Chemically Transforming Dead Leaves Into Adhesives

Problem / Inspiration

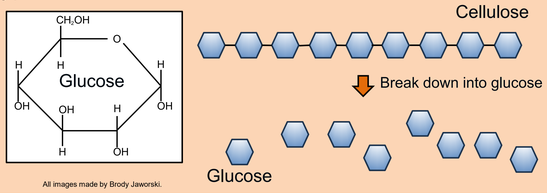
-Each Fall, trees produce 20 million tons of leaf waste that ends up in US landfills.

-Turning the dead leaves into something useful could help the environment by reducing waste and greenhouse gases.

Image from Lee Sullivan "How do towns collect hundreds of tons of leaves?" Lake Norman Publications (12-8-2021)

Background Research

- Leaves have cellulose, Na, K, Ca, Mg, Si, P, C, N, and lignin in them
- Cellulose is a long polymer chain of glucoses
- Polymers are molecules connected like a chain
- Glucose is a sugar, is sticky, and is biodegradable
- Hydrogen bonds between glucose are good to make adhesives
- Adhesives can be organized into categories whether it chemically reacts to harden or not
- Adhesion is when molecules stick to other materials, but cohesion is when molecules stick to the same type of molecule.



All images made by Brody Jaworski.

Hypothesis

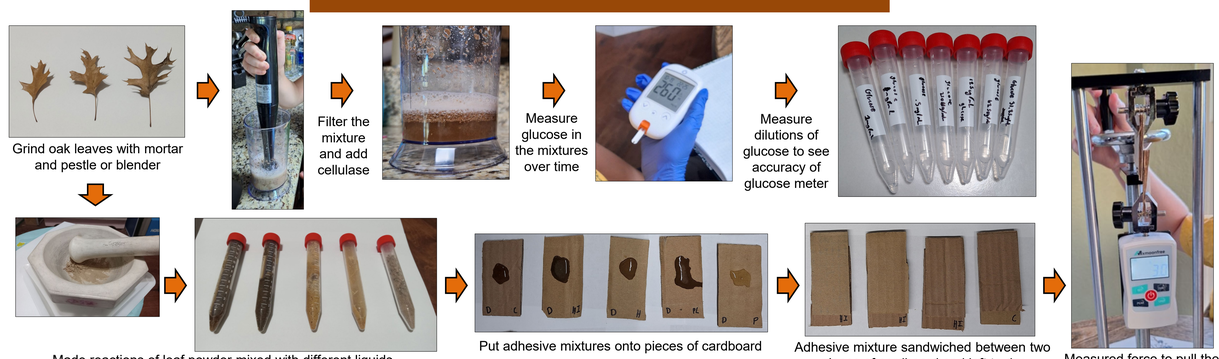
- I want to make a biodegradable adhesive by transforming the cellulose in leaves.

- My hypothesis is that I can break down the cellulose in leaves to get glucose which is a sugar, and the glucose will be sticky enough to be a good adhesive.

Variables & Measurements

Controlled Constants	Independent variables	Dependent variables
• The amount of leaves put in the tube • The volume of liquid put in the tube • The amount of the mixture put onto the cardboard	• Time of reaction • Liquid mixture used to dissolve the leaves • Let the mixture dry before or after sticking the cardboard together	• Measured force needed to pull apart the piece of cardboard • Measured amount of glucose produced from the reaction

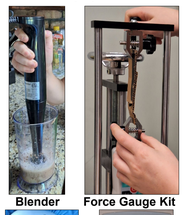
Research Plan



All photos taken by Brody Jaworski.

Materials

Equipment



Blender, Force Gauge Kit

Glucose meter, Force Gauge

All photos taken by Brody Jaworski.

Quantity	Materials
1 cubic cm	Iron Rich Dirt
14 mL	Hydrogen Peroxide
1 magnet	Neodymium Magnet
7mL	Pineapple Juice
1 set	Mortar and Pestle
1 bag	Dead Leaves
2 ft. by 3 ft.	Cardboard
100mg	Cellulase
100mL	Saline Buffer
1 blender	Hand Blender
1 kit	Glucose Meter
1 kit	Force Gauge
10 mg/mL solution	Glucose

Methods

- Get dried leaves and use magnet to collect Iron from rocky soil
- Crush leaves using mortar & pestle for making powder (or mix with blender for finding glucose concentration)
- Put powder from exactly 3 ground up leaves in each tube then add 7mL of different liquids (pineapple juice, hydrogen peroxide with and without iron, cellulase) to dissolve the leaves
- Wait for a set amount of time for reaction (for making adhesive it was 1 hour or 1 day) (for checking glucose production with glucose meter it was 12, 24, or 48 hours)
- Put 0.5mL of each mixture on a different piece of cardboard (3 in. by 1.5 in.): three sets each
- Let the mixture dry on the cardboard first or set a piece of cardboard on top and let it dry. I tried both of these to see what kind of adhesive it could be.
- Let it sit for 1 day and measure force needed to pull apart the two pieces of cardboard that are stuck together with the different adhesive mixtures
- Take average of the force to pull apart the cardboard for each adhesive mixture and for both reaction times

Observations

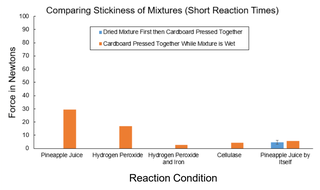
- The hydrogen peroxide mixture caused no immediate bubbling, but after one day when I opened the tube it released gas and bubbled.
- When I used Iron and hydrogen peroxide it turned black and bubbled immediately and later became pale and the leaves dissolved.
- The pineapple juice caused no bubbling at first, but after 1 day the leaf mixture turned black.
- The cellulase mixture caused no bubbling and remained brown at first but after 1 day it became dark brown and nearly black.

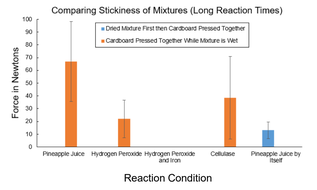
Force it Took to Pull Apart the 2 Pieces of Cardboard in Newtons

Dried Mixture First then Cardboard Pressed Together	Pineapple Juice	Hydrogen Peroxide	Hydrogen Peroxide and Iron	Cellulase	Pineapple Juice by Itself
Sample 1	0	0	0	0	19.2
Sample 2	0	0	0	0	6.3
Sample 3	0	0	0	0	13.9
Average	0	0	0	0	13.1333333
Standard Deviation	0	0	0	0	6.48408308

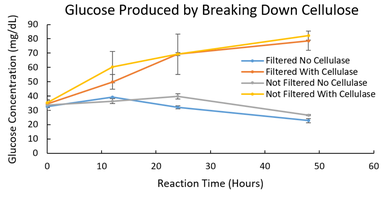
Cardboard Pressed Together While Mixture is Wet	Pineapple Juice	Hydrogen Peroxide	Hydrogen Peroxide and Iron	Cellulase	Pineapple Juice by Itself
Sample 1	103.1	12.1	0	11.9	0
Sample 2	45.7	15.2	0	74.5	0
Sample 3	52.3	39	0	28.9	0
Average	67.03333333	22.1	0	38.4333333	0
Standard Deviation	31.40849142	14.7176764	0	32.3705628	0

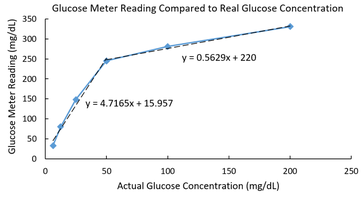
Graphs & Charts





Glucose Produced by Breaking Down Cellulose									
Reaction Time (hours)			0	12	24	48	0	12	24	48
			Glucose Meter Reading (mg/dL)				Actual Glucose Concentration (mg/dL)			
Filtered Leaf Mixture	No Cellulase	Trial 1	181	196	180	143	33.3	39.4	33.0	21.9
		Trial 2	178	196	176	151	32.2	39.4	31.5	23.9
	Cellulase	Trial 1	180	224	246	253	33.0	53.7	68.5	74.0
		Trial 2	189	211	248	264	36.4	46.5	70.0	83.6
Not Filtered Leaf Mixture	No Cellulase	Trial 1	175	186	194	160	31.2	35.2	38.5	26.4
		Trial 2	189	192	200	162	36.4	37.7	41.1	27.0
	Cellulase	Trial 1	190	246	260	265	36.8	68.5	80.0	84.5
		Trial 2	182	223	234	260	33.7	53.1	60.0	80.0





Real Glucose Concentration Compared to Glucose Meter							
Glucose Meter Measurement (mg/dL)	331	281	245	148	80	33	Too Low
Real Glucose Concentration (mg/dL)	200	100	50	25	12.5	6.25	3.125

All images made by Brody Jaworski.

Analysis of Results

- The experiments where I tested how sticky the mixture was by pressing together while wet showed the most force it took to pull the two pieces of cardboard apart was for the positive control (pineapple juice with leaves) then the cellulase with leaves was next strongest.
- The experiments where I tested how sticky the mixture was after drying and then pressing the cardboard on it showed that only the pineapple juice alone was still sticky and could be reused.
- After 24 hours, the cellulase was able to cut the cellulose into glucose

Conclusions

- The cellulase cut the cellulose into glucose and made a good adhesive
- Except for the control, the cellulase reaction made the strongest adhesive which could hold 9 pounds (40 Newtons).
- The Hydrogen Peroxide with Iron did not work very well as an adhesive, because I think that the Iron catalyst made the reaction too fast so it cut all the bonds in the cellulose and cut it randomly.
- These experiments show that my hypothesis was correct, because the glucose made from cutting the cellulose in the leaves was sticky.

Applications

- Since most adhesives are made from petroleum products that do not degrade easily and cannot be recycled, I think this can be a good way to make biodegradable adhesives
- Adhesives are used in many ways like packaging, construction, and in everyday use like glue and tape.

Future Work / Improvement

- In the future, I would see if there is any way that I can make it have better adhesion by combining it with other substances.
- A problem with this now is that the solutions takes a long time to dry, so I hope I could improve this by making it more concentrated with either more leaves or using less liquid in the reaction mixture.

Works Cited

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