



WPI

Quantifying Chemical Pretreatments for Sustainable Biofuel Production

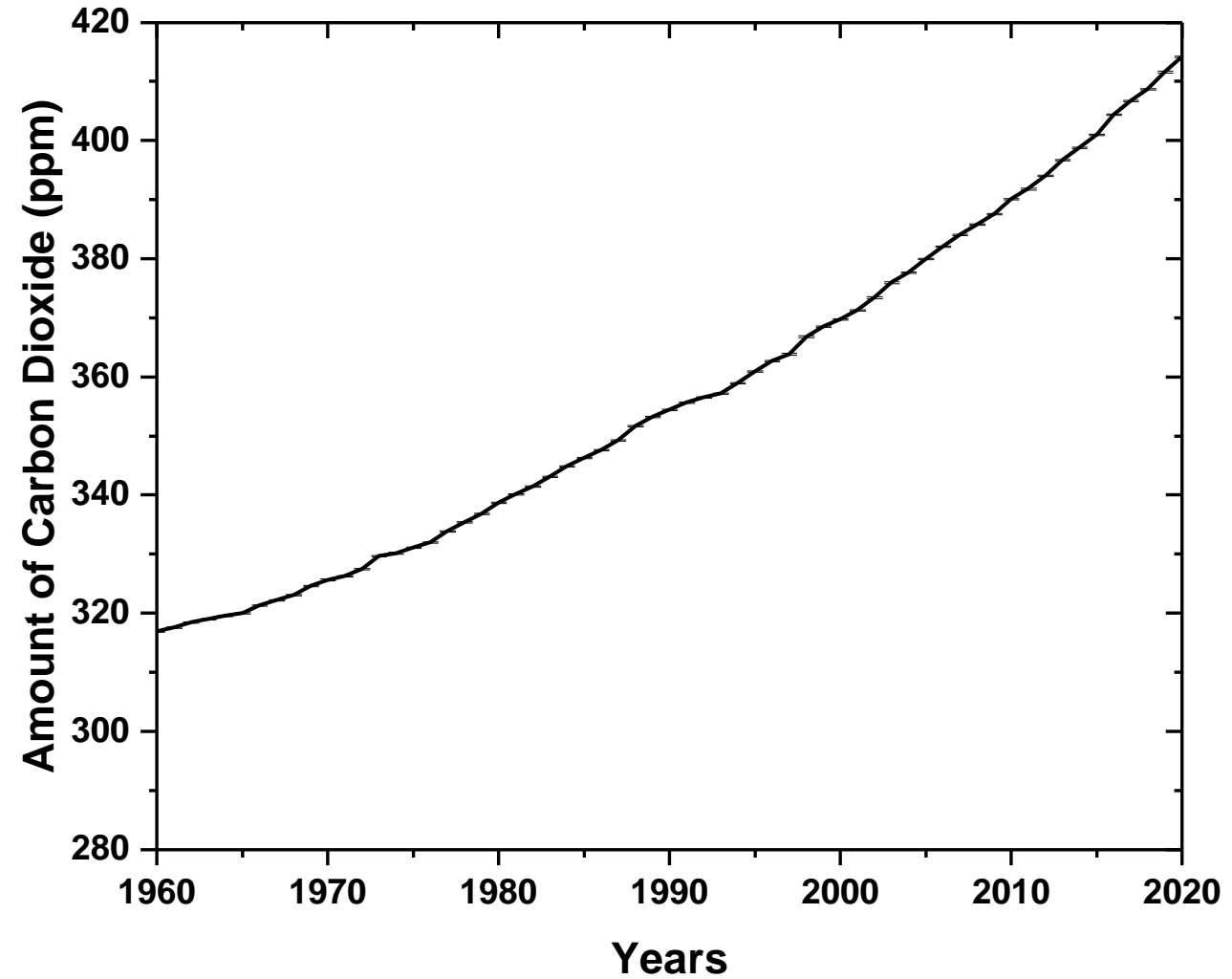
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Chemical Engineering Department

15th Annual WPI Sustainability Project Competition (2023)

Harsh Reality of Climate Change



Harsh Reality of Climate Change

Changes in Weather Patterns

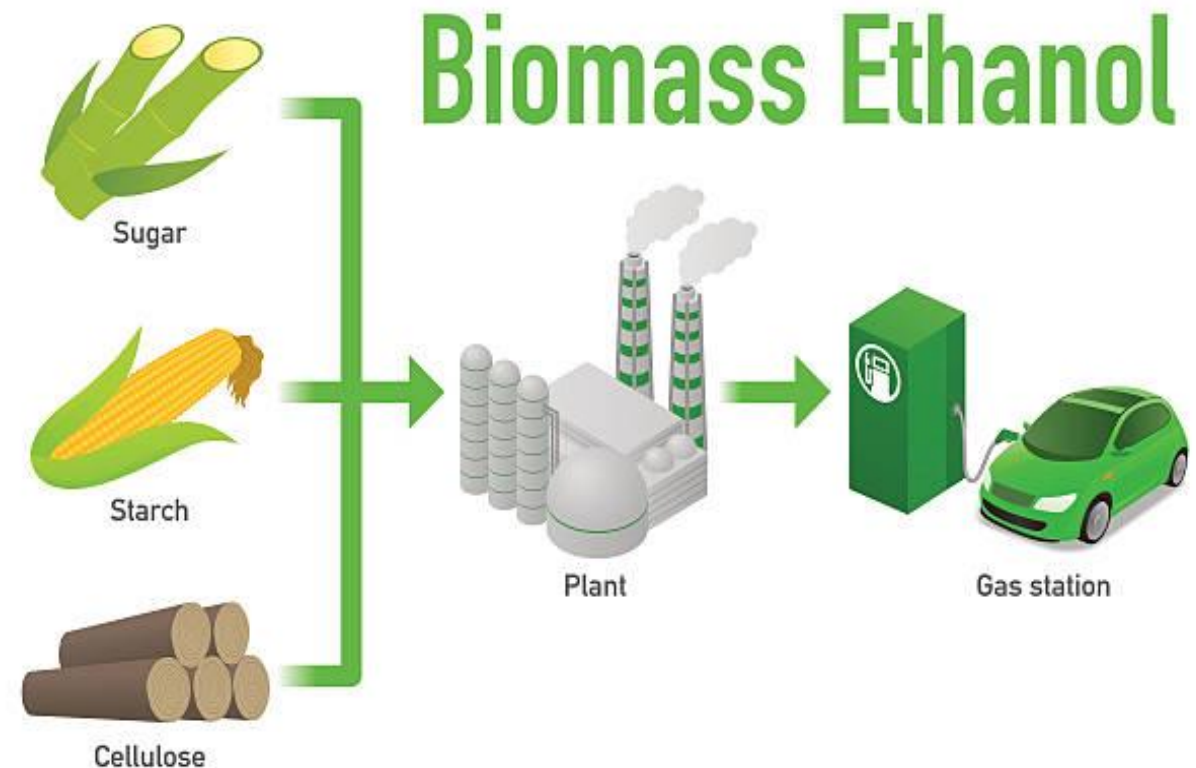
- **Longer Wildfire Seasons**
- **More Droughts and Heat Waves**
- **Stronger and more Intense Hurricanes**



Years

Biofuel Basics

- Ethanol is commonly made by fermenting glucose produced through the process of conversion of starches into sugars (hydrolysis) from any biomass high in carbohydrates.
- Normally made from starches and sugars, but scientists are developing technologies to allow it to be made from lignocellulosic biomass.



What is Lignocellulosic Biomass?

- Wood is still the largest biomass energy resource today, but other sources of biomass can also be used.
- These include food crops, grassy and woody plants, and residues from agriculture or forestry.
- Made up of cellulose, lignin and hemicellulose, in which cellulose is used for ethanol production

Switchgrass



Agriculture Waste



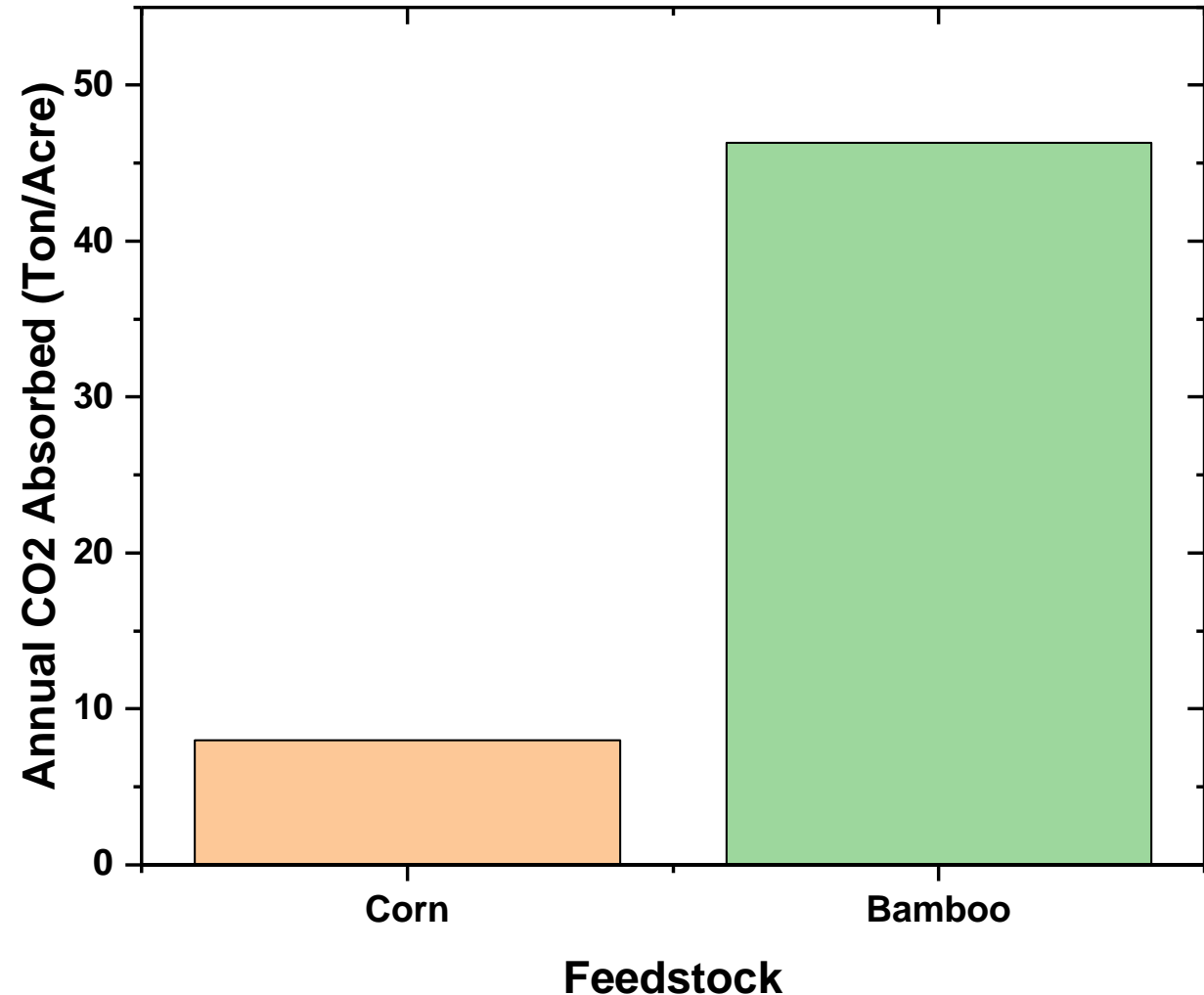
Bamboo



Poplar

Why Lignocellulosic Biomass?

- Bamboo absorbs ~6x the amount of carbon corn absorbs when being grown annually per acre.
- Lignocellulosic feedstocks have the potential to be used for carbon neutral biofuel production without competing food supply.



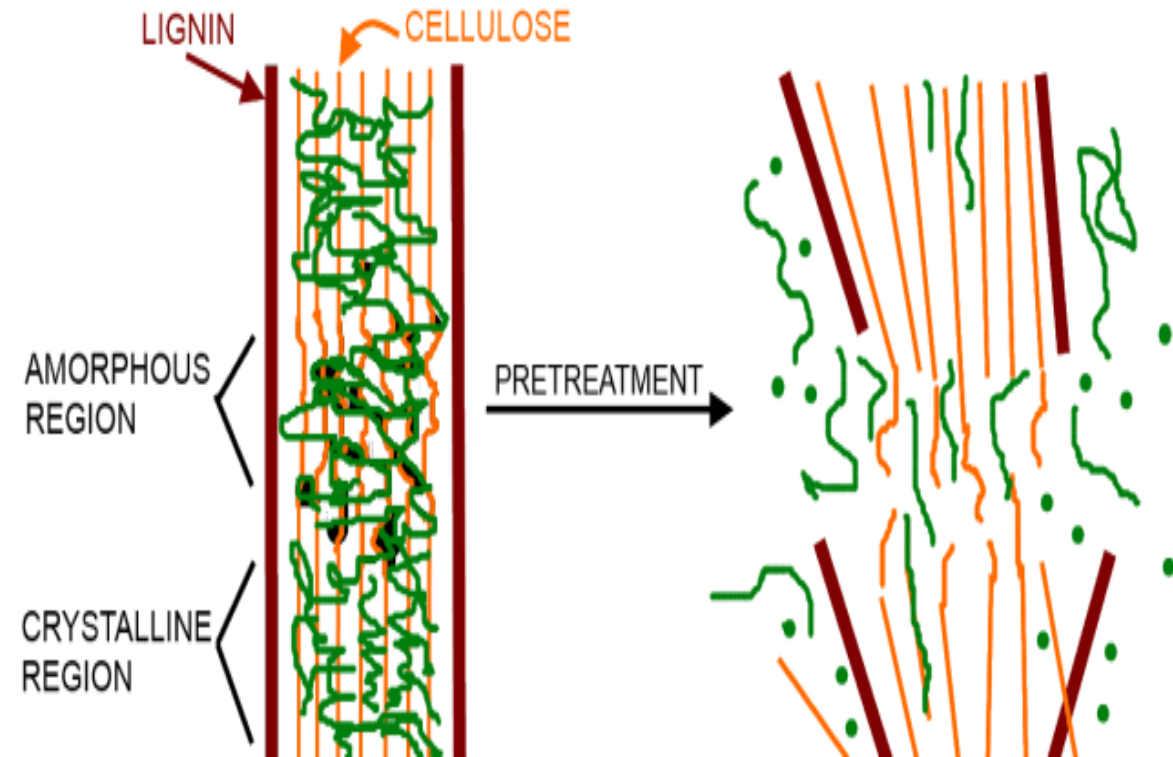
⁽¹⁾Corn's carbon cowboy busts outstanding yields | AgWeb. (n.d.).

⁽²⁾Nature Publishing Group. (2021, March 30). *Bamboo plants can act as efficient carbon sinks.*

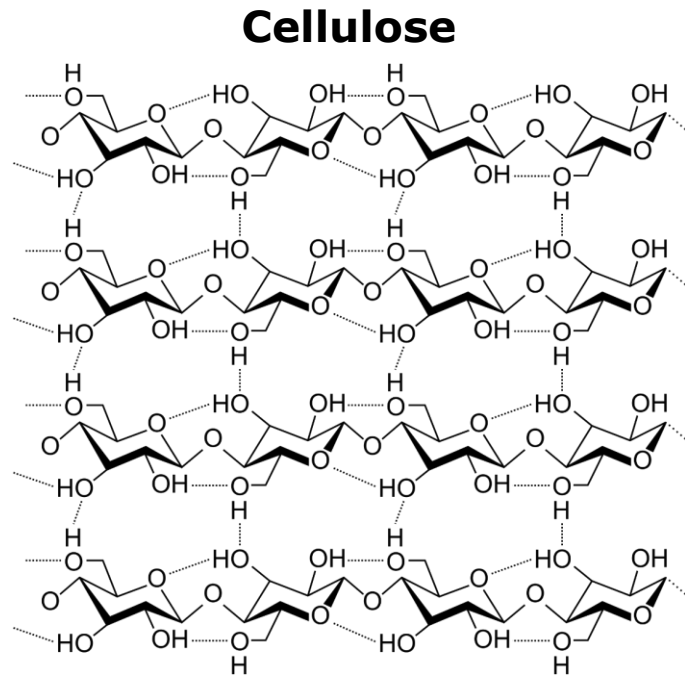
Nature News.

Issues with Lignocellulosic Ethanol Production

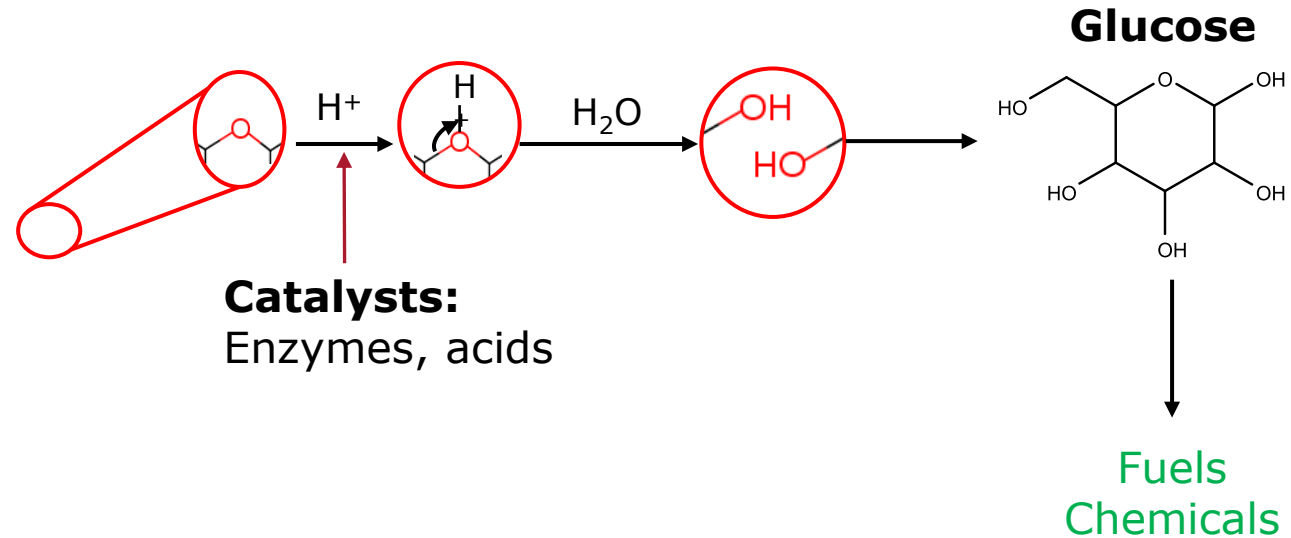
- Costly to break down lignocellulosic biomass into cellulose
- Current methods are not competitive at large scale
- Common method of choice for pretreatment is to ball-mill the cellulose into the more reactive form of amorphous cellulose after removing lignin



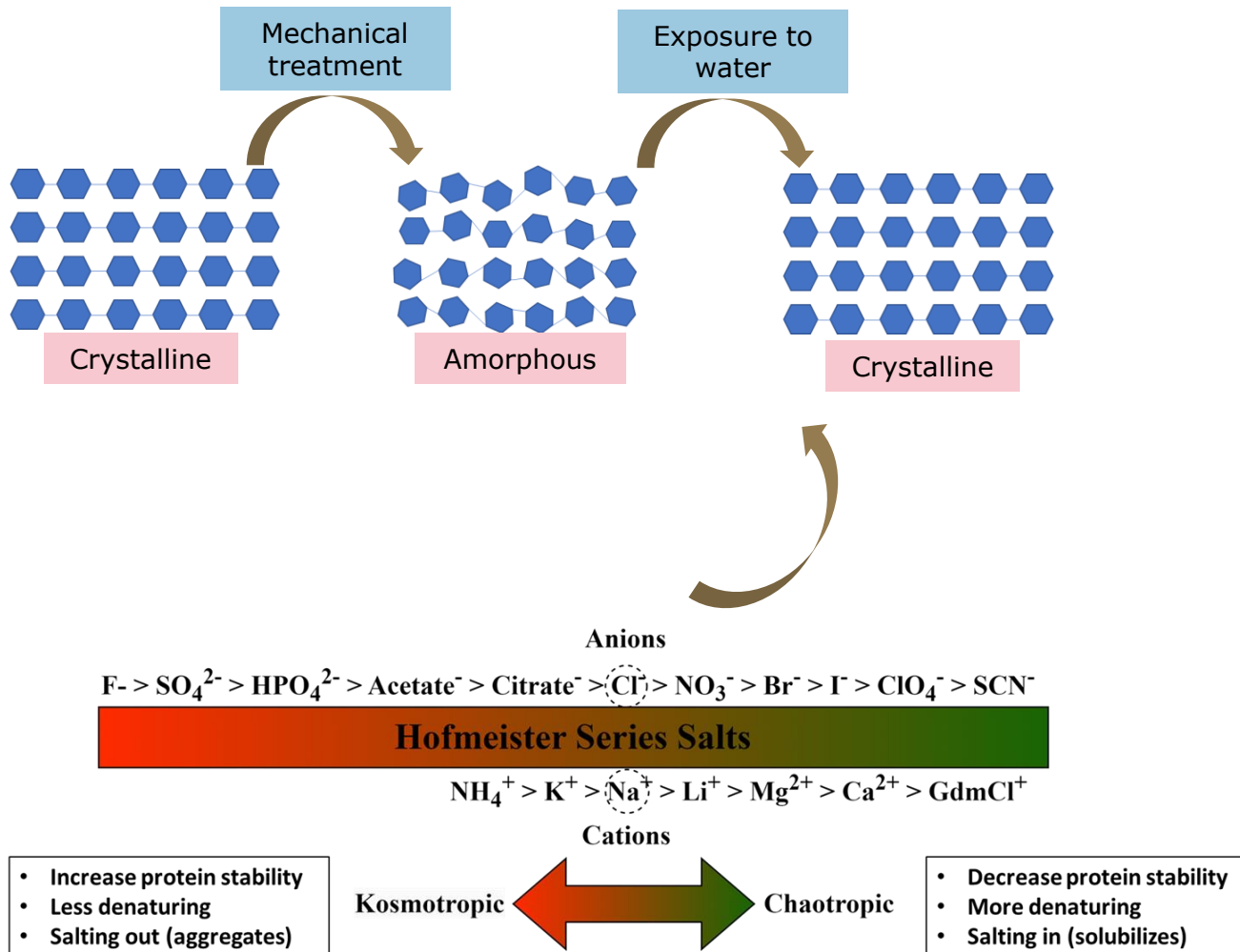
Cellulose Conversion via Hydrolysis



- One step conversion
- Simple chemistry



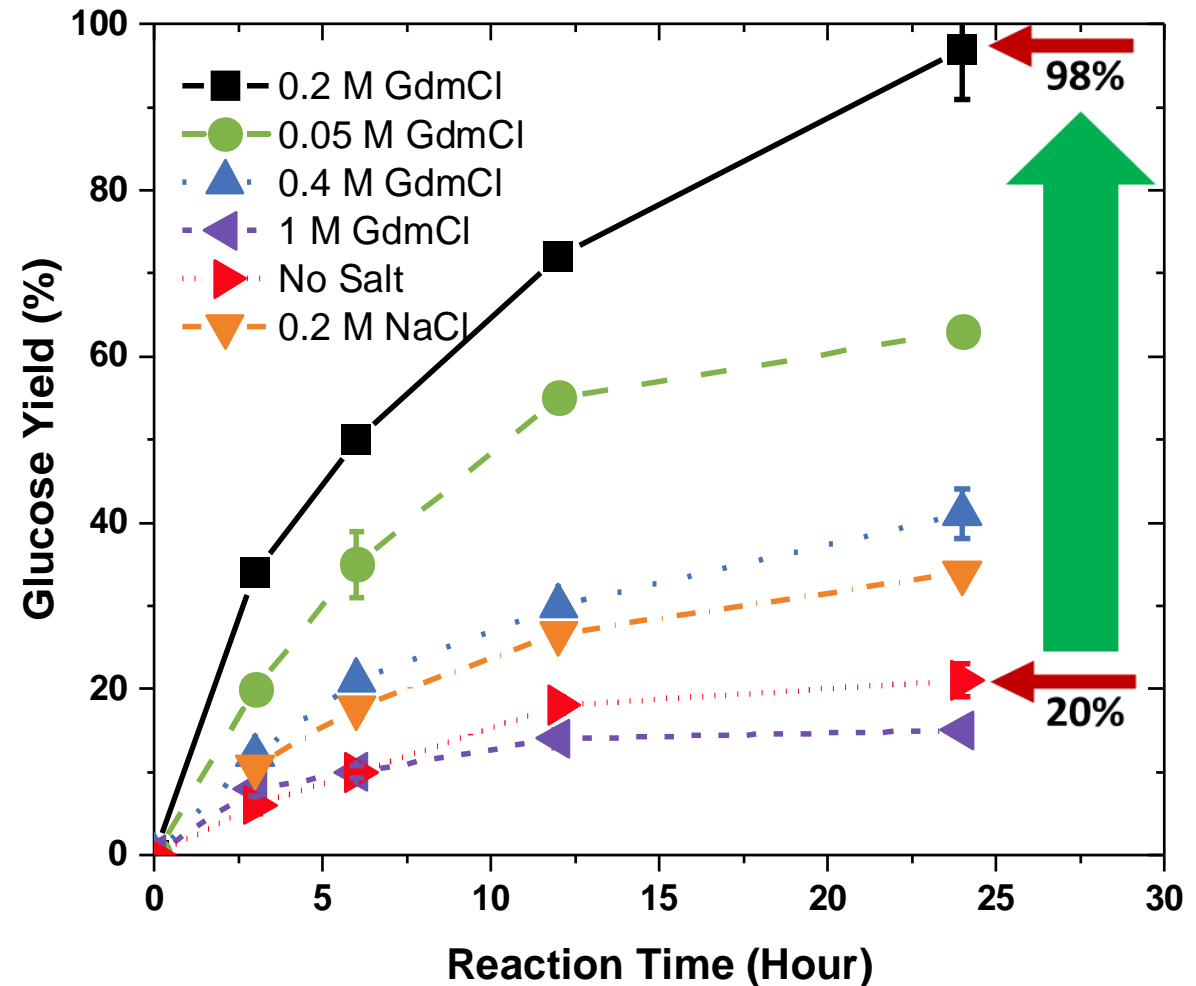
Suppressing Recrystallization in Water



- Cellulose spontaneously recrystallizes in water leading to lower sugar yields
- Hofmeister series salts able to suppress the rate of recrystallization, maintaining high selectivity for the cellulose

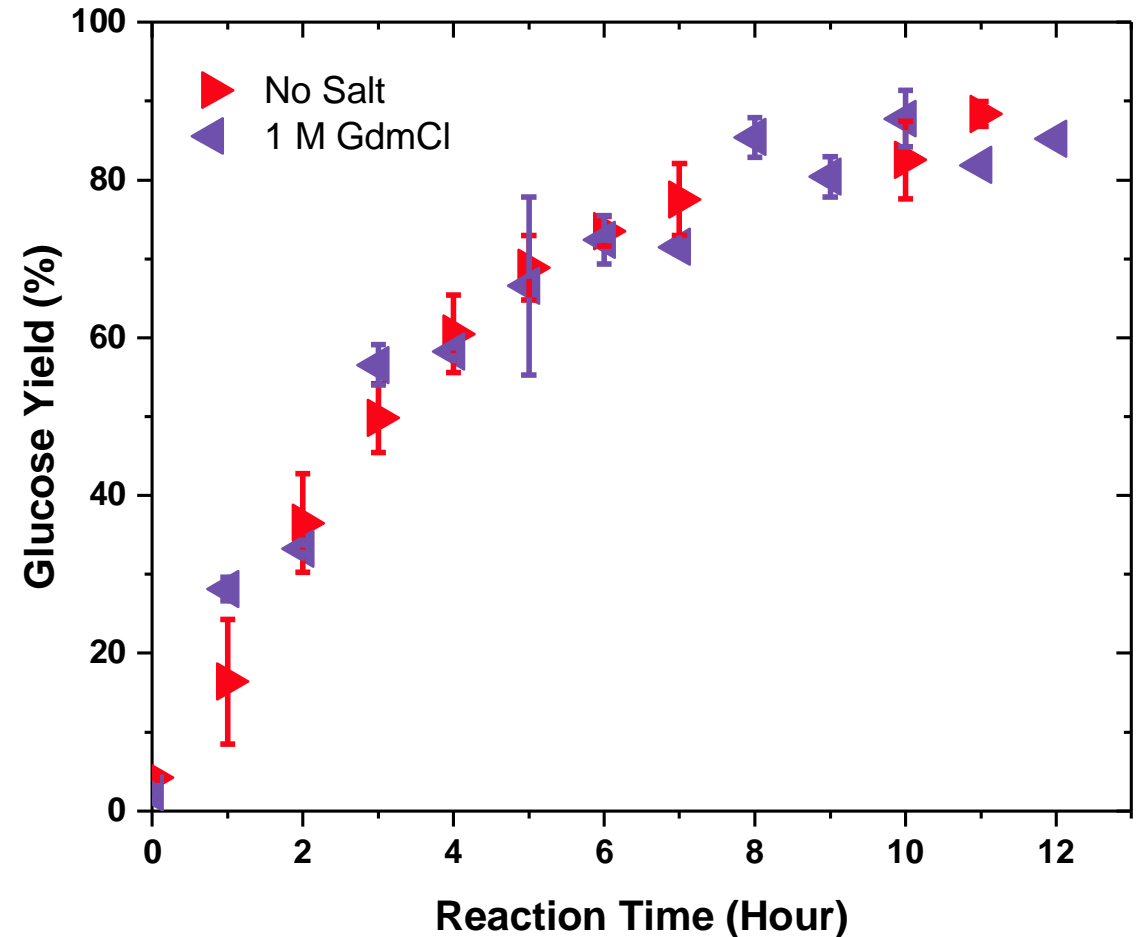
Glucose Yield: Quantified using HPLC

- Key Findings: Utilization of the Hofmeister series salt guanidinium chloride (GdmCl) at the concentration of 0.2 M **increases sugar yields by ~80%** after 12 hours of reactions
- Mystery behind the mechanism occurring for the improved yields further work needs to be done to understand



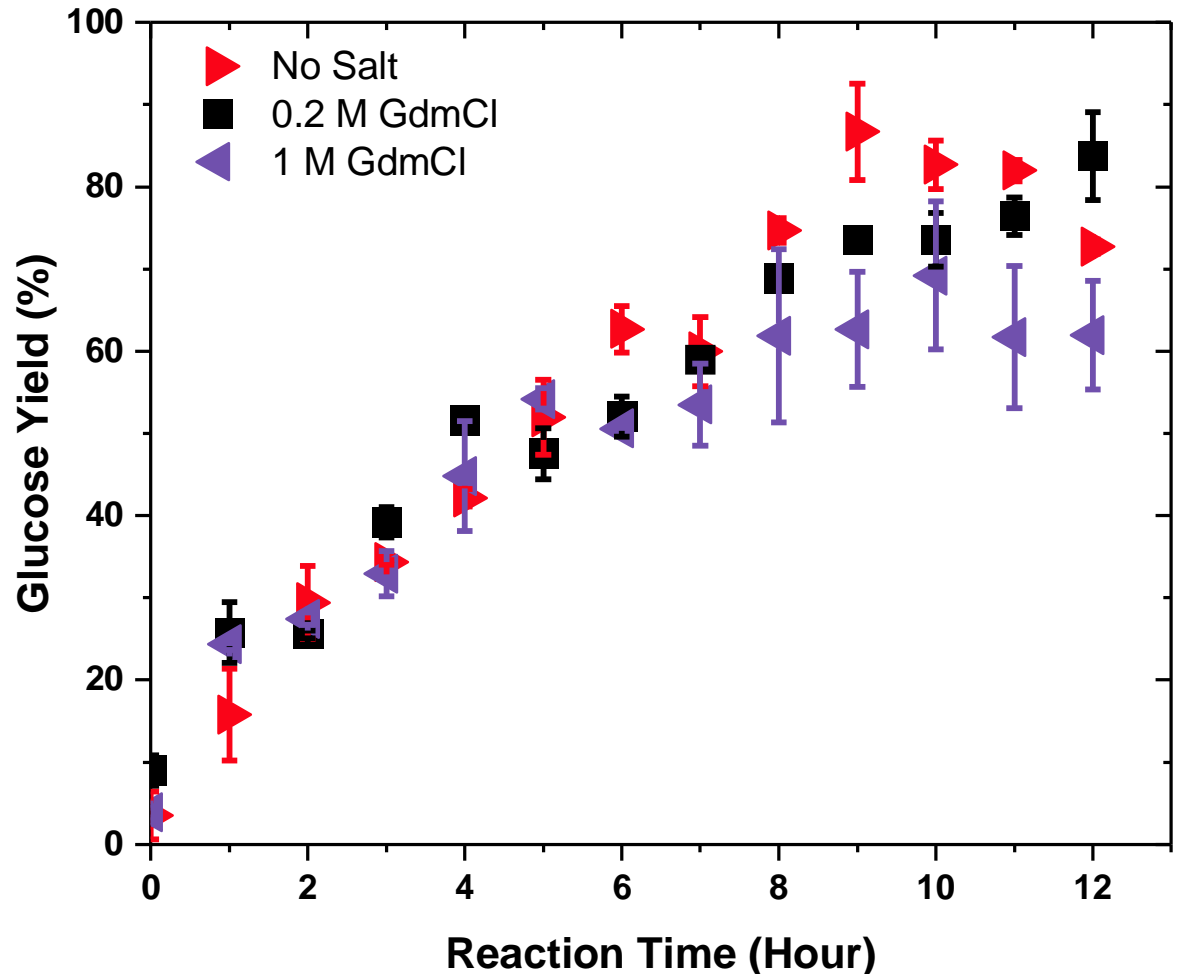
Current Work: Cellobiose Acid Hydrolysis

- Cellobiose not affected by crystallinity due to it being a small molecule and does not exhibit same structure
- The utilization of GdmCl in the hydrolysis reactions did not have an affect on the glucose yield



Current Work: Cellobiose Enzyme Hydrolysis

- Enzyme hydrolysis of cellobiose (a simpler version of cellulose) was used to understand the interaction between the enzyme and the salt
- Glucose Yield differs slightly between no salt added and with the optimal amount of 0.2 M GdmCl added





Conclusion

- Lignocellulosic ethanol production has the potential to be a sustainable energy creation process
- Hofmeister series salts hold the key to creating competitive biofuels by reducing the pretreatment cost and improving sugar yields which in turn improve ethanol yields
- This project targets Goal 7.2 (By 2030, increase substantially the share of renewable energy in the global energy mix)



Thank You!