum. On the other hand, there are many bioplastics that are biodegradable, meaning that they will degrade naturally over a much shorter period of time. The researchers also found, however, that when specific biodegradable bioplastics biodegrade, they release methane gas which is bad for the environment. Similarly, the researchers found that bioplastics emit much less carbon dioxide than synthetic plastics, meaning that switching to bioplastics would reduce the carbon dioxide emissions, thereby reducing the rate of climate change.
Research Question/Problem/ Need	Are there environmental benefits of bioplastics compared to synthetic plastics, and if so, is it worth to switch from synthetic plastics to bioplastics?
Important Figures	None (review)
VOCAB: (w/definition)	None
Cited references to follow up on	Curry, N., & Pillay, P. (2012). Biogas prediction and design of a food waste to energy system for the urban environment. *Renew. Energy, 41.*
Follow up Questions	How much more would a switch to bioplastics cost?

	Is it easy enough to mass produce bioplastics compared to synthetic plastics? How difficult would it be, and how long would it take to completely switch to bioplastics from synthetic plastics?

Article #21 Notes: Corn Starch (*Zea mays*) Biopolymer Plastic Reaction in Combination with Sorbitol and Glycerol

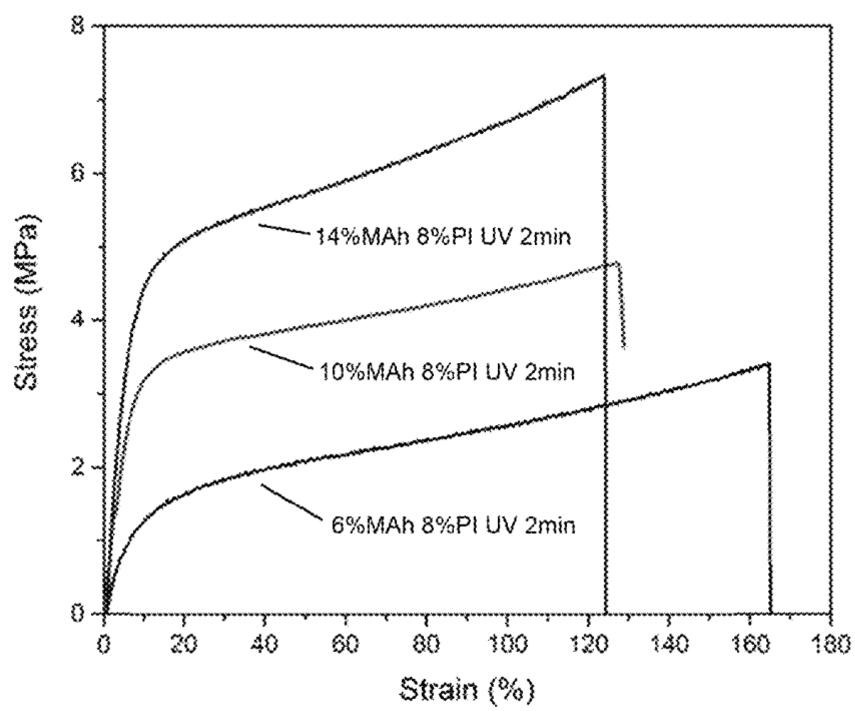
Source Title	Polymers
Source citation (APA Format)	Hazrol, M. D., Sapuan, S. M., Zainudin, E. S., Zuhri, M. Y. M., & Abdul Wahab, N. I. (2021). Corn Starch (*Zea mays*) Biopolymer Plastic Reaction. *Polymers, 13*(2), 242. **https://doi.org/10.3390/polym13020242**
Original URL	https://www.mdpi.com/2073-4360/13/2/242
Source type	Journal Article
Keywords	Corn, Starch, Sorbitol, Glycerol, Plasticizer, Biodegradable Films
#Tags	#Bioplastics, #ChemEng, #MaterialsScience
Summary of key points + notes (include methodology)	The authors of this paper wished to fabricate bioplastics (or as they call them, biodegradable films) using corn starch as well as a combination of sorbitol and glycerol as a plasticizer. Specifically, some of the films were plasticized with either just glycerol, just sorbitol, or some combination of the two. The step by step process on how the bioplastics were fabricated is mostly explained in the figure below, but I am also writing an explanation here. The first step in the bioplastic fabrication process was to mix whichever plasticizer was being used with distilled water. The cornstarch was then added to said mixture, which, after thorough mixing and heating, was able to be cast into the biodegradable film shape. The mechanical properties of these bioplastics varied based on the plasticizer, with films plasticized with sorbitol (specifically at a 30% concentration) having the highest tensile strength. Out of these three types of plasticizers, glycerol

	performed the worst (i.e. had the least tensile strength). The same "ranking" was true for Young's modulus as well, showing that, at least for the mechanical properties of the bioplastic, a film plasticized with sorbitol is superior to the other two possibilities.
Research Question/Problem/ Need	Does and how does a combination of glycerol and sorbitol as a plasticizer affect the physical and mechanical properties of corn starch-based bioplastics?
Important Figures	

	
VOCAB: (w/definition)	None that were not previously defined.
Cited references to follow up on	Sun, Y.; Liu, Z.; Zhang, L.; Wang, X.; Li, L. Effects of plasticizer type and concentration on rheological, physico-mechanical and structural properties of chitosan/zein film. *Int. J. Biol. Macromol.* **2020**, *143*, 334–340. [**Google Scholar**] [**CrossRef**] Sanyang, M.L.; Sapuan, S.M.; Jawaid, M.; Ishak, M.R.; Sahari, J. Effect of plasticizer type and concentration on physical properties of biodegradable films based on sugar palm (arenga pinnata) starch for food packaging. *J. Food Sci. Technol.* **2016**, *53*, 326–336. [**Google Scholar**] [**CrossRef**] [**Green Version**] Razavi, S.M.A.; Mohammad Amini, A.; Zahedi, Y. Characterisation of a new biodegradable edible film based on sage seed gum: Influence of plasticiser type and concentration. *Food Hydrocoll.* **2015**, *43*, 290–298. [**Google Scholar**] [**CrossRef**]
Follow up Questions	How do combinations of other plasticizers with glycerol/sorbitol perform against the plasticizers shown here? Would the results of this study (physical and mechanical properties) be any different if the bioplastic was fabricated with a different starch source than corn? How much might the process of fabrication for these bioplastics affect the physical and mechanical properties of the bioplastics plasticized with glycerol vs. Sorbitol vs. a combination of the two?

Patent #1 Notes: Biodegradable protein-based plastics with improved mechanical strength and water resistance

Source Title	N/A (US Patent)
Source citation (APA Format)	Jiang, L. & Ma, Q. (2023). *Biodegradable protein-based plastics with improved mechanical strength and water resistance* (U. S. Patent No. 11,739,216). U. S. Patent and Trademark Office. https://patents.google.com/patent/US11739216B2/en?oq=11739216
Original URL	https://patents.google.com/patent/US11739216B2/en?oq=11739216
Source type	Patent
Keywords	None given.
#Tags	#Bioplastics, #BioEng, #ChemEng, #MaterialsScience
Summary of key points +	In order to address the two problems underlined below (tensile strength & water

notes (include methodology)	resistance) in soy protein isolate, the authors of the patent used an extra strengthening agent (which makes the bioplastic stronger) as well as a photoinitiator (which absorbs light in order to crosslink proteins). The patent's authors also used plasticizers to help strengthen their bioplastic. Their results showed that the bioplastic was the strongest when the photoinitiator was at 8% and UV light was shone on it for 8 minutes. The authors also showed that the bioplastic became stronger with cellulose nanofibers added onto it. These results show that using photoinitiators alongside UV irradiation and cellulose nanofibers can help make bioplastics not only stronger, but more water resistance, allowing them to be used commercially. The authors also created different samples of MSPI-based resins, one of which (MSPI-3) reached a staggering MPA of 21.19 to 26.69!
Research Question/Problem/ Need	How can two of the biggest problems with bioplastics, specifically their tensile strength and water resistance, be addressed?
Important Figures	 *FIG. 4*

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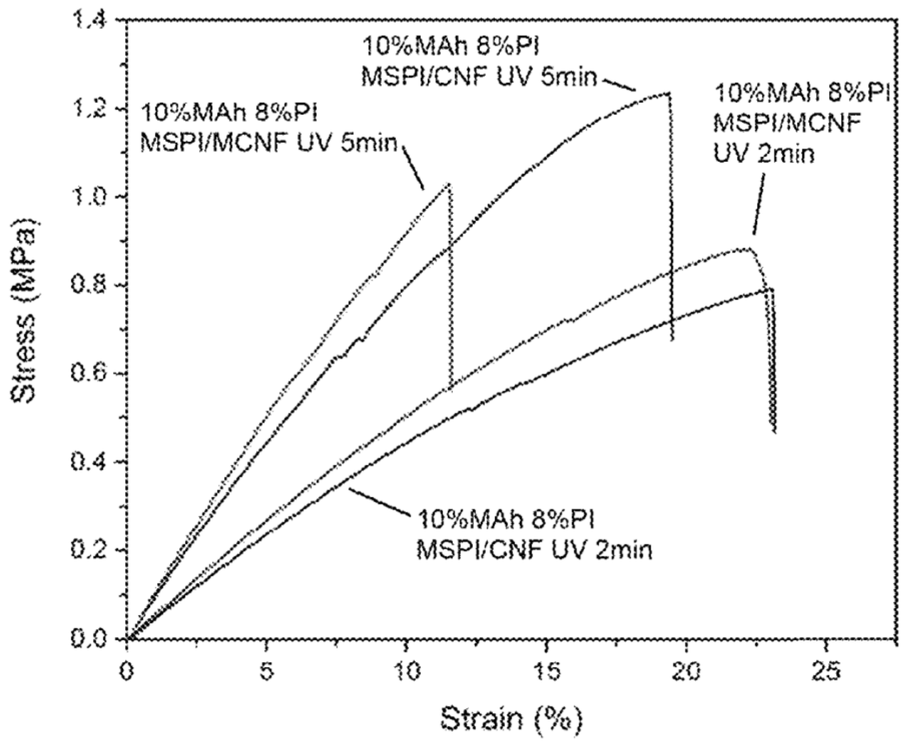
<tr><td></td><td>

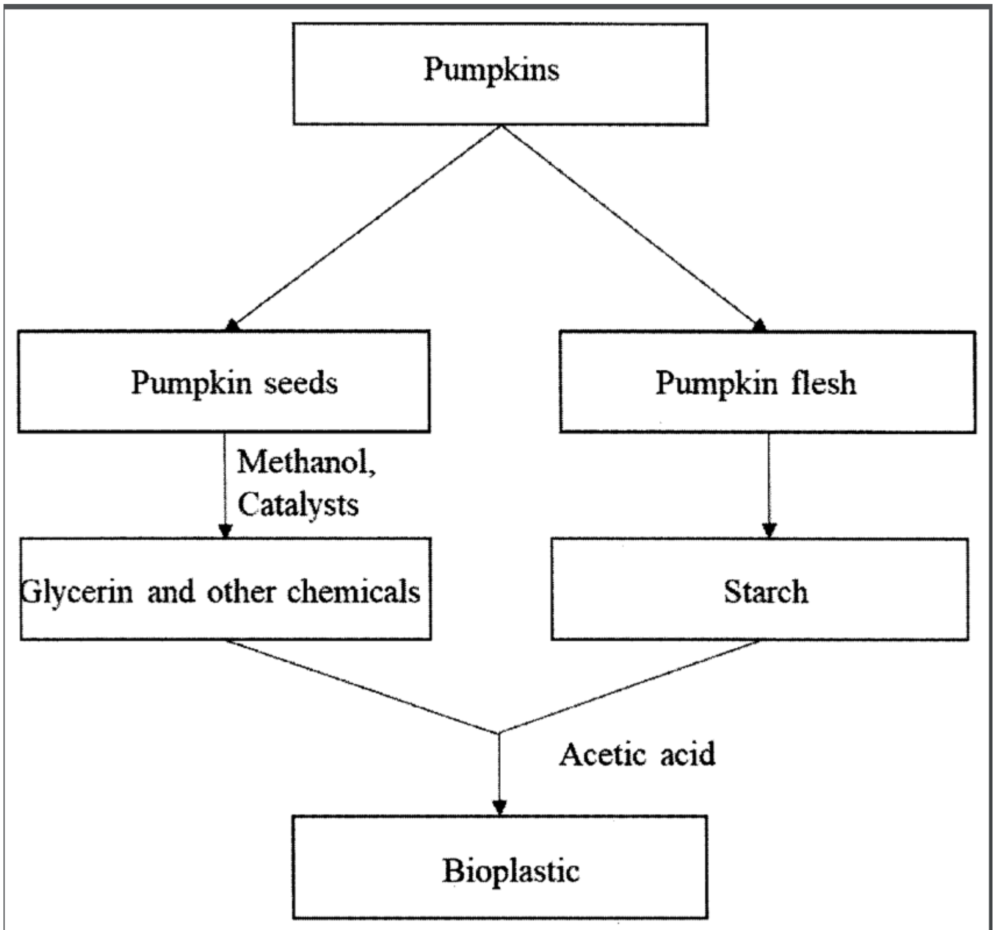
FIG. 7</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Crosslinking proteins: A process that makes proteins stronger and more water resistant.</td></tr>
<tr><td>Cited references to follow up on</td><td>Ye et al. “Bio-based films with improved water resistance derived from soy protein isolate and stearic acid via bioconjugation”, Journal of Cleaner Production, vol. 214, pp. 125-131, 2019.</td></tr>
<tr><td>Follow Up Questions</td><td>Can cellulose nanofibers also be used for other starch-based bioplastics?

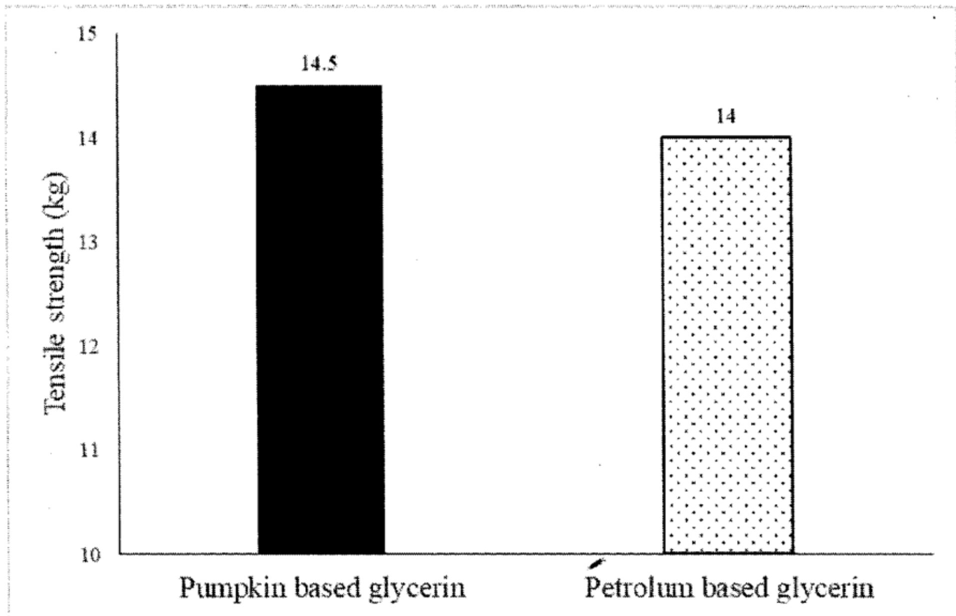
How does UV curing actually help toughen the bioplastic, i. e. what is the chemistry behind this?

How cost-effective would these bioplastics be, given that cost is also one of the main concerns with bioplastic fabrication right now?</td></tr>
</table>

Patent #2 Notes: Method of Producing Plant Biomass-Based Bioplastic

Source Title	N/A (US Patent)
Source citation (APA Format)	Yang, K. (2020). *Method of Producing Plant Biomass-Based Bioplastic* (U. S. Patent 20200048179). U. S. Patent and Trademark Office.
Original URL	https://patents.google.com/patent/US20200048179A1/en?oq=2020%2f0048179
Source type	Patent
Keywords	None Given.
#Tags	#Bioplastic, #BioEng, #ChemEng, #MaterialsScience

Summary of key points + notes (include methodology)	The author of this patent decided to use pumpkins to fabricate their bioplastic. Interestingly, unlike other papers I have read, the patent didn't use starch from the seeds to fabricate the bioplastic. Instead, the author of this patent used starch found in pumpkin flesh as well as glycerin found in pumpkin seed oil to fabricate the bioplastic. The bioplastic was fabricated by first extracting starch from pumpkin flesh and glycerin from pumpkin seed oil. These two were combined with acetic acid to finally make the bioplastic. The bioplastic was tested to be more biodegradable and stronger than regular, synthetic plastics.
Research Question/Problem/ Need	Can a sustainable, biodegradable bioplastic be created using the starch and glycerin found in pumpkins?
Important Figures	 Figure 1



15
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Tensile strength (kg)
Pumpkin based glycerin
Petrolum based glycerin

Figure 2

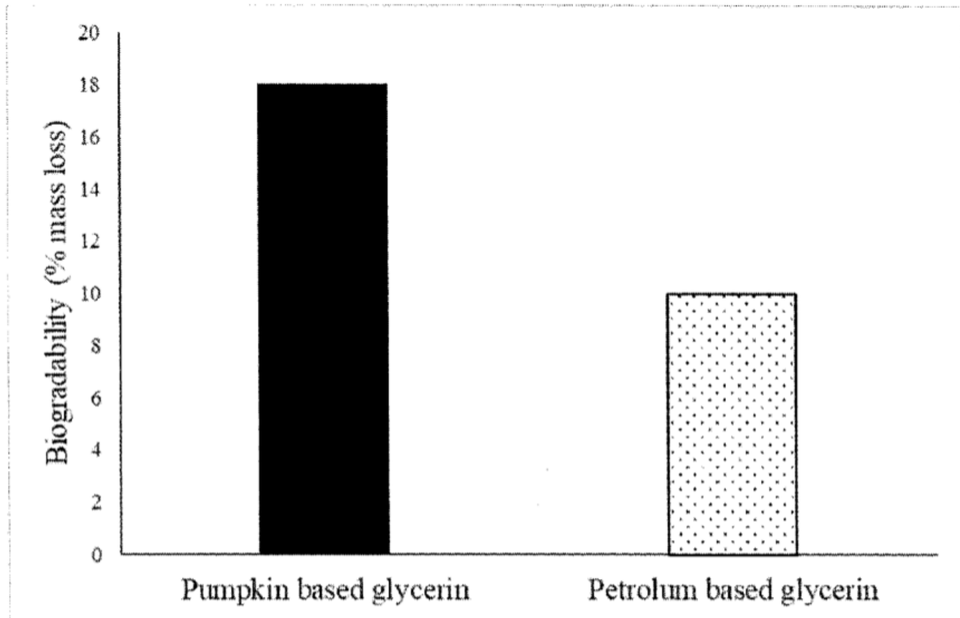
<table>
<tr><td></td><td>

Figure 3</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>None</td></tr>
<tr><td>Cited references to follow up on</td><td>Setiawan et al.2017Development of more friendly food packaging materials base on polypropylene through blending with polylacticacid

(Just a note I realized: the article I did my STEM Update Meeting #2 presentation on is a reference to this article!: Nguyen et al.2022Development of Starch-Based Bioplastic from Jackfruit Seed)</td></tr>
<tr><td>Follow up Questions</td><td>Can these pumpkin based bioplastics be used commercially in products that currently use synthetic plastics?

Are these pumpkin based bioplastics cost-efficient enough to be sustainable for the future?

This patent was published four years ago: have there been any advances in pumpkin based bioplastics since then?</td></tr>
</table>