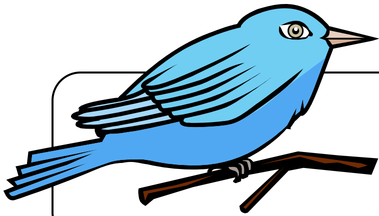


Starch Yer Thinkin' About Corn Products

Summary:

In the next two lessons, students will learn about the parts of corn and began to particularly explore the role of starch. In this lesson they will extend this analysis by learning about the behavior of cornstarch in water using physical science tools. This concoction is also useful to create an environmentally-friendly replacement for packaging peanuts, which biodegrade with ease. Corn is a consumer and earth friendly product.

In some activities, students will utilize simplified and symbolic models to explore processes that a difficult to understand. Model building is an important part of a scientific investigation because it allows us physically represent particles of a substance that are intricate and too small to see, such as the behavior of starch and water at the particle level.

Background Information:

Corn kernels consist of four main parts: the *pericarp* (the hull or outer covering), the *germ* (the part that sprouts), and the *endosperm* (the starch inside that expands), and the *tip cap* (where the kernel's attached to the cob). The starch is the "food" for the corn and provides energy for its growth. Starch can be separated from other kernel components through a method called wet-milling. It can then be dried and used in a number of practical ways (please see Appendices).

Combining water and starch is a physical change—the molecules do not permanently attach. When you apply a slow, small force to a starch & water mixture, the starch granules have time to keep their even spacing and, therefore, it moves like a liquid. When you move it quickly, the granules jam together and it acts like a solid. In addition to providing an interesting tool for exploration of physical properties, this concoction can be molded and dried into a useful plastic-like solid.

Polymers are long chains of repeating, smaller molecules that are stuck together. Starch polymers are made of a string of repeating sugar molecules. Heating up a starch & water mixture causes it to form a gel because of chemical changes at the molecular/particle level. Granules of starch are penetrated by fast-moving water particles, and the water breaks up and tangles the starch polymers.

The regular packaging peanuts are made of polystyrene, which is a kind of plastic like Styrofoam. They are made into solid from the clear liquid styrene, which is made from petroleum and natural gas byproducts. These materials are not soluble in water, so water can't penetrate the peanut and enter the air spaces like it can with air-puffed starch. Because petroleum is oil, it is going to repel water, in fact. Their chemical structure is extremely complex, so it is really hard to break them down in anyway (except by physically chopping them up!). In a compost, microorganisms (which are commonly found in soil) are able to break substances down chemically because of the enzymes they secrete. Then these simple sugars can be used as energy sources by the microorganisms.

Grade Level: Middle school

Goal: Discover connections between features and functions of corn and corn products. Gain insight into the importance of corn refining in Wisconsin, and the benefits of its byproducts.

Key Concepts: cultivate, refining, wet milling, starch, iodine test, mixture, physical vs. chemical change, modeling, adhesive, plastics, biodegrading, enzymes, plastic, compost, eco-friendly

Objectives: Upon completion of this lesson, students will:

- *identify* the presence of starch in corn.
- *offer insight* into the some of the industrial and everyday uses of starches process through corn refining.
- *recognize* model building as an important part of a scientific investigation because it allows us physically represent particles of a substance that are intricate and too small to see.
- *make observations* about the properties and behavior of a starch & water mixture involving different variables.
- *prepare* a physical model of water and stones that can be used for experimentation and manipulation to *make conclusions* and predictions about particles, which we cannot see.
- *Conduct an experiment* that compares petroleum vs. cornstarch-based plastic products to determine which are made of organic, water-soluble ingredients (meaning they won't occupy as much space in landfills and they will have less of an impact on living things in the natural environment.)

Teaching Location: Large classroom complete with sinks. Field trips to corn fields and refineries, if available.

Lesson Time: approx. three sessions of 85 minutes each. Activity 3 requires 5 consecutive days of brief data collection. Writing activities not completed in class may be homework.

Subject Areas for Infusion: Science, Social Studies, Language Arts, Art

Standards Addressed: please see References page at end.

Materials: overhead projector, dried corn kernels, exacto knife, magnifying glass, bag of frozen corn, bowl, slotted spoon, water, cheesecloth, food coloring, newspapers, box of sturdy plastic ziplock bags, iodine, children's books about corn, corn starch, plastic containers (one per group), sand, bag of colored stones, twist ties, corn oil, packaging peanuts (corn and plastic), paper plates, measuring spoons, eye droppers (one per group), "Degradibility" lab materials (see Activity 3) which includes composting activators.

Vocabulary:

- *A mixture* is a material consisting of two or more substances that are not chemically bound to each other and can be separated.
- *Wet milling* is a process involving techniques such as grinding, screening, and centrifugation to separate purified starch from fiber, oil, and protein.
- The *endosperm* makes up over 80 percent of a kernel, and is the source of starch (energy) and protein for the new corn plant. (It's also visible as the white, fluffy part of popcorn.)
- *Plastics* are synthetic (man-made) materials made of polymers. Polystyrene is the plastic known as Styrofoam, and it's made of petroleum and natural gas byproducts.
- *Biodegradable* means something is capable of being broken apart by natural biological processes. the microorganisms.
- *Dissolving* is a physical change where particles of the solute disperse amongst the particles of the solvent into which it's placed, striving to reach equal distribution (equilibrium).
- *Starch* consists of basic and naturally occurring elements: carbon, hydrogen, and oxygen. *Starch polymers* are a chain of repeating sugar molecules. This means that starch can be broken down into more simpler sugars.
- *Enzymes* are naturally occurring chemicals that help to promote biochemical reactions.

Set-Up:

1. Divide corn kernels (one per student) in half vertically with an exacto knife and keep moist.
2. Gather frozen corn, a bowl, and a potato masher. Complete steps 1-3 of the Homemade Cornstarch recipe. Create an additional batch to have dried for the 2nd half of Activity 1.
3. Gather materials for starch modeling activities into bins for lab groups to retrieve. Have teacher demo at hand.
4. Create/photocopy overhead transparencies and lab data collection sheets for each student.
5. Lay down newspapers for Gooblek activity.
6. Gather materials for Biodegradiblity lab (Activity 3) into bins for lab groups to retrieve. Labels groups of plates A, B, and C. Create teacher demo at hand.

Procedure:

Parts of a corn kernel

The **pericarp** protects the endosperm and germ from being physically injured, and also from some insects and diseases. It resists water and water vapor.

The **tip cap** is the point where the kernel was attached to the corncob. It served as the major pathway for food and water to the kernel.

The **germ** is the only living part of a kernel. It contains all the information the kernel needs in order to grow into a corn plant, plus vitamins and minerals the small plant will need. The *germ* is made up of 25% corn oil.

The **endosperm** makes up over 80 percent of the kernel. It is the source of starch (energy) and protein for the new corn plant.

Introduction: Provide each student with a magnifying glass and a large kernel of corn that has been split in half. In their lab books, the students will work with their lab partner to draw a picture of the vertical cross-section of the kernel (or color in an outline of the kernel provided by the teacher). They will then refer to an overhead of the following information to label the parts of the kernel. Afterwards, the class will share information to revise their diagram.

This will provide a basis of knowledge for the materials that can be found inside one of Wisconsin's most popular crops: corn. The rest of the class will focus on the corn's energy source: starch.

Activity 1: Starch Extraction

1) In order to create usable starch material for the day's model-building activity, the students must dive right into the seeing process of extracting these particles. Start with steps 4 and 5 (see below), and explain to the students what was done previously. The teacher says they will continue this "kitchen component" in about 15 minutes.

Homemade Cornstarch

Part One

1. Thaw a package of frozen corn and place in a bowl.
2. Crunch up the corn with a potato masher, cover with water.
3. Let stand about 24 hours.
4. Remove the corn from the bowl with a slotted spoon.
5. Allow the water to stand another 15 minutes.

Part Two

6. Very slowly, gently pour the corny water through a piece of cheesecloth. The starch to become trapped in the cloth--You can feel and see it.
7. On a small portion of the cheesecloth place a drop of iodine. (If starch is present, the iodine changes from a reddish-brown to a blue-black.)
8. Allow the remainder of the cheesecloth to dry overnight.
9. In the morning, feel and taste the powder remaining on the cheesecloth…cornstarch!

2) The teacher will bring around the bowl to all the group clusters, and students will be asked to record some initial observations about the corn concoction in their journals. How has the corn size changed, what is the color of the water, are certain parts sinking in the liquid, etc. What's going on inside the corn, what happening to the water? What could the teacher be up to?

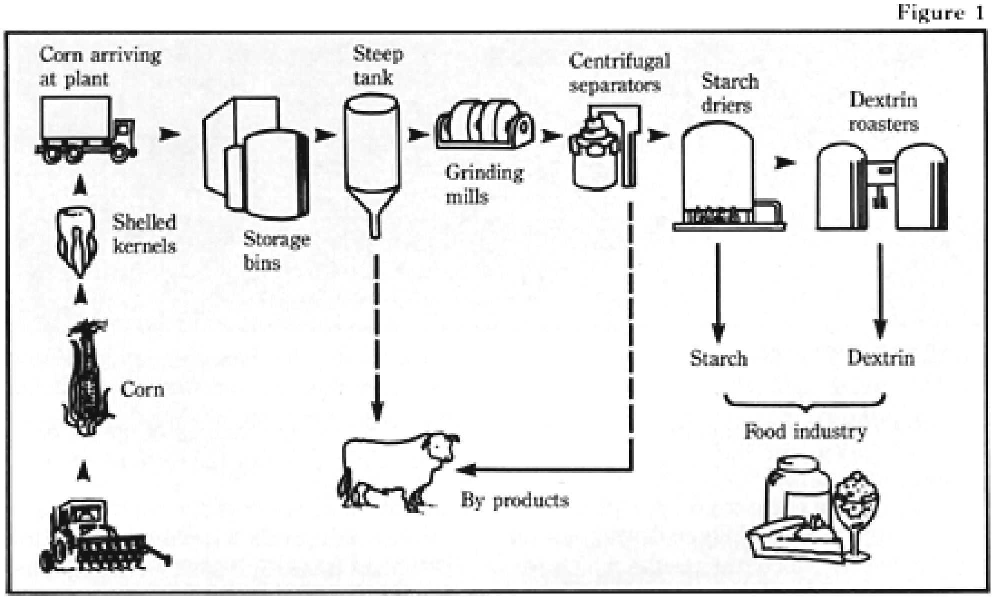
3) Review again the parts of corn on the large diagram.

4) The teacher asks students why they think corn refineries exist. (It would be relevant to define "refine" in this context.) Possible answers may include that there are used to recycle unused leftover corn, that they are to clean corn, that they are for cooking, or that they are to chop up corn. The teacher explains that the purpose of corn refining is to separate out the four parts of the corn kernel (pericarp, tip cap, germ, and endosperm) and the convert them to higher value products like sweeteners, starch, oil, fuel, and animal feed.

5) The teacher may decide at this time to read chapter nine "The Plant of Many Uses" from the book *The Story of Corn* by Peter Limburg, paying special attention to the paragraphs that overview the refining process and discuss why it's important. It would be fabulous if there was a way for students to take a field trip to a corn refinery or processing plant to see this chain of events in action. Explain that today's science discovery is centered around the corn's starchy mass that, as they recall, is found in the endosperm.

6) Place an overhead transparency of the diagram at right on the board. Explain the following: cornstarch is often extracted from the kernel through a process of wet milling. The process involves techniques such as grinding, screening, and centrifugation to separate purified starch from fiber, oil, and tightly bound protein (see diagram to right).

Figure 1



The corn wet milling process

Now explain the steps of the refining process (see below). She or he might draw a diagram of this process during the short lecture for students to follow along, or ask students to sketch one as they listen. It would be helpful to have brought in samples of corn that show how the parts might look (more or less) in the various stages. The teacher should constantly make reference to the students' observations of the corn kernels from the previous lesson.

WET-MILLING PROCESS *(from www.ncga.com)*

STEP ONE: STEEPING

1. At the refinery, the corn is inspected and cleaned.
2. The corn is steeped, or soaked, in cool water for 30 to 40 hours.
3. The kernels double in size as they absorb the water.
4. As the kernels swell, the gluten (protein) bonds loosen and the starch is released.
5. The steep water is drained and used in animal feeds.
6. The corn is coarsely ground to separate the germ from the rest of the kernel.

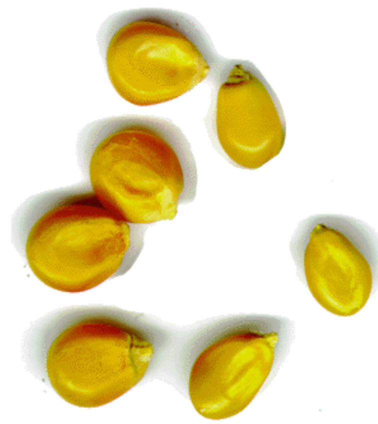
STEP TWO: GERM SEPARATION

7. The coarsely ground corn is mixed with a small amount of water.
8. The mixture is moved to a germ separator that spins the corn germ out of the water.
9. The germ is screened to make sure no starch is present.

10. Corn oil is then extracted from the germ and any remaining germ is used in animal feeds.

STEP THREE: STARCH AND GLUTEN SEPARATION
11. After the germ has been removed from the coarsely ground corn, the rest of the kernel is ground again.
12. It is mixed with a little more water.
13. The fiber is screened out of the corn, so that only a starch-gluten mixture remains.
14. The gluten has a lower density than starch so a centrifuge is used to separate the two.
15. The gluten is a protein used in animal feed.
16. The starch can be dried and marketed as unmodified cornstarch, or it can be modified into specialty corn starch, or converted into corn syrup or sugar, or processed into biodegradable plastics, or fermented and used in ethanol.

7) Tell the students that they will be experimenting with cornstarch today to learn how starch particles react in water, and how knowledge about that mixture is useful for making products in our society. The teacher will solicit some of the students' newly-considered ideas about mashed corn. Now complete the class will complete part two of the "homemade cornstarch" recipe, which is essentially a rudimentary way of processing corn. Since it takes overnight for the liquid to evaporate, the teacher will have already prepared a batch of the corn starch to study. The teacher should walk around the classroom allowing the students to see, touch, smell, and even taste the residual remnants.



8) Give a brief explanation about *indicators*, in this case, iodine (the liquid's chemicals react only with certain substances). It's best for each student group to have its own sample of cornstarch-laden cheesecloth to test with iodine. Review by telling students that this test gives evidence of the large amount of starch within the corn.

9) Because it isn't feasible to create enough homemade cornstarch to suffice the entire population of the class, the remainder of the day's activities can be done using boxed cornstarch. Make sure the students understand this substitution and accept it as logical and valid.

Activity 2: Gooblek adhesive

1) MAKING OBSERVATIONS: Divide students into small groups. Each group member should measure out ¾ cup of cornstarch and ½ cup of water and place in a plastic container.[1] If desired, student can add 3 drops of food coloring to make the substance more observable. Tell them to use a spoon to evenly blend the water and cornstarch until it's thick enough to roll a ball between their palms. Give the students a chance to explore this material for at least 5 minutes, simply playing around with it (safely) and noticing its attributes. How does it feel? How does it look? They can talk within their group to share reactions.

2) MAKING INFERENCES AND GENERALIZATIONS

1) The teacher now poses the question: What state of matter is this creation? (Students will respond with different ideas and justifications because it behaves as both a solid and a liquid.) At this point students should retrieve their science journals (they might get a little slimy here, but that's okay!). Dividing one page vertically, students should jot down 8-10 properties of their cornstarch slime on the left, and on the right, classify that characteristic as evidence of it being a solid, liquid, or gas.

2) The teacher should have an overhead transparency of further investigative ideas for the students to consider within their groups, and should also be encouraged to come up with additional points of analysis. Examples include:

- *Roll* Gooblek into a ball between your palms, then let it sit in one hand. What happens?
- It is possible to *break* Gooblek into pieces?
- Does the "liquid" ever splash when you slap your Gooblek chunk?
- Touch the Gooblek in your cup, then squeeze some on your hand. Is it wet, dry, or both?
- Can you rest any objects on top of Gooblek, or do they always sink?

3) Group presentation of ideas: For the sake of fluidity and consistency of presentations, each small group should have filled out an overhead with notes on those three categories. (For example, a group might say: *We*

[1] It's wise to avoid pouring Gooblek down the drain because it will clog. Disposing of it in the garbage is the best. It is non-toxic and biodegradable (it's just corn!)

they noticed it behaved like a liquid when you just set it out, and it stays like a liquid when you pour it from the cup. It seems solid when you squeeze it, plus you can rip it if you go fast. We think it's both liquid and solid, somehow. We still wonder why it doesn't stretch like taffy, if it matters how much water there is, or if what happens if we heat it up).

4) Conclude this portion by summing up for students that fact that this material does not behave clearly as a solid nor as a liquid in every respect. But is it possible to be both, or something completely different? When we mix these particular solid and liquid substances together their particles interact in different ways depending, mostly, on the force we apply to it. Moving it slowly, it seems to flow like a liquid, but pushing or pulling on it makes it seem as though it's solid. At this point, the idea is to figure out what is going on inside this mixture to allow the water and starch particles to behave in these atypical ways.

5) Point out that what's being looked at is a physical change. The teacher will have evidence of this feature by having already set aside some Gooblek that has been set out in the sun for several hours. Ask what's left of this concoction (it's dry and powdery, like cornstarch) and has students observe what happens when water is added (it turns back into Gooblek again). The teacher reminds students that this is evidence of a physical change because neither material has changed its essence when they were combined. It could once again go back to its original state. Also, the teacher formally introduces the work mixture as being "a material consisting of two or more substances that are not chemically bound to each other and can be separated."

3) DEVELOPING PHYSICAL REPRESENTATIONS (AND TESTING THEM AGAINST OBSERVATIONS)

1) Tell students that in order to help them better understand the movement of particles in Gooblek, they are going to all make a physical model of the water particles and starch pieces. Each group receives a sturdy clear plastic bag and a twist ties (to seal the end, but not make it totally air-tight), 2 cups of sand, and 10 darker-colored ½ inch diameter stones. Ask students which substance refers to the water particles and which refers to the starch grains. (They should reply that the starch is larger—because it's solid and you can see each individual piece). Explain that the proportions of the materials are also similar to the original Gooblek recipe (to be true to the model).

2) Instruct the students to fill their bags with the materials and close the top with the twist tie, trying not to trap too much air. The students should spend a few minutes manipulating their models in the same way they originally did with the Gooblek, squishing it, rolling it, letting it rest in their hands, gently throwing it, pressing it, etc. Does it seem to behave in the same way as the Gooblek? Is this model directly correlated to everyone's previous observations? (The teacher should specifically ask in which ways it's similar and in which ways it is not.) The teacher says they can study the interactions of the sand and pebbles in the model to see how the water and starch particles in Gooblek respond to different kind of forces applied to the mixture.

3) Encourage the students to notice how the sand doesn't completely sink to the bottom, but intersperses amongst the stones and fills in the spaces they leave behind. Not all stones are touching one another. At this point, the teacher can introduce the word suspension and apply it to this phenomenon by noticing how we are hanging (suspending) particles of one substance in another substance. The suspension of solid cornstarch is in liquid water, so it acts like both a solid and liquid. Mixing the two together spaces out the starch grains evenly throughout the water.

4) Ask students to take turns first moving the bag slowly so the sand and stones "pour." They should record their observations of the movement of the stones and sand in their science journals. Responses should be similar to "the sand and stones move slowly together, and at the same pace." Next, students record what happens when they move their model quickly (by squeezing, rolling, or slapping). Students might observe how the particles compact and get hard, or how the stones really have no place to move. The teacher should lead the class into a discussion about how, when you move the Gooblek (and model) slowly, the grains have time to keep their even spacing and, therefore, it moves like a liquid. There is more time there is for the water to fill the spaces between the grains and provide lubrication so they will slide against each other and flow. On the contrary, when you move it quickly, the grains jam together and it acts like a solid. There is not enough water between the spaces, and friction between the grains of sand resists the flow. A picture on the board might help see this relationship in "freeze-frame."

5) The teacher can now ask students to predict what would happen if the liquid completely evaporated from the gelatinous glob. Indeed, only the solid starch remains. The teacher poses the scenario: So if, for example, two pieces of paper were

surrounding the starch/water gel, what would happen to them eventually? Through discussion, students should conclude that the water would eventually evaporate, and the molecular mesh of starch would harden onto the surfaces of the paper. Tell students that this is actually how glue works! For homework, ask students to come up with some practical uses for the concepts learned in class (mixtures and gels using cornstarch). Where else do they show up in our lives?

Activity 3: Corn: A Fantastic Plastic

1) *Observation of the Phenomenon:* To each student, the teacher passes out a magnifying glass, one polystyrene (Styrofoam) packaging peanut (on plate labeled A), and one starch packaging peanut (on plate labeled B). The teacher elicits answers from the children about the nature of these products. What are they used for? What might they be made of? The first part of the attached data sheet (A & B) should be filled out by each student as they use all their senses to observe these two different materials. For the "reaction to tongue" column, tell the students not to eat the object but rather to simply touch one end of it to their tongue and describe what happens. In groups, the students compare answers with their classmates in their lab group of 3-4 students and together they note apparent distinctions between these two materials. Each group briefly presents their findings and thoughts to the whole class. At this point, the students will realize they are both packaging materials and are useful as padding because they are rather soft, light, and slightly squishy.

2) Next, each student receives a thick Ziploc bag, an unlabeled container of cornstarch, a small unlabeled bottle of corn oil with an eyedropper, a container of water, and 2 tablespoons for measuring (wet and dry). Each student should follow this procedure:

1. *Place a tablespoon of the white powder in your plastic bag.*
2. *Add two eyedropper drops of the yellowish liquid to the bag.*
3. *Add one tablespoon of water.*
4. *Mix the ingredients by rubbing the bag gently in your hands.*
5. *Place all the group's bags in the microwave oven for 25-30 seconds. Don't completely seal the bags.*
6. *Use oven mitts to remove the bags from the microwave—Careful, they're hot!*
7. *When they are cooler, but still warm and malleable, try to roll your blobs into snakey pieces.*
8. *Start making observations about this material. What do you think it was made of? How does it behave? Make detailed observations on your data sheet in the "C" row and compare it to the other materials you previously handled.*

Data Sheet: Comparisons between packaging peanuts

	color	texture	smell	size & shape	elasticity (squeezability)	reaction to tongue	further descriptions
A							
B							
C							

3) After completing the chart, students should communicate their comparisons with other lab members. They should have hopefully noted that materials B and C were similar in many ways (much more so than A and C). As students try to figure out the nature of these materials, they should have noted that material C seemed pretty similar to the Gooblek ingredients from a previous experiment, except for the yellowish oil that was added. Since materials B and C seemingly moistened and disappeared on their tongues, the students might conclude that they are natural and safe to eat (they were even a little sweet!)

4) Inform students that materials B and C were indeed both made from corn starch. If the end product in C were mechanically interspersed with air particles to be lighter and more “puffed up,” they would have been almost exactly the same. Each group recalls and lists on the board two different properties that were learned about corn starch from the previous two activities.

5) The teacher points out how effectively cornstarch can be transformed into a packaging peanut—it looks and acts like regular loose fill packaging material. The students have the chance to perform the iodine test on their packaging peanuts. As they should recall, the resulting blue/black color is caused by a chemical reaction between the corn starch and the iodine. What happens when they put a drop on A and one on B? What does this tell about the nature of the materials in each kind? Clearly peanut A has no starch. What about when they are each placed into water? The teacher places each into a separate glass of water. What happens? Which one dissolves? As the students examined in the previous activity, dissolving is a physical change where particles of solid material (the solute) disperse amongst the particles of water (the solvent) striving to reach equal distribution (equilibrium). The packaging peanut with the starch and water together begin to dissolve and form a mixture. The other peanut (A) remains intact. The teacher can ask the students what they can conclude from this short experiment.

- Given these two equally useful and rather similar kinds of materials, which is the best one to use for the environment?
- What happens to these packaging peanuts when they reach the landfill? (What happens to “biodegradable” products? Do they simply disappear? Are they broken down into different things? What causes them to “degrade?”*)*

6) Gathering Data: Each of the lab groups are going to conduct the same experiment that will shed insight onto the “degradability” of these commercial packaging materials.

Note: This activity is adapted from “Now you See It...Now You Don’t!” from www.microbe.org

The groups receive the following materials:

- 6 clear plastic or glass jars (minimum 1-cup volume)
- masking tape and marker
- teaspoon and measuring cup for liquids
- eye dropper
- test tube
- large spoon or other stirring utensil
- 7 biodegradable packing peanuts made of starch (B)
- 7 polystyrene, or Styrofoam, peanuts (A)
- corn starch
- iodine tincture solution (drugstore antiseptic version that contains iodine and iodide salts; should be brown)
- 1 1/2 cups aged tap water (let the tap water sit out overnight to "age" and lose its chlorine--this might otherwise interfere with the iodine reaction.)
- compost activator that contains live microorganisms (This is available at garden supply stores. Be sure the label says it contains live microorganisms and not just extra nutrients.)

Procedure:

1. With the masking tape, label your jars 1 through 6. Put ¼ cup (50 mL) in each one.
2. Place 1 tsp. of corn starch in jars 1 and 2, two starch peanuts (B) in jars 3 and 4, and two “other” peanuts (A) in 5 and 6.
3. Add 1 tsp. of compost activator to jars 2, 4, and 6.
4. Mix the contents of each jar, cleaning the spoon thoroughly between jars.
5. Test the contents from each jar for starch. Put five drops of the mixture from jar 1 in a test tube. Add a drop of iodine to the tube. Record the results on the data sheet. Repeat this procedure for each of the other jars. Note: Be sure to rinse out your test tube thoroughly before testing the contents of the next jar or use a new eye dropper for each jar.
6. After discussing your theories with your lab group, form a hypothesis about what will happen to these jars over the course of 5 days? What kinds of changes do you suspect will happen to the liquid and to the peanut? What about the starch—will it change in any way? Record some of these thoughts on the data sheet.

7) Each day for the next five days, the lab group will retest the jars' contents for starch and record the results. They will also be noting changes in the packaging peanuts themselves. What kinds of changes are taking place? What variables seem to be affecting this reaction? How long does it take before the changes occur?

8) Each group should present their findings to the whole class as well as their conclusions about the process by which these two kinds of commercial packaging peanuts degrade. They should have noticed that the regular packaging peanuts (polystyrene) are not affected in any way by time or the presence of compost activator. The jars with the starch peanuts have completely dissolved, but interestingly, the jars with compost activator no longer indicate the presence of starch. The corn starch "control" acted the same way. What did they learn from this activity? How might this activity relate to their everyday life?

9) Now talk about the bottles with the compost activator added. The students should have discovered that the one with polystyrene peanuts remains unchanged, but the ones with starch or starch peanuts have lost their trace of starch (as indicated by the iodine test). The whole class has a brief discussion about what a compost is (hopefully some children will have a compost in their family). In a compost, natural products break down into the soil. A compost activator, then, helps "activate" this process.

The teacher reads the label from the compost activator box that says it contains live microorganisms. They may have (hopefully) learned this from a previous unit on recycling. Explain that microorganisms (which are commonly found in soil) are able to break substances down chemically because of the enzymes they secrete. Then these simple sugars can be used as energy sources by the microorganisms. All in all, this is what it means to biodegrade—a natural material is capable of being broken apart by natural biological processes into its smallest, most natural kind of particles.

This discovery should help shed light on the reason for which nothing happened in the bottle with polystyrene peanuts and compost activator. The chemical bonds that make up this product are too strong and stable. The polymers in plastic are much, much more complex than those of corn starch. Therefore, they do not break apart easily in water the way the bonds in starch do. Also, there are no enzymes that exist to break apart polystyrene (plastic is not a natural product).

10) The teacher asks the students in their groups to determine what would happen if these peanuts were buried for a few months in regular soil. With the previous explanations and experiments, the students should be able to conclude that the regular polystyrene peanut will remain intact but there will be no evidence of the starch peanut because it was converted into sugars by the microorganisms and used as food.

11) In addition, for students who are interested in how corn starch packaging peanuts are made, the Eco-Foam website offers this brief explanation: http://www.eco-foam.com/loosefill.asp The National Starch company was working on making cereals stay crunchier in milk, and ended up making this environmentally-friendly packaging material: Eco-Foam.

Assessment:

The students will make a list of some plastic products they think could be altered or enhanced with this new corn plastic-making technology. Is it feasible to use corn products to make plastic instead of fossil fuels (petroleum and natural gas), which are toxic to the air and polluting to the soil.

Adaptations: Data sheets could be evaluated as a team instead of individually to encourage interaction and interdependency. The teacher can provide notes of background information and terms to students so they are not bogged down with copying information or concentrating to take notes during experiements and modeling activities. If working with an advanced group of students, the teacher could introduce the concept of a polymer by talking about what happens when "Gooblek" is heated. (This is essentially how pudding is made). The students could consider this *chemical* reaction and create a human model of the change taking place when the molecules are heated and become attached to each other. They could also model the creation of polymer chains. Students could enhance experiments by testing other variables such as heat, time, proportions of ingredients, etc. Also, students could come up with their own experiments that test the presence of corn starch in common household materials.
<u>Extension activities for multiple intelligences:</u> Art: Students can create a collage from colored eco-foam starch packaging peanuts that are made from the same starch considered in class. They could also make corn

starch plastic sculptures out of a mixture of lots of corn starch, some water, and tiny bit of corn oil. What happens when you bake them? Students could also create a mural or quilt that depicts some of the multi-faceted uses of corn products throughout the world. When we look around us, where does corn pop up? **Literacy**: There are a number of books on corn, its biological nature, the chemistry of corn and its products, etc. Students could further research a corn-related topic of interest to them and write a short news article about it. They could also write a short story incorporating as many corn-based products as possible. A poem about corn, describing the complexity in such a small, simple, natural thing might be best described in a haiku. A persuasive letter might be a creative and proactive way for students to take social action regarding an environmental or political concern about corn that they have developed. Writing an informative and convincing letter to a congressman might just get results!

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Standards Addressed:

Science: A.8.3, A.8.6, A.8.7, C.8.1., C.8.2, C.8.5, C.8.6, C.8.7, D.8.1
E.E.: A.8.1-A.8.4

Appendix I:
Glossary of Corn Terms

Bushel	A unit of weight equal to 56 pounds. 39.4 bushels of corn equals approximately 1 metric ton.
Corn Belt	Region of the U.S. where much of the nation's corn is raised. Extends from western New York State to western Nebraska and from the Canadian border to the panhandle of Texas.
Corn Checkoff	For each bushel of corn sold in 19 different states, a specified rate or checkoff can be invested at the first point of sale. These funds are collected at the state level. A state checkoff or promotion board, commission or council made up of farmer-directors invests the money in state programs of research, market development and education to increase demand for corn. Farmer-directors can also invest in the National Corn Development Foundation (NCDF), which is the financial watchdog of the National Corn Growers Association. At the national level, the NCGA invests corn checkoff dollars in research, market development and education. The mission of the NCGA is to enhance corn profitability for corn growers.
Corn Germ Meal	By product of processed corn after oil has been extracted. Largely used as feed for swine and poultry.
Corn Gluten Feed	By-product of processing corn typically containing protein, fiber, phosphorus, and potassium. Largely used as feed for cattle.
Corn Growers & the Corn Industry	U.S. corn farmers produce more corn than any other farm commodity. The value of corn at the farm gate totals more than $20-billion. Corn growers make up one segment of the corn industry, which includes: processors; merchandisers; millers; and exporters. The National Corn Growers Association (NCGA) represents American corn growers.
Corn Varieties	Most American farmers grow dent, or "field" corn. In 1936, farmers planted this type of corn on more than 100 million acres, and produced a little more than two billion bushels. In 1996, farmers planted dent corn on about 65 million acres, and produced more than 7.3 billion bushels.
Corn Uses	Most corn grown in the U.S. is used to feed livestock. Poultry, beef, pork and dairy producers use more than 60-percent of all the corn grown in the U.S. The rest is exported (most corn sold to other countries is also used to feed livestock) or processed into such things as: starch (examples: baby food, baking powder, salad dressing, bookbinders, glue, many more); syrup (examples: soda pop, chewing gum, dessert icing, fireworks, adhesives, many more); ethanol fuel (examples: popular additive to reduce reliance on foreign oil and improve air quality in polluted U.S. cities), dextrose (bakery goods, fruit juices, peanut butter, antibiotics, citric acid, lysine, many more) and oil (examples: margarine, potato chips, soup, soap, paint, rust preventative, many more).
Dry Milling	Processing method which separates elements contained in the corn kernel by mechanical force.
E-85	Clean motor fuel blended at a rate of 85 percent ethanol and 15 percent gasoline. First mass-produced, commercial automobile that runs on this type of fuel introduced by the Ford Motor Company in 1996.
Ethanol	Clean motor fuel derived through the conversion of starch by processing corn. Typically mixed in

the U.S. at 10 percent ethanol, 90 percent gasoline.

Hybrid	Offspring of two different plants that grows better and with more vigor than parent plants. Corn breeders produce hybrid corn by placing pollen from the tassels of one desirable strain of corn onto the silks of another strain.
National Corn Development Foundation (NCDF)	The funding watchdog of the National Corn Growers Association. Five elected grower-leaders make up the officer team. The NCDF also has a 36-member board of directors also made up of corn grower-leaders elected by their peers. The NCDF invests farmer checkoff dollars in such things as research, market development, and communications in and outside of the corn industry.
Oxygenates	Motor fuel containing oxygen atoms in molecular structure which reduce carbon monoxide emissions.
Wet Milling	Most popular method of processing corn. Mix of water and grinding of dent or "field" corn separates corn into chemical constituents such as starch, protein, fiber and oil.
Zea Mays L.	Scientific name for corn.

Appendix II: Varieties of Corn

- **Flint corn**
  Flint corn is very hard and gets its name from flint, a hard type of stone. The colors of flint corn range from white to red. (Flint corn is also known as Indian corn.) Flint corn is commonly used for industrial purposes and livestock feed. Today, flint corn is widely grown in Asia, Europe, and Central and South America.
- **Popcorn**
  Popcorn is a special type of flint corn with hard, small kernels. The natural moisture inside the kernels turns to steam when heated, but the outer coat of the kernel is so hard that the moisture is trapped. This causes the steam to build up pressure until the kernel explodes. The wild ancestor of corn is believed to have been a type of popcorn. Today, the United States is responsible for producing almost all of the world's popcorn.
- **Dent corn**
  Dent corn is softer than flint corn. It has a dent in each kernel. Most kernels are yellow or white. It is commonly grown in North America and often used as livestock feed. It is also used to make many processed foods.
- **Flour corn**
  Flour corn has a very soft starchy kernel. It is easily ground and is used in baked goods. Flour and Flint corn were the chief types of corn raised by Native Americans. Today, it is used mostly for food by the people who grow it. It is one of the oldest kinds of corn.
- **Sweet corn**
  Sweet corn has more natural sugar than other types of corn. Today, it is eaten on the cob or it is stored frozen or canned. Most Native American tribes didn't grow sweet corn because they didn't like the sweet taste.
- **Pod corn**
  Pod corn is thought to have been the first type of corn grown. Each kernel grows in its own husk, so it is difficult to use without incorporating a lot of labor. It is raised today for scientific research.

Appendix III: THE MANY USES OF CORN

Based on yearly production…

source: http://www.ohiocorn.org/about_use_many.htm

0.2% Seed - High-yield hybrids are planted annually.

1.2% Food - Americans eat little whole kernel corn, but eat 120 million bushels in processed foods.

2.6% Starch - This extract thickens foods and is used in numerous "new" industrial products such as biodegradable plastics.

5.0% Alcohol - Ethanol from corn powers cars and a variety of other engines.

8.0% Sweeteners - Corn syrup has replaced imported sugar in a host of products like soda and candy.

50.1% Animal Feed - Feed for cattle, hogs and poultry continues to be the largest market for corn.

22.6% Exports - The U.S. provides about 80 percent of the world's corn needs and is the world's largest exporter. Corn exports create jobs in the U.S. and help our balance of trade.

10.3% Ending Stocks - Corn held at year's end provides a sustained food supply in bad crop years.

The kernel - Extract from the germ ( ) is used as cooking oil. Versatile starch ( ) can be a food, a component in building materials, or can be converted to ethanol fuel or corn sweeteners. The hull, or shell ( ), is high in protein and is an important source of livestock feed.