

Our Goal: Improve Rigidity of Biodegradable Plastic Sticks for Frozen Dessert Bars

Plastics, made from long-chained molecules called polymers, are widely used in many applications.

Biodegradable plastics offer many benefits over traditional petroleum-based plastics that contribute to pollution. Our sponsor, EcNow Tech, specializes in compostable alternatives to products made from petroleum-based plastics.



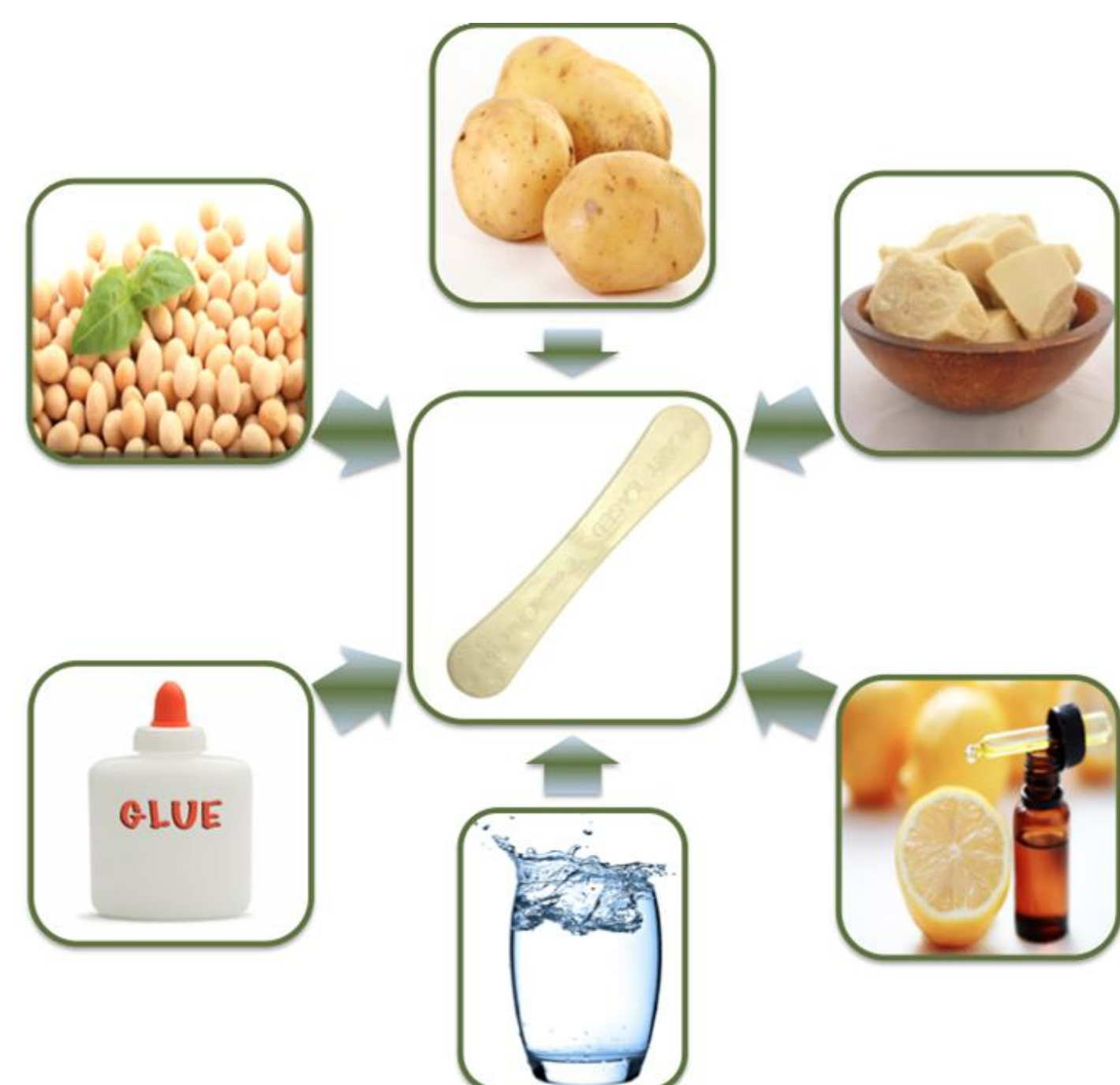
The most common type of bioplastic is thermoplastic starch (TPS), which can be blended with additives to give specific properties.

Long-term goal: create a TPS stick for frozen dessert bars (shown below) using GMO-free materials.



Our focus: optimize the ingredients in the TPS recipe to increase stick stiffness, choosing low-cost additives to decrease material and production costs.

Ingredients of a Bioplastic



Thermoplastic Starch (TPS): plant-based starch

Plasticizers: increase flexibility and processability

Surfactants: encourage even dispersion of starch

Molding Agents: prevent sticking to molding frame

Fillers: add strength and color to bioplastic

COMPOSTABLE POLYMER MIXING STUDY

Danielle Boyd, Sultan Al-Busaidi, Vanessa Kung, Elisabeth Sherry

Polymer Processing: How are Bioplastics Made?



Mixing

Raw ingredients mixed according to recipe

Extruding

Mixture melted under high temp, high shear to form plastic

Pelletizing

Resulting plastic chopped into small pieces

Injection Molding

Pellets melted and pressurized to form mold shape

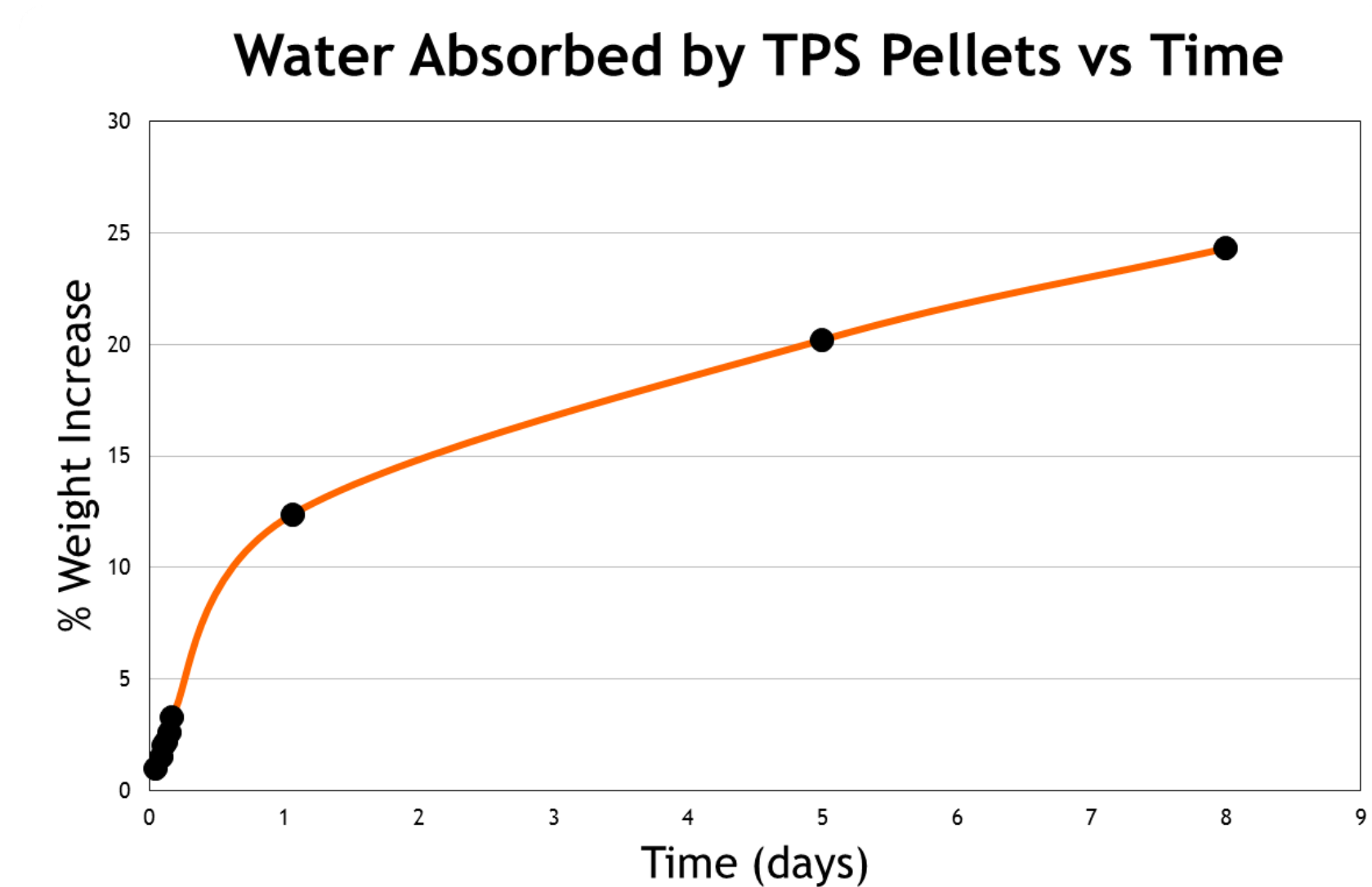
Frozen Dessert Stick

Finished product after molding

Challenge: Moisture Control in Reprocessing TPS Pellets

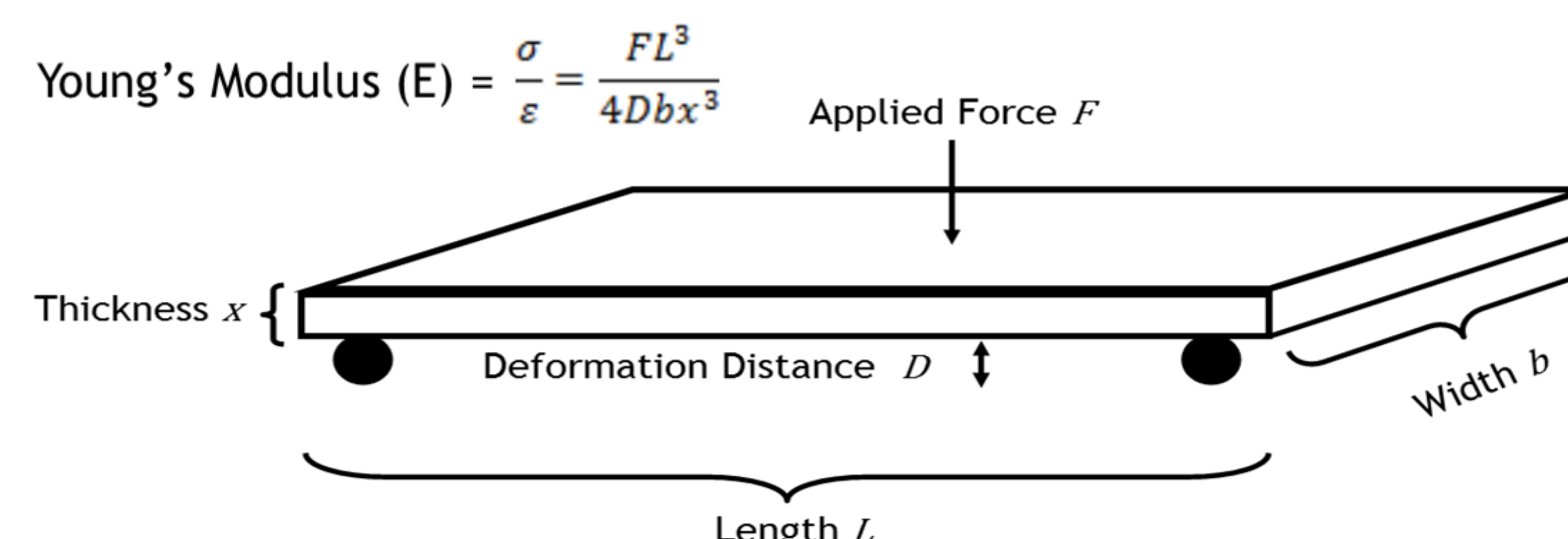
TPS pellets can be stored and later re-processed in the extruder. However, they lose water during extrusion. Even a 5% loss in moisture content causes the bioplastic to gel and clog the extruder. The following steps were taken:

- Pellets were cured in high-humidity (95% relative humidity) and high-temperature (30°C / 86°F) storage rooms to allow water vapor to diffuse into porous pellets
- Change in weight was measured to determine amount of water absorbed over time
- A curing time of 6 hours gave a desired 5 wt% increase in moisture content



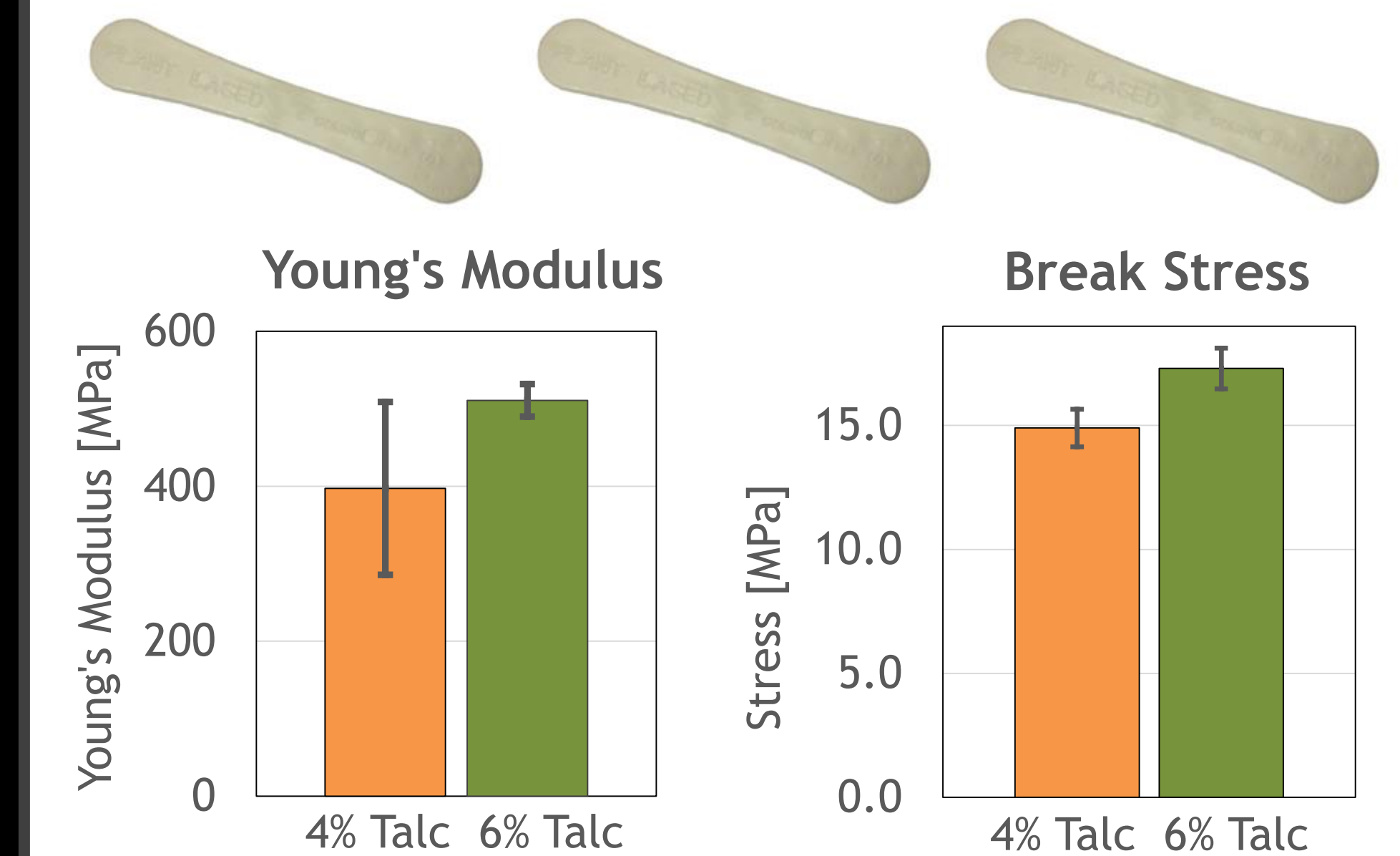
Mechanical Testing: How Strong are the Molded Sticks?

Strength and rigidity was measured using a 3-point bend test, which applies a steady, increasing load to the sample. The Young's Modulus quantifies bending distance under an applied load. The peak load, peak stress, break point conditions, and Young's modulus were evaluated for samples with 4 wt% and 6 wt% talc filler.



Results

After injection molding, bioplastic sticks with added 4 wt% and 6 wt% talc appear rigid and sturdy.



Results of mechanical testing performed 24 hours after molding are shown above. Increased Young's Modulus and break stress indicate higher rigidity of the 6 wt% talc vs. 4 wt% talc.

New issue (shown to the right): **Bioplastic sticks lose rigidity several days after molding.**

Possible causes include retrogradation (polymer matrix recrystallizes and loses plasticizers over time) and water absorption.



Future Work

Determine whether bioplastic stick flexibility is due to retrogradation or water absorption

- Polarization microscopy to track changes in polymer matrix as stick loses rigidity
- If retrogradation is suspected, add an anti-retrogradation compound to recipe

Acknowledgements

Chris Vitello (Industry Sponsor), Dr. John Simonsen (Faculty Sponsor), Kunal Kate (Graduate Advisor), Zack McClure (Undergraduate Assistant), Dr. Skip Rochefort (Thermal Analysis), Scott Leavengood (Mechanical Testing), Dr. Philip Harding (Faculty Advisor)

References

Citric Acid. Digital image. N.p., n.d. Web. <http://unclefunkydaughter.com/media/catalog/product/c/i/citric-acid.jpg>. Glue. Digital image. N.p., n.d. Web. 11 May 2015. <http://ep.yimg.com/ai/bevfabricsrafts/adhesives-tapes-glue-mod-podgr-polymer-epoxy-2.jpg>. Industrial Food Mixer. Digital image. BBC North Yorkshire, n.d. Web. Injection Molding. Digital image. Services. EcNow Tech, n.d. Web. Mini Bars. Digital image. Index of Product Images. So Delicious Dairy Free, n.d. Web. Potatoes. Digital image. N.p., n.d. Web. 11 May 2015. <http://moreinterest.org/wp-content/uploads/2014/05/interesting-about-potatoes.png>. "Regarding Cocoa Butter." Beard Monster. N.p., n.d. Web. 11 May 2015. <http://monstereardcans.com/blog/news/1702946-regarding-cocoa-butter>. Swain, Jason. Plastic Waste. Digital image. Plastic Stock Photos. Getty Images, n.d. Web.