Kitchen Chemistry
DRAFT 8, 6/3/2012
Science Museum of Minnesota
Leigha Horton

Start show onstage, wearing a chef's hat and lab coat, with all experiments pre-prepped and ready on the table.

PowerPoint, Slide 1: Intro/Title on screen.

INTRODUCTION:

Hello, everyone, and welcome to the Science Museum of Minnesota! My name is ____ and this is *Kitchen Chemistry*.

I know you all know what kitchens are, but what about chemistry?

PowerPoint, Slide 2: Chemistry title card.

What *is* chemistry? *(gather answers)* Great answers!

PowerPoint, Slide 3: Chemistry Definition (formal).

The formal definition of chemistry is *(spoken in a snooty and boring tone)* "a science that deals with the composition, structure, and properties of substances and with the transformations that they undergo."

PowerPoint, Slides 4-8: Chemistry Definition (informal), clicking through as each description appears.

Another way to say that is, "chemistry is a science that deals with what stuff is made of, how it’s held together, how it behaves, and how it can change.”

Hold up tray of cookie dough in one hand; hold up plate of finished cookies in the other.

So when food changes form – for example, from cookie dough into cookies - that’s chemistry! Cooking IS chemistry.

PowerPoint, Slide 9: image of spaghetti.

Today we’re going to explore the science of spaghetti!

BOILING WATER:

Now first thing’s first when you’re making spaghetti - you have to boil water to cook your spaghetti noodles, whether they’re dry and brittle or fresh and floppy, right?

Indicate clear glass container of boiling water, and hold up box of spaghetti noodles.

Boiling is what happens when we rapidly change water from a liquid to a vapor using heat.

Before we continue, let’s quickly review the three basic states of matter. Who remembers the three basic states of matter? *(raise hand while saying this, to indicate you’re looking to call on someone to answer – get their answer.)*

That’s right – solids, liquids, and gasses.

PowerPoint, Slide 10: solids, liquids, gasses.

There are other kinds of matter, like plasmas, which stars are made out of; and the Bose-Einstein Condensate, which deals with matter at super-cold temperatures, but for today we're going to look at the basic three.

Now, I need a couple of volunteers to help me demonstrate these basic states of matter.

Choose three volunteers from the audience.

What are your names? Thank you for volunteering today, ___, ____, and ____!

First, I'd like you to stand in a line facing the audience *(arrange volunteers in a line parallel to the audience)*, and place your hands out in front of you like this *(demonstrate balled fists).* Your fists should be touching. Right now, together, you're a solid. All of your molecules are very close together, and if one moves, they all move. (*Gently push on one hand, and all hands will move).*

Now, the audience and I are going to add heat to you by quickly rubbing our hands together and throwing the heat on you. *(Demonstrate)* You are going to take a teeny step apart and your hands are going to get a little wiggly. But not too crazy, because you're a liquid, and molecules in a liquid still flow together and fill their container. (*Gently push on one hand, until all hands move).*

Finally, we're going to add even more heat to you, and you're going to turn into a gas – this time, I'd like you to wiggle your hands and walk back to your seats while you're doing so.

Volunteers return to their seats.

Let's give a round of applause to our solids, liquids, and gasses!

So, again, boiling is what happens when we rapidly change water from a liquid to a vapor using heat.

PowerPoint, Slide 11: image of boiling water.

Vapor is just another word for a gas that at room temperature is normally a liquid or a solid.

When enough vapor forms inside water so that the pressure of the vapor inside the water is equal to the pressure of the atmosphere above the water, the vapor can then push the air above the water away and allow vapor bubbles to be released. We call this process boiling.

The two basic factors that affect boiling are the pressure and the temperature. If the pressure changes, then the boiling temperature will also change.   It doesn't take as much heat to boil water in the mountains because the air pressure is lower in the mountains.

STARCH STRUCTURE:

So now that our water is boiling, we can toss the pasta in and let it work its way from dry and brittle to soft and supple.

Place dry pasta in original clear glass container of boiling water to cook.

Most pastas are made out of flour, salt, water, oil and eggs (which have special proteins that hold everything together). Some pastas don't use eggs, but still need that special protein, so they swap out the flour for a special kind of wheat.

PowerPoint, Slide 12: image of pasta starch from On Food and Cooking*, page 575.*

During cooking the starch granules absorb water and expand, and the proteins in the egg and flour form a network that binds the starch granules tightly together so they don't just dissolve in the water.

If you add cold water to a starch, the granules absorb a little bit of it, but they remain pretty much unchanged. But if you add right amount of warm water, the starch granules swell, break down and release some of their contents into the water. In other words, they gelatinize.

To help demonstrate this behavior, we're going to do a test with iodine. When iodine comes into contact with starch, it changes from red to blue.

Put on nitrile or latex gloves.

Here I have a graduated cylinder with some broken, uncooked pasta and some cold water. If I put a few drops of iodine in the cylinder, nothing happens. It remains red. That means no starch granules have gelatinized.

Add a few drops of iodine to the cold water graduated cylinder (#1).

Hold up cylinder to show audience.

I have another graduated cylinder, but this time we're going to take some of our hot cooking water. If I put a few drops of iodine in the cylinder…

Add a few drops of iodine to the hot cooking water graduated cylinder (#2). Hold up cylinder to show audience.

…it turns from red to blue. I didn't even put any pasta in here! But the iodine changing from red to blue proves that the heat has made the starch break down and release some of its contents into the water. The pasta has gelatinized.

Oobleck, a mixture of cornstarch and water that you can easily make at home, helps us see what can happen to starches on the molecular level – a size so small that we would measure those starch molecules in nanometers.

PowerPoint, Slide 13: image of nanoscale.

A nanometer is a unit of measurement – much like a centimeter or meter – only it's much, much smaller – it's actually a billion times smaller than a meter!

Refer to the "How Tall Are You" poster.

How small?! Well, if we put a million lines in between two of these millimeter lines – one of those million lines would be a nanometer!

Hold up container of Oobleck and slowly sink gloved fingers into it.

As you can see, Oobleck has a thick, gluey consistency and I can sink my fingers into it.

But if I hit it – placing extreme, rapid pressure on it – this starchy mixture acts very differently – it's hard and tough.

Then hit it with a rubber mallet, to demonstrate the different properties.

And if I hit it repeatedly, very rapidly – like with the vibrations from a speaker cone – it will act very strange, indeed!

Place the mixture on the speaker cone, turn the unit on so that the vibrations start (if possible, use a mobile unit, so that this can be walked closer to the audience, or use a camera and live video feed).

As you can see, the vibrations are causing the cornstarch mixture to create wildly moving tendrils. This happens because Oobleck is what we call a "non-Newtonian fluid" – meaning that when it's disturbed, it becomes viscous, or thick and sticky. But just like our spaghetti noodles, when exposed to water the starch absorbs the water, expands, and gelatinizes.

This was a really good way to see chemistry in action! Remember that chemistry is a science that deals with what stuff is made of, how it's held together, how it behaves, and how it can change? We just saw some pretty cool behavior that led to a pretty cool change.

LUBRICANTS V. GELATION:

Now there's one thing that can really ruin a good bowl of spaghetti, and that's noodles that are all stuck together in a giant clump.

Noodles stick to each other during cooking when they're allowed to rest close to each other just after they're added to the cooking water. Their dry surfaces absorb the small amount of water between them so there's none left for lubrication, and the partly gelatinized surface starch glues the noodles together.

Use a slotted-spoon to remove two large spoonsful of spaghetti onto two plates (one spoonful per plate).

Sticking can be minimized by constantly stirring the noodles for the first few minutes of cooking, or by adding a spoonful of oil to the pot and then lifting the noodles through the water surface a few times to lubricate them. Salt in the cooking water not only flavors the noodles, but limits starch gelation and so reduces stickiness.

Stickiness after cooking is caused by surface starch that dries out and cools down after the noodles have been drained and develops a gluey consistency. It can be minimized by rinsing the drained noodles, or moistening them with some sauce, cooled cooking water, oil, or butter.

We're going to use oil.

Put a few spoonsful of oil over the spaghetti on one plate, leave the other plate as-is.

The only really good way to test if our spaghetti has avoided gelatinization in a way that everyone can see it is if we throw it. Yep, I said throw it and see if it sticks. I'm going to need a volunteer from the audience who has excellent aim.

Choose a volunteer from the audience, give them an apron and a non-latex glove to wear.

Thank you for volunteering today, ____. Now, I'd like you to lob this handful of plain spaghetti at this giant cookie sheet.

Throw spaghetti at a large, ungreased, (and NOT non-stick) cookie sheet with a trash receptacle or butcher paper placed beneath it.

Look at that! It stuck! The starch on this spaghetti got pretty gelatinized.

Now let's try this again, only this time using the spaghetti that we added the oil to. And…. slides right off! The oil served as a lubricant, and prevented our spaghetti noodles from gelatinizing.

Get apron back from volunteer and invite them to re-take their seat.

Thank you for your help with our spaghetti tossing, _______. You can go ahead and re-take your seat.

FLAVOR PERCEPTION:

Pass around squeeze bottles containing cotton balls treated with essential oil.

Now that our pasta is done cooking, we could add some tomato sauce, grated cheese, and basil. Ever notice how that sauce gets really fragrant once it's warmed up?

PowerPoint, Slide 15: image of a person smelling food.

The aroma of foods is mainly due to the molecules interacting with air. When food is heated, more of these molecules are released and make the food smell stronger.

I've got three squeeze bottles with cotton-balls inside, and these cotton balls have some essential oils on them. I'd like three volunteers who have good senses of smell and like jellybeans to join me up here, too.

Choose three volunteers from the audience.

What are your names? Thank you for volunteering today, ___, ____, and ____! Hold the bottle about waist-high, and give them a squeeze. Can you tell me what you smell?

Hand them bottle #1 (orange), and make sure they hold each bottle at *about waist-high (too much closer to the face reduces the effectiveness). Also, use whatever scents you'd like, but make sure mint is always last – it's too strong otherwise and makes anything following difficult to identify.*

Let them smell the first bottle and identify the smell.

And how about this one?

Let them smell the second bottle (bottle #2, vanilla) and identify the smell.

And this one?

Let them smell the third bottle (bottle #3, mint) and identify the smell.

Good! You all got those scents right! And as you can plainly see, what you were smelling was not actually an orange, vanilla, or mint – it was just essential oil - tiny particles, too small to see, of orange, vanilla, and mint.

PowerPoint, Slide 16: image of scent molecules.

It turns out that our noses are highly developed nano-sensors. Your sense of smell works by identifying the shape of scent molecules. These molecules are so small that they're measured in nanometers.

Hold up model of a scent molecule (or show all three and their different shapes via PowerPoint).

Remember from our Oobleck experiment that nanometers are itty-bitty units of measurement. We can use our sense of smell to explore the world on the nanoscale, because we can smell some things that are too small to see.

It turns out that a great deal of what you taste is actually a matter of smell, and to demonstrate that, I'd like our volunteers to help me out.

I am going to give each of you a red jellybean, which could be either watermelon, cherry, or cinnamon – but before you put it in your mouth, I want you to pinch your nose and keep it pinched. Then I'd like you to pop in the jellybean, chew *very slowly*, and don't swallow until I tell you to. Keep those noses pinched!

Ensure that the recipients aren't allergic to jellybeans, and then hand out one jelly bean per person in a hygienic method (disposable hospital pill cups or small condiment cups recommended).

Can you identify the flavor? No? Okay, now go ahead and unpinch your nose. How about now?

Give focus to the volunteer's reaction, which will probably be pretty strong/surprised.

What could you taste?

Have each volunteer identify the flavor of their jellybean for the audience.

If you haven't already, you can go ahead and swallow your jellybeans now.

Give our volunteers a big round of applause! Thank you, you may go ahead and have a seat.

On the way into your mouth, foods are giving off vapors that waft up into your nose. Once you start chewing, more vapors travel the retronasal route, up the pharynx and into the nasal cavities.

PowerPoint, Slide 17: image of human olfactory system.

At the back of each nasal cavity, the scent molecules hit the olfactory membrane, a postage stamp-sized patch of yellowish gray tissue responsible for determining odors.

SUMMARY:

PowerPoint, Slide 18: outro/title

And there you have it! We've just explored a whole lot of science in just one simple bowl of spaghetti!

From boiling water, to the behavior of starches and lubricants, to the nanosensors that determine your perception of taste and smell, cooking is a complex chemistry, and *we* are complex in how we experience our food.

Give yourselves a big round of applause - thank you for joining us for *Kitchen Chemistry!*