

Name: ____ **Teacher's guide** ____

Partner(s): _____

Class: _____

Polymer Pie!

Background:

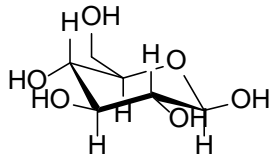
When we often think of polymers, the first thing that comes to mind might be plastics or rubber. However, polymers exist in nature as well as being created synthetically in the lab. Plants synthesize polymers of repeating glucose molecules in order to store sugar more effectively in grains and tubers (a specialized root) in order to use the energy in the future. There are 2 main types of starches: *amylopectin* which is highly branched and exhibits a star-like structure of hundreds of glucose units, and *amylose* which exhibits little branching. These two starches have very different properties from each other and will interact with water quite differently.

How is starch used to form a gel? Starch consists of two main components amylose and amylopectin. Amylose is a linear polymer, which forms a helical crystalline structure, while amylopectin is branched. Due to the many hydroxyl groups along the backbone of these polymers they are able to form many interchain hydrogen bonds. When heated in water these hydrogen bonds break allowing the amylopectin to swell. At the same time the amylose is extracted into the water. This process will drive a thickening of the solution. When the solution cools gelation will occur as the amylose molecules reform interchain hydrogen bonds resulting in a three-dimensional load bearing network. Therefore, the ratio of amylose to amylopectin changes the properties of the gel. A higher fraction of amylopectin (such as in potato starch) typically results in a better thickening at high temperature and a softer gel when cooled. The opposite is true in a higher amylose starch (such as corn starch) which has poorer high temperature thickening properties, but forms stronger gels.

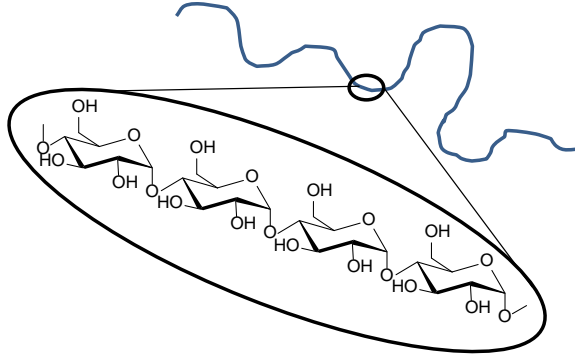
Pre-lab: (internet access required)

Draw the following structures:

Glucose



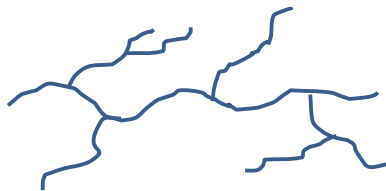
Starch (polyglucose)



amylose: straight



amylopectin: branched



Define and describe: **adjust your requirements as needed; the answers below are the minimal requirement**

Polymer: a molecule of high molecular mass consisting of repeating units known as monomers. For example starch is poly(glucose) formed by repeating glucose units.

Glycosidic bond: A covalent bond joining a sugar molecule to another molecule. Starch is formed by successive glycosidic bonds between glucose molecules forming polymer chains. Here the glycosidic bond is formed as an ether linkage (oxygen bonded to two carbons) by the condensation of two hydroxyl (-OH) groups with water (H₂O) as a byproduct.

Viscosity: The viscosity quantifies a liquids resistance to flow. For example, molasses has a much higher viscosity than water.

Gel: A gel is a material that shows solid like behavior (resistance to flow), while being primarily composed of a liquid (typically > 90%). This is typically accomplished by the presence of a polymer which forms a three-dimensional load-bearing network in the liquid.

Tyndall effect: scattering of light due to small particles suspended in solution

Hydrophobic: water “fearing;” hydrophobic molecules are not soluble in water. A good example is oil, which forms droplets when mixed with water.

Phase separation: phase separation occurs when two substances are not compatible forming separate phases. A good example is oil and vinegar, which separates into two distinct layers when left unstirred.

Rheology: Study of flow.

List and describe at least 3 desirable properties of a good pie filling. Focus on texture and stability.

Answers will vary but should include properties like shelf life, ability to hold other “fillers” like sugar and flavorings, ability to be cut into pieces and still maintain shape, etc.

Problem: The recipe on the cornstarch package states that it is necessary to dissolve $\frac{1}{4}$ cup of cornstarch into 2 cups of water. How much water is needed to prepare 4.0 g of cornstarch? ($\frac{1}{4}$ cup of cornstarch = 32.0 g, 1 cup of water is approximately 225 mL)

$$\begin{array}{|l|l|l|l|} \hline 4.0 \text{ g C.S.} & \frac{1}{4} \text{ cup C.S.} & 2 \text{ cups H}_2\text{O} & 225 \text{ mL} \\ \hline & 32.0 \text{ g C.S.} & \frac{1}{4} \text{ cup C.S.} & \text{.cup H}_2\text{O} \\ \hline \end{array} = 60.0 \text{ mL}$$

Materials

50 mL graduated cylinder

Syringe or pipette

Balance

2 small test tubes

150 ml beaker

2 Semicircular lenses or petri dishes

Hot plate or burner/ring stand apparatus

Handheld laser

Thermometer

Lugol's reagent (really dilute: 4-5 drops per 20mL H₂O works well. Should just barely have an amber color)

Stir rod/stir plate

Cornstarch

High amylose starch such as potato, kuzu root, or rice

Procedure:

Day 1:

1. Obtain 4.0 grams of cornstarch and place it in the beaker.
2. Add your calculated amount of water from the pre-lab problem.
3. Stir constantly and heat the mixture slowly. Record the temperature when you notice a change in the appearance of the mixture.
4. Use the syringe or pipette to add 1.0 mL of the mixture to the test tube. Add 1 drop of the Lugol's reagent and stir. Record the time that it takes to see the characteristic dark blue color.
5. Pour the rest of the mixture to the petri dish and set aside to cool.
6. Repeat the procedure with the other starch.

Day 2:

1. Obtain your gel sample from yesterday and describe the extent of gelation and the appearance of the 2 gels.
2. Shine the handheld laser through the sample from the side and describe what you see.
3. Discuss within your group ways that you could improve the consistency of your gel, finalize a plan, get approval from your instructor, and test it.

Your procedure:

Data:

Starch	Mass	Water (mL)	% by mass of starch	Drops of Lugol's reagent that it took to turn the gel blue	Angle of refraction/ extent of scattering
corn				Will vary, but should be the highest number	All scatter light
High amylose				Lowest number	All scatter light
yours				Varies on procedure chosen	All scatter light

Conclusions

1. Calculate the % by mass of the starch in your samples using the following formula:

$$\frac{\text{Mass of starch} \times 100\%}{\text{Water} + \text{starch}}$$

2. How did the amylose content of the starch affect the final quality of the starch? Why do you think this is the case?

The higher amylose starch tends to form a less viscous mixture at high temperature, but a stronger gel when it sets. This is because the amylopectin drives the main thickening effect of the water, while the amylose is responsible for the final gelation of the material.

3. What type of a mixture did you create? How do you know? (hint: homogeneous, heterogeneous, which specific type)

Heterogeneous; colloid: evidenced by the light scattering ability using the laser or other small light source.

4. Was there a difference in the number of drops that it took to turn the Lugol's reagent blue? Why do you think this is the case?

The higher the amylose, the fewer drops. Amylose forms a helical crystal structure. The iodine is able to enter this helix and complex with the amylose resulting in a blue color due to its interaction with light.

Extension: choose one of the following projects. All projects must contain at least 2 references.

- Create a vegan gelatin dessert complete with a recipe and bring in for the class
- Build a model showing how water "swells" the starch molecules along with a description of what is happening
- Scale up your recipe to create a higher amylose pie using another starch other than corn starch. Make sure to provide a recipe.
- Write a 1-2 page report about how the human body digests amylopectin vs. amylose.
- Create a meal plan following the USDA's dietary recommendations that includes high amylose carbohydrates
- Design and conduct an experiment to test the flow rate of the starch