Custards and Puddings

Unit: Preparing Foods

Problem Area: Baking and Pastry

Lesson: Custards and Puddings

Student Learning Objectives.

Instruction in this lesson should result in students achieving the following objectives:

1. **Summarize basic custard and pudding ingredients and equipment.**
2. **Examine types of custards and puddings, as well as their preparations.**
3. **Analyze physical changes and chemical reactions that occur in custard and pudding preparations.**

Resources.

The following resources may be useful in teaching this lesson:

E-unit(s) corresponding to this lesson plan. CAERT, Inc. http://www.mycaert.com.

Burton, Jacob. "FS 001| What is an Emulsion? A Cook's Guide," *Stella Culinary.* Accessed June 19, 2018. https://stellaculinary.com/cooking-videos/food-science-101/fs-001-what-emulsion-cooks-guide.

Draz, John, and Christopher Koetke. *The Culinary Professional.* 3rd ed. Goodheart-Wilcox, 2017.

"Getting to Know: Thickeners," *Cook's Country.* Accessed June 19, 2018. https://www.cookscountry.com/how_tos/9126-getting-to-know-thickeners.

Gisslen, Wayne. *Professional Baking*, 7th ed. Wiley, 2016.

Guggenmos, Karl, et al. (Johnson & Wales University), *Culinary Essentials*. McGraw-Hill Education, 2010.

Labensky, Sarah R., Priscilla A. Martel, and Eddy Van Damme. *On Baking(Update): A Textbook of Baking and Pastry Fundamentals,* 3rd ed. Pearson, 2016.

Alfaro, Danilo. "Liaison: A Culinary Term for a Sauce Thickening Technique," *The Spruce Eats.* Accessed June 19, 2018. https://www.thespruce.com/what-is-a-liaison-995775.

Grygus, Andrew. "Starches, Thickeners & Gels," *Clovegarden.* Accessed June 19, 2018. http://clovegarden.com/ingred/starch.html.

Equipment, Tools, Supplies, and Facilities

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials

Key Culinary Terms.

The following terms are presented in this lesson (shown in bold italics):

- amylose
- amylopectin
- bain-marie
- bain-marie technique
- baked custard
- bavarian cream (bavarois)
- blancmange
- bloom test
- blooming gelatin
- charlotte russe
- cheesecake
- chiffon
- coagulate
- coagulation
- cornstarch pudding
- crème anglaise
- crème brûlée
- curdling
- custard
- double boiler
- flan
- floating island
- gel
- gelatin
- liaison
- mise en place
- mousse
- panna cotta
- pastry cream
- pudding
- quiche lorraine
- saccharide
- slurry
- soufflé custard (soufflé)
- starch
- Spanish cream
- stirred custard
- temper
- weep

Key Science Terms.

The following terms are presented in this lesson (shown in bold italics):

- absorption
- caramelization
- chemical reaction
- colloidal suspension
- colloid
- condensation
- conduction
- convection
- disaccharide
- emulsion
- endothermic reaction
- evaporation
- exothermic reaction
- foam
- gelatinization
- heat transfer
- homogenous mixtures
- hydrolysis
- hygroscopic
- immiscible
- invert sugar
- lecithin
- monosaccharide
- pan flow
- pH
- pH scale
- physical change
- polymer
- polysaccharide
- radiation
- retrogradation
- surface tension
- syneresis
- viscosity

Interest Approach.

Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

> *In England, pudding is used as a generic term for any sweet dish served after the main dish. It is also a term for savory, meaty baked puddings, such as steak-and-kidney pudding or Yorkshire pudding. However, traditional Brits consider bound, solid puddings, such as plum pudding or bread pudding, to be a pudding. A "Pudding Club" was established in 1985 to preserve real British pudding from disappearing from daily menus. Today, they still have a thriving club. Many British puddings are accompanied by pourable custard. In short, some British puddings are sweet and some are savory (meaty or breadlike).*

> *American pudding, a dessert, is much different from its British counterpart, being prepared with milk, eggs, sugar, salt, and flavorings. During this lesson, students will prepare and taste different puddings and custards used in American cuisine. This lesson is a primer for a host of desserts prepared by U.S. pastry chefs that use custard or pudding bases. Use the VM–A visuals to help introduce this lesson.*

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Summarize basic custard and pudding ingredients and equipment.

Anticipated Problem: What is custard? What is pudding? What basic ingredients and equipment are used in custard and pudding preparation? How do starches work?

I. ***Custard*** is a creamy, light dessert or sauce made from boiling or baking an egg-and-milk mixture. Custards are of two types—stirred or baked. They are used as desserts, sauces, bases for other desserts, and some savory dishes, such as a quiche or a frittata. ***Pudding*** is a creamy dessert or filling made from eggs, milk, sugar, flavorings, and a thickener (such as cornstarch or gelatin). American puddings are boiled and made with cornstarch or gelatin (cornstarch is used more often). All custards and puddings are stored under refrigeration. [NOTE: Originally, pudding referred to a savory product, often a meat- or cheese-based dish (Haggis, Roman sausage, or croustades). The English claim the invention of puddings. They still enjoy savory Yorkshire pudding (a thick popover-like batter baked in a shallow pan containing a layer of beef drippings) and black pudding (blood pudding). All references to pudding in this lesson will be about boiled pudding, which is what Americans associate with pudding.] Basic custard and pudding ingredients, terms, and equipment will be covered throughout this section of the lesson.

A. STARCH: ***Starch*** is a complex carbohydrate, a polysaccharide of bonded carbohydrate molecules found in plants. The plants' molecules are tightly packed into small granules. Complex carbohydrates are composed of three or more sugar units. Starches are found in seeds, fruits, tubers, roots, and the stems of plants. The starch molecule contains long chains of glucose that form two types of structures, a long, straight-chain starch called amylose and a short, branched-chain starch called amylopectin. Starch molecules contain both amylase and amylopectin.

1. *Amylose*: ***Amylose*** is a part of starch that has very long, unbranched chains, is insoluble in water (unless heated), tightly wound, highly glucose-based, and makes up about 20 percent of starch structure. Amylose entraps large amounts of liquid, but cannot dissolve or form a gel in hot water. A ***gel*** is a semisolid substance that is similar in appearance to jelly. Root starches (e.g., tapioca starch) have longer chains and more thickening power than seed starches (e.g., cornstarch).
2. *Amylopectin*: ***Amylopectin*** is a short chain starch that is highly branched. Amylopectin can create a starch gel in hot water, and is very soluble in water. Amylopectin makes up about 80 percent of natural starch molecules. Cornstarch and wheat flour contain more amylopectin (about 80 percent) compared to tapioca starch (about 75 percent).

B. TYPES OF STARCH: There are three types of starch used in cooking. All of them have different characteristics that make them compatible with different dishes.

1. *Grain Starches:* Grain starches (wheat flour, corn, and oat) are clear when heated, but they are cloudy when cold. Grain starches thicken when heated at higher temperatures. Thickening begins at 190°F. Puddings and custards made with grain starches do not freeze well. After a grain starch is thawed, it may ***weep*** (seep liquid). In order to thicken and not taste "starchy," grain starches must be cooked after they are added to a mixture. These are good for baked and high-heat dishes.
2. *Root Starches:* Root starches (tapioca, arrowroot) are clear when hot or cold. Root starches thicken at lower temperatures than grain starches, from 140°F to 160°F. Puddings and custards made with root starches freeze well. Root starch breaks down at high temperatures and becomes thin and stringy. These are good for custards made over a double boiler.
3. *Waxy Starches:* Waxy starches (waxy maize, rice) are clear when hot or cold and at their thickest when hot. Waxy starches are used in commercial preparations and provide frozen products that do not weep. They are higher in amylopectin. Thickening begins at 140°F to 160°F.

C. HOW STARCHES WORK: All starches work by absorbing liquid into individual starch grains. The amount of liquid a starch grain will absorb (and how concentrated the grains are in the liquid) affects how thick the mixture becomes. Some starches will completely "set" a liquid (as in a molded gelatin salad). When a starch solution is heated, the liquid molecules begin to move around quickly and bump into the grains of starch. Then, the starch granules soak up the liquid, swell, and pop. For example, cornstarch must be at a temperature of 203°F (95°C) before thickening begins. At that point the mixture quickly turns from cloudy to transparent. When the granules pop, starch moves quickly into the liquid to thicken it.

1. Too much sugar or acid (such as citrus) in the solution may prevent starches from thickening properly. Starch must be added carefully to a liquid to avoid lumps. For example, starch and sugar can be mixed before the liquid is added to a pudding or custard mix. Also a ***slurry*** mixture (a blend of equal parts of cool liquid and powdered starch) may be used to thicken other liquids. The slurry mixture is softened and stirred to remove any lumps before adding other ingredients.
2. Starch and flour both function in custards and puddings to provide flavor, structure, thickening, and gluten development.

D. GELATIN: ***Gelatin*** is a colorless, flavorless, collagen-based, water-soluble, edible substance. The collagen comes from proteins found in various animal body tissue. Gelatin prevents coarse crystals from forming in the pudding mixture and creates a smooth texture for chilled mousse and soufflé desserts.

1. *Bloom:* Gelatin displaces moisture due to its strength or "bloom." Gelatin can come in a granular, powdered, or sheet form. ***Blooming gelatin*** is the act of gelatin absorbing a liquid, enlarging, and stabilizing. Due to its collagen base, as the liquid is absorbed, gelatin molecules stretch and enlarge, creating a

more solid appearance—a gel. To bloom gelatin, a cook would need to do the following:

a. Stir gelatin into a small amount of cold liquid.
b. Let it soak for five minutes without stirring until the gelatin has absorbed the liquid. It will look translucent and have a gelatinous consistency.
c. You can strain the gelatin mixture to remove excess water or simply move to the next step.
d. Add the gelatin mixture into warm liquid. It will dissolve again, and your pudding, sauce, or other dish will become firmer.
e. For more information about blooming gelatins, see the short video, "How to Bloom Gelatin," on the Marx Foods website at http://www.askmarxfoods.com/what-is-blooming-gelatin/.

2. *Bloom Test:* The ***bloom test*** is a measurement of the gel strength of a gelatin. Generally, about $2^1/_4$ tsp. of unflavored gelatin sets about 2 cups of liquid. Gelatin sheets (and other forms of gelatin) are labeled by a number that categorizes its bloom strength.
   a. Low bloom: 50-125
   b. Medium bloom: 175-225
   c. High bloom: 225-325
3. pH levels: Gelatin completely dissolves in a hot liquid, and it gels as it cools. Gelatins work best in a pH range of 4 to 10. They do not work well in low pH or acidic solutions. (See more information about pH in Objective 3.) Fresh or frozen pineapple, kiwi, figs, papaya, peaches, ginger, mango, and honeydew melon contain an enzyme that breaks down gelatin and inhibits gelling. These foods should be avoided in the hot liquid that is being thickened. Precooking or incorporation into an already chilled gelatin sauce is recommended.

E. EGGS: Chicken eggs that are grade AA large (about 2 oz. each or 8 per lb.) are the most common eggs used in baked goods. Eggs are a valuable source of vitamins A and B and some D. fresh egg should have a nicely rounded yolk that is well centered in the white. The egg, still in its shell, should sink to the bottom of a water-filled container (good way to check freshness). Cracked eggs have a danger of salmonella and should be discarded. Eggs are easiest to separate when they are cold. To beat whole eggs or egg whites to their greatest volume, they should be brought to an internal temperature of 65°F to 75°F. If more cooking time is used to thicken the pudding or custard, less eggs are needed in the recipe. Weighing eggs is more accurate than measuring.

1. *A Large Egg White:* About $1^1/_3$ oz. or $2^2/_3$ tbsp.
2. *A Large Egg Yolk:* About $^2/_3$ oz. or $1^1/_3$ tbsp.
3. *Functions:* Eggs function in custards and puddings to provide:
   a. Leavening (via air incorporation from beating or whipping)
   b. Emulsification (eggs act as a binding agent, a structure that holds other ingredients together)
   c. Moisture

d. Color (egg yolks add color)
e. Flavor (eggs add a distinctive taste to custards and puddings)
f. Texture
g. Thickening via coagulation [***Coagulation*** is the changing of a liquid to a semisolid or solid mass via protein denaturation. When proteins denature, they ***coagulate*** (bond together to form solid clumps).]

F. LIQUIDS: Custards and puddings incorporate various types of liquids. Most include milk or cream, but there are exceptions, such as a lemon pudding that utilizes fresh lemon juice. Weighing liquids is more accurate than measuring.
   1. *Weighing:* The metric system is preferred for measuring liquid, as it does not differentiate between fluids and solids—a gram is a gram and a kilogram is a kilogram. (Two cups of water and two cups of molasses are the same volume but different weights.)
   2. *Functions:* Liquids function in custards and puddings to provide:
      a. Moisture and hydration (for proteins and starches, including gelatins)
      b. Flavor (milks, creams, juices, yogurt, sour cream)
      c. Color (browning from milk and fruit sugars)
      d. Steam leavening (from the conversion of liquid to steam)
      e. Proper gluten development (when mixed with flour)

G. SUGAR: Sugar is a carbohydrate that is soluble in water, usually crystalline in form, and sweet in taste. ***Saccharide*** is the scientific name for sugar (or an organic compound containing sugar). Sugars are produced from various types of plants, such as canes (sucrose), beets, sugar maples, and palms. Solid sugars include cane and beet sugars. Liquids can include honey, molasses, corn syrup, or various manmade liquid sweeteners produced for dietary purposes. The various grinds of solid sugar (such as granulated, powdered, superfine, or brown) impact finished products. When baking, liquid sugars do not react in the same fashion as solid sugars.
   1. *Weighing:* Sugar by weight is more accurate than sugar by volume.
      a. A cup of granulated sugar is about 7 oz.
      b. A cup of confectioners' (powdered) sugar is about 4 oz.
      c. A cup of packed brown sugar is about 7½ oz.
      d. A cup of molasses, honey, or corn syrup is about 12 oz.
   2. *Functions:* Sugar has many functions within custard and pudding. It can provide flavor, tenderization (too much sugar keeps starches from thickening), color (caramelization), and moisture retention (sweetened products stay moister than savory ones).

H. SALT: Salt is a crystalline compound (NaCl, sodium chloride) primarily used as a condiment that comes in two types—sea salt distilled from seawater and rock salt found in the earth.
   1. *Cooking Salt:* Sodium chloride (table salt) was the first salt discovered by humans. Iodized salt (table salt with added iodine) has been the salt most

often utilized in American cooking; however, sea salt has become more popular over the last few years.

2. *Functions:* Salt functions in custards and puddings to provide flavor (adds complexity and highlights other flavors), texture (toughens soft fat-and-sugar combinations), and strength (to gluten).

I. FAT BASICS: Fats are plant- or animal-based, oily ingredients that melt at low temperatures. Fats are compounds of carbon, hydrogen, and oxygen. Lipids are molecules that include fatty acids, triglycerides, cholesterol, and various nutrients. Fats are lipids found in animal and vegetable tissue. (From animals, butter and lard are produced. From vegetables, nuts, legumes, oils and shortenings are made.) Solid fats (butter, margarine, and hydrogenated products) remain solid near room temperature. Oils can solidify when refrigerated or cooled. A byproduct of creating hydrogenated shortenings is the production of trans-fatty acids (trans fat) that may cause a health risk. Shortenings are 100 percent fat. A half-and-half split with butter is a good shortening mixture. Four common fats can be used to make baked goods. Butter, margarine, and cream are the most common fats used in custard and pudding.

J. FAT FUNCTIONS: Fats provide many functions in a cake.

1. Flavor and richness (especially butter or lard)
2. Moisture
3. Tenderness (shortens gluten strands)
4. Leavening (when creamed)
5. Browning
6. Emulsification
7. Even distribution of added flavors (vanilla, almond, etc.)
8. Flavoring

K. FLAVORINGS AND ADDED INGREDIENTS: In small quantities, flavorings and aromatics can add something special to a custard or pudding. Flavorings may include extracts (concentrated oils or essences diluted with alcohol), natural liquids (such as vanilla, almond, or cherry, also derived from concentrated oils), seeds and beans (vanilla, nutmeg, chocolate, coffee), and spices (like cinnamon, ginger, cloves, or nutmeg). Flavorings enhance (or fundamentally change) the taste of baked goods. Other added ingredients can include citrus (and other juices), nuts, chips, coconut, cherries, apples (and other fruits), chocolate, and vegetables.

L. HAND TOOLS AND EQUIPMENT: Basic hand tools and equipment are necessary for creating a well-mixed, balanced, and evenly-baked item.

1. *Scales:* Platform, digital, or balance scales are used to accurately measure ingredients. Platform scales are often used to measure moist ingredients, and balance scales measure dry ingredients. Digital scales are best to measure small amounts (spices, herbs, leavening agents) or portion control (such as 2 oz. of custard per ramekin).

2. *Custard cups:* A custard cup is a small, heat-resistant, glass or porcelain bowl (similar to a ramekin) in which an individual custard or pudding is baked. Typical custard cups are 6 oz. and 8 oz. in size.
3. *Molds and Dishes:* Multiple pudding and soufflé recipes are cooked in specialized dishes or molds.
    a. Soufflé: Soufflé dishes are generally round with straight sides. They range from 1 qt. to 2 qt. in size.
    b. Charlotte: Charlotte dishes are plain, round, metal molds with heart-shaped handles. They also range from 1 qt. to 2 qt. in size. Ramekins are smaller, individually sized versions of a soufflé dish. These dishes are also used for mousse and frozen desserts.
    c. Flan: Flan molds are a round, shallow, flat dish. Often made from metal, versions can be found in glass, porcelain, or silicone. Flan molds are from 1 qt. to individual in size and are sometimes called Maryann pans. Some versions include an attached bain-marie.
    d. Pudding molds: The usual volume of pudding molds is from 7 to 12 cups. These molds have a center tube and fitted lid. Generally metal, they may have decorative sides, bottoms, and tops. Typically, a steamed pudding is cooked on the top stove rack. The bottom rack contains a pan of water, producing steam—hence, steamed pudding. Steamed pudding is found more often in British dishes.
4. *Bain-marie:* A ***bain-marie*** is a hot water bath ("bain" is the French term for bath) used to slow cook foods or keep them warm. In a shallow pan, custard cups, ramekins, or soufflé dishes are placed. Then, hot water is poured around the dishes (about half way up the sides). The water is kept near boiling (either on top of the stove or in the oven) to produce an even heat and to prevent the custard or pudding from overcooking. [NOTE: Bain-marie can refer to a utensil or to a cooking technique.]
5. *Double Boiler:* A ***double boiler*** is a saucepan that is made up of two pans that nestle together—the bottom pan is filled half full (or less) with simmering water, and the top pan holds the ingredients. Typically, the top pan does not touch the simmering water. Custard and pudding mixtures coagulate and/or curdle easily, so the upper pan must not come in contact with the hot water in the lower pan. (The trick is to gently heat the proteins in egg and milk while slowly stirring.)
6. *Instant-Read Thermometer:* An instant-read thermometer is a small, thin instrument with a temperature gauge or digital readout. The sensor is located at the tip. To accurately measure the temperature, the sensor must be in the middle of the custard or pudding.

Teaching Strategy: *Use VM–A to introduce the lesson with examples of a variety of pudding and custard dishes. Use VM–B to illustrate amylose and amylopectin starches. Use VM–C to review how starch works. Use VM–D to summarize the functions of basic custard and pudding ingredients. Use VM–E to see some of the equipment and tools used to prepare custards and puddings.*

Objective 2: Examine types of custards and puddings, as well as their preparations.

Anticipated Problem: What are types of custards? What are types of puddings? What are standard custard and pudding preparation and serving techniques?

II. Custards are of two types: stirred and baked. Both types create a rich, smooth sauce served warm or cold. Baked custards are prepared with whole eggs and are cooked in an oven with water surrounding its dish. Stirred custards contain egg yolks and are cooked on the stovetop, often in a bowl over water. Although the United Kingdom refers to suet- and flour-based items as puddings (that are steamed or baked), Americans' think of pudding as a boiled egg and milk dish. This lesson will cover boiled pudding. All puddings are stored under refrigeration.

A. STIRRED CUSTARD: ***Stirred custard*** is a soft, creamy custard made on the stovetop. It is softer in texture than baked custard.

1. *Cooking Stirred Custard:* Stirred custards can be cooked over a double boiler or by using a ***bain-marie technique*** (the process of heating ingredients by placing of a bowl over a pan of boiling water). The egg mixture is stirred continuously to stabilize the eggs and prevent curdling. A bain-marie insulates the pan or cups so that the custard does not cook too quickly. Ingredients in stirred custards are egg yolks, granulated sugar, cornstarch (generally), milk, and flavorings (such as vanilla). Examples of stirred custards are pastry cream and crème anglaise. [NOTE: See more information about emulsions and colloids in Objective 3.]

a. Curdling: ***Curdling*** is the congealing of overcooked proteins that occurs when heat is applied too rapidly. The result is the formation of lumps (cooked protein pieces). A curdled mixture is referred to as "broken" (separated or congealed). When an egg mixture curdles, it tastes like scrambled eggs.

b. Tempering: ***Tempering*** is the changing of an item's consistency through heat. The tempering of eggs involves slowly heating the egg mixture while constantly whisking. This stabilizes the mixture and keeps it from curdling. Using a high heat toughens and shrinks the egg albumen, keeping it from successfully combining with the other ingredients.

c. Creating stirred custard: A cook would follow the following steps to create a custard:

(1) Gradually add hot liquid (cream) to beaten eggs, whisking constantly.

(2) Continue cooking until the custard reaches 175°F on an instant-read thermometer. The mixture should be thick enough to coat the back of a spoon. ***Coats the back of a spoon*** is a cooking test for thickness (a liquid mixture is at the right thickness when it coats the back of a spoon). The custard is done when the spoon is removed from the custard and, after running a finger across the back of the spoon, leaves a clear, distinct trail.

(3) Next, the mixture is removed from the heat and strained to remove any coagulated egg protein (usually the egg white). It is now ready to be part of a dessert.

2. *Pastry Cream:* ***Pastry cream*** is a stiff, creamy, stirred custard that is used as a filling. It is used in pastries (cream puffs and éclairs), tarts, and cakes (Boston cream pie)—as well as a base for fruit curds. There are various recipes for pastry cream creations.
   a. Crème patissière: Crème patissière is a classic, French pastry cream. The difference between this and a regular pastry cream is the use of flour as a thickener (along with the usual cornstarch). A recipe can be found on the website, A Little French Bakery, at http://littlefrenchbakery.com/blog/pastry-creme-creme-patissiere.
   b. Tarts: Cream and fruit tarts are an easy pastry-cream dish, because once the cream is done, it can be placed right in the crust and served. Pastry creams can also be the base for a fruit curd (a basic stirred custard, with fruit juices and zests added—usually citrus).
   c. Recipes: Multiple recipes can be found online. Below are a few website examples.
      (1) The Joy of Baking website has a "Fruit Tart Recipe and Video" at http://www.joyofbaking.com/FruitTart.html
      (2) Ina Garten's recipe for lemon curd can be seen on the Food Network website at http://www.foodnetwork.com/recipes/ina-garten/lemon-curd-recipe/.
      (3) Martha Stewart: https://www.marthastewart.com/343977/pastry-cream
      (4) Duff Goldman: http://www.chefduff.com/recipes/ (rompope-filled churros)
      (5) Tartelette: http://www.tarteletteblog.com/2008/08/chocolate-eclairoh-pierre.html
3. *Crème anglaise:* ***Crème Anglaise*** is a thin, lightly sweet, custard sauce. Literally translated "English custard," it is thickened mainly by the egg yolks. Ingredients are egg yolks, granulated sugar, milk, salt, whipping cream, and flavoring. It is the base for most ice creams and mousse desserts, the filling for many pastries, and the foundation of most dessert soufflés.
   a. Thickening: The thickening agent in crème anglaise is a liaison. In cooking, a ***liaison*** is a thickening agent made of egg yolks and heavy cream. The liaison technique consists of warming the egg yolks with a scalded milk mixture, instead of over water. This mixture is gradually heated, just enough to thicken the liquid but avoiding temperatures hot enough to scramble the eggs (below 185°F).
   b. Creating a crème anglaise: A cook would complete the following steps to create crème anglaise.
      (1) Step 1: Scald the milk, and slowly add it to a mixture of beaten egg yolks, sugar, and salt. The egg mixture is tempered by slowly adding

the milk while whisking. This keeps the temperature from rising too fast.

(2) Step 2: The mixture is placed on the stovetop over low heat until the custard coats the back of a spoon.

(3) Step 3: After cooking is complete, the crème anglaise is removed from the heat and placed in a cold-water bath to stop cooking. Stirring continues until cool.

(4) Step 4: Strain the sauce to remove the egg white that invariably clings to the yolks. Then, vanilla and cream are added. (Folding in whipped cream creates a mousse.) The sauce can be chilled for use with a cold dessert, or it can be poured directly over a warm dessert. [NOTE: Many recipes have the vanilla (or other flavorings) and half of the sugar added to the milk at the beginning of this process.] A crème anglaise recipe is on the Epicurious website at http://www.epicurious.com/recipes/food/views/creme-anglaise-4984.

c. Ice cream: Ice cream is a frozen dessert made from cream, butterfat, sugar, and eggs. When created with a crème anglaise base, ice creams are rich and velvety. A french-vanilla recipe can be found on the Baking Bites.com website at http://bakingbites.com/2011/01/homemade-french-vanilla-ice-cream/.

d. Mousse: ***Mousse*** is the folded mix of a custard base and whipped cream. It can be lightened by whipped cream, whipped egg whites, or a combination of both. In French, mousse literally means froth or foam. A "Chocolate Mousse for Pastries" recipe and video is on the Callebaut website at http://www.callebaut.com/en-US/chocolate-video/technique/mousse-sauce#group-items-wrapper.

e. Chiffon: ***Chiffon*** is a flavored custard in which whipped egg whites are folded into a cooled custard sauce. It is used as a base for chiffon cakes or pies. Most chiffon preparations are baked, due to the raw egg whites, but some are not. Chiffon cakes have a creamy, fluffy texture. Chiffon pies are light and airy, and they usually include gelatin as a thickening agent. The "Lemon Chiffon Pie with Gingersnap Crust" recipe is on the Epicurious website at http://www.epicurious.com/recipes/food/views/lemon-chiffon-pie-with-gingersnap-crust-235364.

f. Floating island: A ***floating island*** is a dish of poached meringue afloat a crème anglaise. This dessert is a classic French dish. Cafe Johnsonia has a version of a Julia Child recipe at http://cafejohnsonia.com/2012/07/julia-childs-floating-islands-recipe.html.

B. BAKED CUSTARD: The most common custards are baked. ***Baked custard*** is a light, slightly eggy custard that has been cooked in the oven. Ingredients include eggs, granulated sugar, salt, steaming milk, and flavoring. These custards typically retain the shape of their container and are relatively solid. Preparing baked custard is a simple process, in which the ingredients are whipped together, strained through a fine sieve, poured into custard cups or pie/tart shells, and baked in a water bath. Keeping the custard dishes surrounded by water allows for

even heating. This tends to keep the individual custards consistently baked, instead of being over- and undercooked in different areas. Examples of baked custard desserts and main dishes include custard cups, custard pie, flan, crème brûlée, crème caramel, cheesecake, and quiche lorraine.

1. Doneness: Unlike golden-brown cakes and pastries, perfectly baked custard should be creamy yellow in color. The doneness is tested by inserting a thin knife that comes out clean. Baked custards set more firmly than stirred custards and many have a skin that forms on top. Knowing when a baked custard is done can be tricky. Some bakers look for a skin formation or insert a thin knife in the center. A classic test is the gentle shaking of the dish. The entire center of the custard should jiggle "at once." If any element of the custard jiggles independently, it is not done. Also, baked custards continue to cook after being removed from the oven, so experience with a specific recipe is helpful in determining when the dessert is "done." An "Easy Old-Fashioned Baked Custard" recipe, using whole eggs, is on The Spruce Eats website at https://www.thespruce.com/easy-old-fashioned-baked-custard-3059894.
2. Custard pies: A custard pie is the addition of uncooked custard added to an uncooked or partially cooked piecrust that is baked until the custard is set. ***Cheesecake*** is a baked custard that is made with the addition of cream cheese. It typically has a crumb crust made of cookies or graham crackers. It is generally baked in a springform pan. For a "Classic Custard Pie with Nutmeg" recipe that uses a pre-baked crust, go to The Spruce Eats website at https://www.thespruce.com/classic-custard-pie-with-nutmeg-3052755.
3. Flan: ***Flan*** is a Hispanic classic—baked custard served upside down (unmolded), usually in a sauce. Flan comes from a line of desserts called crème caramels. A ***crème caramel*** is a sweetened baked custard that is served upside down (unmolded) with a caramelized-sugar sauce. On The Spruce Eats website, look at the "Dulce de Leche Flan" recipe that uses sweetened condensed milk at https://www.thespruce.com/dulce-de-leche-flan-3029065. See the "Crème Caramel Recipe" on the Easy French Food website at http://www.easy-french-food.com/creme-caramel-recipe.html.
4. Brûlée: ***Crème brûlée*** is baked custard served under a crispy sugar-topped crust. It is typically served in a ramekin or shallow baking dish. Find the simplified "Crème Brûlée" recipe on the Betty Crocker website at http://www.bettycrocker.com/recipes/creme-brulee/67864cdb-de54-48b0-adca-02b9839ba033. On this site, look at the "Expert Tips" section about using the broiler instead of a torch to caramelize the sugar.
5. Quiche: ***Quiche lorraine*** is a savory custard pie from the Lorraine region of France. Originally, this dish was prepared with only eggs, heavy cream, and bacon or chopped ham (and no cheese). The term "quiche" actually comes from the German "kuchen," meaning cake. In general, a quiche is any savory, baked custard pie. Today, numerous vegetables, meats, seafood, and cheeses are used in quiche recipes. The Martha Stewart website has a quiche lorraine recipe at http://www.marthastewart.com/338286/quiche-lorraine. This recipe uses a tart crust that is available through a link on this site.

6. Soufflé: A ***soufflé custard (soufflé)*** is a baked custard prepared with whipped egg whites for an extremely light, highly risen finish. It can be either a sweet dessert or a savory pie baked in the oven.
    a. Fluffiness and height are achieved when whipped egg whites are folded into a pastry cream. The soufflé custard is baked immediately after folding the batter into an individual, 1 qt., or 2 qt. ramekin that has been buttered and sugared. For savory soufflés, salt and spices take the place of sugar and flavorings.
    b. ***Mise en place*** (a French cooking term that means "to set up" or "to arrange") is especially important when constructing baked soufflé custard. The oven must be preheated, the egg whites at room temperature, and the soufflé ramekin and optional collar (oven-safe paper wrapped to keep soufflé from expanding over edges) readied prior to mixing. Savory soufflé custards are most popularly cheese-based, but can include anything. Other popular items are seafood, asparagus, and mushrooms.

C. PUDDING: When Americans refer to pudding, they are referring to boiled pudding. Boiled puddings have a thicker consistency than custard, and they are made with cornstarch or gelatin.
    1. *Cornstarch Pudding:* ***Cornstarch pudding*** is a boiled pudding thickened with cornstarch. Generally, they are a mixture of milk, sugar, cornstarch, and eggs that are cooked until thickened into a smooth, shiny, creamy consistency. An example of a cornstarch pudding without eggs, "Grandma's Corn Starch Pudding," is on the Cooks.com website at http://www.cooks.com/recipe/259q973t/grandmas-corn-starch-pudding.html. There is a basic preparation for most cornstarch puddings, as well as multiple desserts and variations.
        a. Preparation: To Prepare a cornstarch pudding, a cook would do the following:
            (1) Mix the dry ingredients in a saucepan, and gradually stir in a small portion of the cold milk to make a smooth, runny paste.
            (2) Whisk in the remaining milk, and stir constantly over medium heat until the mixture just comes to a simmer.
            (3) Remove from the heat. Stir a small amount of the hot mixture into beaten eggs.
            (4) Stir the warmed eggs back into the milk mixture. Return to low heat, and bring to a simmer.
            (5) Cook and stir constantly for a short time (about one minute) to ensure the starch is evenly distributed and thickening has begun. Remove from the heat and stir in the flavor.
            (6) Chill until the pudding sets into a gel.
        b. Basic cornstarch pudding: Puddings placed in cups, or shaped in molds are the most common home options for cornstarch pudding. Most basic puddings come in vanilla or chocolate. They are served in a cup with whipped cream. A recipe for "Vanilla or Chocolate Pudding" is on the

Martha Stewart website at http://www.marthastewart.com/314077/vanilla-or-chocolate-pudding. This recipe whips the egg yolks into the cold milk before cooking which eliminates the step of warming the eggs.

c. Cream pies: Cream pies are cornstarch puddings that are chilled and placed in a pre-baked pie shell or crumb crust (cookie or graham cracker). A variety of cream pie recipes are available on the Better Homes and Gardens website at http://www.bhg.com/recipes/desserts/pies/cream/cream-pie-recipes/. These recipes include some of the most popular in America—coconut cream, brown-bottom butterscotch, chocolate meringue, and Italian silk pie. Other popular variations are banana cream and lemon meringue.

d. Parfaits: Called trifles in England, parfaits are chilled, cornstarch-pudding dishes made in a sundae or parfait glass. The pudding is sandwiched between layers of whipped cream, cookies, cakes, candies, or any variation of sweets. The goal is to have a variety of textures and flavors in each spoonful. An example, "Parfait Recipes," is on the Huffington Post website at https://www.huffingtonpost.com/2013/02/22/dessert-parfaits-recipes_n_2734345.html?slideshow=true#gallery/282300/0

e. Fillings: Cornstarch puddings are often used as a filling for cakes and cupcakes. Used as a filler between layers or inserted in the middle of the cake, these puddings are typically used to fill butter or sponge cakes. A YouTube video, "Chocolate Cake with Vanilla Pudding Filling," is on https://www.youtube.com/watch?v=wgGNt3t9U08. The assembly of the filled 13" × 9" cake includes an overnight in the refrigerator.

2. *Gelatin Pudding:* Chilled, gelatin pudding has ample levels of cream and eggs. Gelatin puddings can have a higher liquid content, since the gelatin can create a stronger gel strength than cornstarch. Common ingredients include milk, cream, gelatin, granulated sugar, heavy cream, flavorings, and added fruits or fruit juices. The resulting desserts may be kept under refrigeration for several days (or frozen). Dessert applications of gelatin pudding include panna cotta, Spanish cream, bavarian cream (Bavarois), charlotte russe, and blancmange.

   a. Panna cotta: ***Panna cotta*** is an Italian, double-cream pudding made with gelatin and served cold. Panna cotta literally means "cooked cream" in Italian. This rich, light, creamy dessert has a silky mouthfeel. Classically, it is served with a caramel sauce, but it can be found in a variety of flavors—thanks to the onset of international fusions. Watch the "Panna Cotta Recipe and Video" at http://joyofbaking.com/PannaCotta.html.

   b. Molded Creams: Many gelatin puddings have a high milk or cream content. They are often referred to as creams.

      (1) ***Spanish cream*** is a richly flavored, molded gelatin pudding made with milk. Classically, it is flavored with vanilla (and sometimes lemon). See a "Spanish Cream" recipe on Genius Kitchen at http://www.food.com/recipe/spanish-cream-124787.

      (2) ***Bavarian cream (Bavarois)*** is a rich, firm, gelatin pudding made with large amounts of cream. It uses a larger amount of cream than

the Spanish version. Bavarois is the French name for bavarian cream. In the United States, this creamy pudding is used as a filling in tortes, cakes, and donuts, but in Europe, it can be found in elaborate molds. See a yummy bavarian cream recipe by Michael Symon on the Food Network website at https://www.foodnetwork.com/recipes/michael-symon/bavarian-cream-recipe-1939359. A classic, French, vanilla bavarois recipe and video are on the CookerySkills.com website at http://www.cookeryskills.com/recipes/dessert-recipes/vanilla-bavarois/.

(3) A ***charlotte russe*** is a type of bavarian cream that is molded with sponge cake or ladyfingers. "Russe" is French for Russian. Generally, a circular pan or mold ring is lined with ladyfingers and filled with the bavarian cream. After it is chilled, the pan or mold is removed, and the ladyfingers are decorated with a bow, icing, or fruit. See Paula Dean's "Charlotte Russe" recipe on the Food Network website at http://www.foodnetwork.com/recipes/paula-deen/charlotte-russe-recipe/. A modified recipe, "Charlotte Cake Recipe," can be found on the Natasha's Kitchen website at http://natashaskitchen.com/2016/03/18/charlotte-cake-recipe/.

c. Blancmange: ***Blancmange*** is a cold, sweet, classic gelatin pudding molded into various shapes. Some recipes call for the addition of cornstarch in the mixture. This was a favored, fine-dining, pudding recipe from the 1500s to the 1800s, due to its ability to stiffen in elaborate molds and maintain its creaminess. See a recipe for "Downton Abbey Rose Blancmange" pudding (flavored with rose water) on The Modern Gelatina website at https://themoderngelatina.com/category/blancmange/.

D. TROUBLESHOOTING: When custards or puddings fail, the remedies may be easier than first thought. The following are common issues, their reasons, and possible fixes for custard and pudding recipes.

1. *Stirred Custard:* Stirred custard failures usually result from separation, flavor, or texture.
   a. Emulsion breaks: Ingredients separate if the temperature is too high during cooking.
   b. Starchy flavor: If the custard mixture isn't heated long enough for the starch to be absorbed, the flavor gets muddled. Too much cornstarch can cause a similar problem.
   c. Curdling: If the egg mixture is heated too quickly, the egg starts to cook. This forms lumps of scrambled eggs mixed throughout, causing a lumpy texture, odd mouthfeel, and eggy taste.
2. *Baked custards:* Baked custards have similar and unique difficulties.
   a. Cracked or pulled: Sometimes overbaking will cause the custard to crack from the top or pull away from the sides of the pan. This can also cause crispy or hard edges.
   b. Soggy crust: When baking a tart, pie, or quiche, the liquid and density of the custard can keep the bottom crust from cooking. This is an especially common problem when additional items (fruits in a tart or pie, mushrooms

or vegetables in a quiche) touch the crust. Partially pre-baking the crust can correct this problem. [NOTE: A high heat will keep the center from fully cooking before the edges are done. The heat should be lowered and the cook time expanded on the next try.]

c. Not set: If the custard does not set, there could be a few issues. Most commonly, it is underbaked. Other issues could involve the number of eggs used (too few) or the proper blending, whipping, or mixing of the ingredients.

3. *Cornstarch puddings:* Cornstarch puddings tend to have similar issues as other items thickened with cornstarch.
   a. Starchy flavor: If the pudding isn't heated long enough for the starch to be absorbed, the flavor gets muddled. Too much cornstarch can cause a similar problem.
   b. Curdling: If the egg mixture is heated too quickly, the egg starts to cook. This forms lumps of scrambled eggs mixed throughout, causing a lumpy texture, odd mouthfeel, and eggy taste. Acidic ingredients, such as citrus, can also cause milk to curdle.
   c. Not set: The imbalance of eggs, cornstarch, or liquids can cause the mixture to remain runny. Also, undercooking may be the problem.
   d. Lumpy: Pudding can have lumps when the egg has curdled, or the cornstarch was not properly added. Straining before chilling will help solve this problem.
   e. Scorched: A scorched, or burnt, flavor can happen when the temperature is too high during cooking. If a skin or browning is found at the bottom of the pan, this is also a result of a temperature being too high.
   f. Skin forms: If the warm pudding is not covered, a skin can form. Plastic wrap helps with this problem. A skin adds a tough texture to an otherwise silky pudding.
4. *Gelatin puddings*: Common gelatin issues are related to consistency and lumpiness.
   a. Not set: Sometimes, if a gelatin comes in contact with acidic ingredients, the sugar concentration is too high, or it is placed in a boiling liquid, it will not set properly.
   b. Lumpy: If gelatin is not properly bloomed or the pudding mix chills to too long before being incorporated into a meringue or whipped cream, the resulting dessert can have a grainy or lumpy texture.

E. STORAGE: All custards and puddings contain eggs and dairy. This means that they should be covered and placed in a refrigerator to keep bacteria from forming too quickly.
1. Refrigerated custards and puddings should be covered with plastic wrap. [TIP: Plastic wrap placed directly on the surface of warm cornstarch puddings prevents a skin from forming.]
2. Custards and puddings should be cooled to room temperature before refrigeration. This prevents excess condensation from forming.

3. These desserts should be held no more than three days under refrigeration. If frozen, the consistency will change upon thawing. Products tend to lose their freshness and palatability quickly.

F. SERVING: Custards and puddings can be served in a variety of ways. Temperature, added ingredients, and presentation should always be considered.

1. *Baked Custards:* Baked custards can be served warm or cold. They can be topped with spices (cinnamon or nutmeg), whipped cream, meringue, sweet sauces, or fresh berries. [TIP: Blot condensation from baked custards prior to serving.]
2. *Stirred Custards:* Stirred custards can be served warm or cold. Stirred custard can also be used as an element of other dishes (cream puffs, apple crumble, steamed pudding, etc.). Cakes and pastries mix extremely well with custard sauces.
3. *Cornstarch Puddings:* Served chilled, cornstarch puddings do well in a single, large dish or various individual dishes. When molding, individual pre-oiled cups are easier to release than a large mold. They can be topped with whipped cream or meringue. This pudding can be a great filling for cakes or pastries.
4. *Gelatin Puddings:* Gelatin puddings can be served chilled or frozen and topped with whipped cream or sweet sauces. Gelatin puddings hold well for arrangement on chilled trays for buffet service.

Teaching Strategy: *Think about giving the students a deeper understanding of gelatin through a three-part series, "FS 003: Guide to Gelatin," on the Stella Culinary website at https://stellaculinary.com/cooking-videos/food-science-101/fs-003-guide-gelatin.*

Use VM–F, VM–G, and VM–H for descriptions and pictures of custard categories. Use VM–I and VM–J for descriptions and pictures of cornstarch and gelatin pudding categories. Revisit VM–A to review basic custards and puddings. Use VM–F to VM–M to study the different types of custards and puddings. VM–K, L and M have a long list of recipes. Students may use these VMs to select recipes for LS–A. Assign LS–A to compare and contrast prepared custards and puddings in each category.

Objective 3:

Analyze physical changes and chemical reactions that occur in custard and pudding preparations.

Anticipated Problem: What physical changes occur during custard and pudding preparation? What chemical reactions occur during custard and pudding preparation? How do starches react when cooked and/or baked? What is gelatinization?

III. Baking is a science. Many scientific actions occur when making and baking custards and puddings. Numerous physical changes and chemical reactions are necessary to prepare perfect custards and puddings. The difference between a chemical reaction and a physical change is compositional. This section will discuss the definitions and

various situations related to chemical reactions and physical changes when preparing custards and puddings.

A. CHEMICAL REACTIONS: A ***chemical reaction*** is a process that produces a permanent change in the chemical composition and molecular structure of a substance. For example, fresh eggs that are fried cannot become fresh eggs again. The protein in the egg has been permanently changed, and the structural makeup is very different. Heat creates chemical reactions: exothermic and endothermic reactions. An ***exothermic reaction*** produces heat. An ***endothermic reaction*** absorbs heat. Specifically, heat:
   1. Helps produce tiny gas bubbles that help in thickening and rise (such as in a pudding or a soufflé)
   2. Causes egg protein to change and "firm up"

B. PHYSICAL CHANGES: A ***physical change*** is the transformation of a substance that does not alter its chemical properties—a phase change. The change can involve a difference in the way the substance displays appearance (color or shape), texture, temperature, or smell, but it usually results in a change of state, such as liquid to solid. Melting, boiling, and freezing are examples how to create a physical phase change. An ice cube that melts is still water, and its chemical properties remain intact. [NOTE: In the physical change described here, the ice cube and warm temperature are the reactants—the ingredients of physical change. The liquid water is the product, or result, of a physical change.]

C. ABSORPTION: ***Absorption*** is the act of one substance (liquid or solid) taking up (soaking up) particles from another substance (gas or liquid) by physical or chemical means.
   1. *Hygroscopic:* ***Hygroscopic*** is a term relating to the ability of a substance to absorb water from its surroundings. For example, when custard and pudding are prepared, liquid is absorbed into starch or gelatin molecules.
      a. Pan flow: Mixtures with a high proportion of liquid (whether water, milk, or eggs) creates a batter with more ***pan flow*** (the ease with which batter fills a pan's shape).
      b. Viscosity: The higher a batter's ***viscosity*** (a measure of thickness, or resistance to flow), the more resistant it is to flow. Each type of starch has different physical properties related to viscosity—less or more thickening power that affects the viscous nature of puddings and stirred custards.
   2. *Saccharides:* Starch is a complex carbohydrate also known as a polysaccharide.
      a. Monosaccharides: A ***monosaccharide*** is a basic unit of a carbohydrate and the simplest form of sugar. This includes glucose, fructose, and galactose.
      b. Disaccharides: A ***disaccharide*** is two monosaccharides linked together. These include sucrose, lactose, and maltose.
      c. Polysaccharides: A ***polysaccharide*** is a link of multiple monosaccharides. This can be ten or ten thousand. Polysaccharides are an example of a

polymer. A ***polymer*** is a substance created from the linkage of multiple, related molecules.

D. CONDENSATION: ***Condensation*** is the conversion (a physical change) of a vapor (gas) into a liquid—the reverse of evaporation. When cold batter and dough are placed into a warm oven, moisture (condensation) is produced on the surfaces. This action cools down the crust, and it allows the baked good to rise before the crust hardens. A porous surface on a baked good can be due to too much condensation.

E. EVAPORATION: ***Evaporation*** is the conversion (a physical change) of a liquid into a vapor (gas). The rate of evaporation increases with the rise in temperature. Evaporation is used in many culinary processes to concentrate a solution; such as cooking down pan sauces to thicken and intensify the flavor, simmering tomatoes to release moisture, or thickening a roux.

F. EMULSION: An ***emulsion*** is a semi-liquid, stable mixture in which one or more liquids are suspended within another. An emulsion can have two or more ***immiscible*** (unmixable) ingredients. While emulsions are immiscible, ***homogeneous mixtures*** are a mix of ingredients that have a uniform composition (the same properties throughout).

1. Emulsions can be "liquid dispersed in fat" or "fat dispersed in liquid." For example, natural emulsions include butter (liquid dispersed in fat) and homogenized milk and cream (fat dispersed in liquid).
2. Custards and puddings thickened with egg yolks are fats dispersed in liquids. The egg yolks thicken the liquid milk. However, egg yolks cooked to temperatures over 185°F cause the custard to curdle and the emulsion to separate.
3. Egg yolks contain lecithin. ***Lecithin*** is a mix of animal or plant lipids that create a substance which attracts both water and fatty substances for binding. This fatty (lipid) substance is often used as a food and drug additive for binding. [NOTE: For more general information about emulsions, see previous CAERT lessons about emulsions.]

G. HEAT TRANSFER: A ***heat transfer*** is the exchange of thermal energy between two objects, or the physical process of a food absorbing heat from a source. While heating food, molecules absorb energy, vibrate quickly, and bounce off each other. Each collision produces heat, which is transferred to the food. This is the basis of cooking. There are three methods of heat transfer. [NOTE: For more detailed information, the Biscuit People article, "Heat Transfer for Biscuit Baking," can be read at http://biscuitpeople.com/heat-transfer-for-biscuit-baking/. Their process described for biscuits is the same for baked custards.]

1. *Radiation:* ***Radiation*** is the transmission of heat through waves of energy. Microwave and infrared waves are two types of radiation in cooking. Radiant heat is evident with the opening of a preheated oven, a hand stretched over coals, or the feeling of skin near a boiling pot. Warmed air is transferred to food and cooks it (radiation cooks through indirect contact).
2. *Conduction:* ***Conduction*** is the passing of heat between solid objects through direct contact. For example, heat is conducted from stovetop burners to pots

and pans. Heat is then conducted from the pots and pans to the food. Pans transfer heat, by conduction, to a batter.

3. *Convection:* ***Convection*** is the transfer of heat by the circulation of warm air or water. In a convection oven, a fan blows hot air over and around the food. (In savory cooking, sous-vide is a method of cooking sealed bags of food in a warmed water bath. In custards, the double boiler and bain-marie are two convection heat sources used.)

H. CARMELIZATION: ***Caramelization*** is the oxidization (browning) of sugar, or the natural sugars in fruits and vegetables, in order to get a sweet, nutty, brown sauce or coating. Caramelization is the last chemical reaction to occur during baking. It only occurs when sugars are heated. The flavors of caramelization occur after 356°F is reached. Custards baked at 350°F have no caramelized flavor. Each sugar type caramelizes at a different temperature. Crème brûlée is an example of sugar that is caramelized with a torch (or under a broiler) immediately before serving. Each sugar type caramelizes at a different temperature.

1. Fructose caramelizes at 230°F (110°C).
2. Sucrose caramelizes at 320°F (160°C).
3. Baked goods made with honey or fructose develop a darker color, because they begin browning at a lower temperature (honey contains fructose).

I. HYDROLYSIS: ***Hydrolysis*** is the chemical separation of a compound through the addition of water. For example, adding water to sucrose leaves glucose and fructose. The result of this hydrolysis is an invert sugar. An ***invert sugar*** is equal parts glucose and fructose (derived from water and sucrose). The heating of eggs and sugar (prior to whipping) allows time for the conversion of sucrose (table sugar) to begin (with moisture from the fat—including egg yolks). [NOTE: The inversion processes can involve the hydrolysis of sucrose with an acid and some heat (used in candy making).]

J. FOAM: ***Foam*** is a mass of bubbles that is created in or on the surface by whipping or agitation. The act of whipping egg whites causes a protein film that holds the foam. A child blowing bubbles with a wand dipped in a soapy solution creates a type of foam.

1. *Colloidal Dispersion*: All foams are a type of ***colloidal dispersion*** (a substance suspended in another substance) in which air is dispersed without dissolving. The smaller substance suspended within another substance is called a ***colloid***.
2. *Surface Tension:* Not all ingredients foam. To foam, a liquid must have a low surface tension. ***Surface tension*** is a property of a liquid that allows it to resist external forces. The surface of a liquid, where the liquid is in contact with gas, acts like a thin elastic sheet. (Remember the soap bubble? It's a pressurized bubble of air contained within a thin, elastic surface of liquid. This is surface tension.) Warm temperatures lower the surface tension of liquid eggs, making it easier for bubbles to form. Eggs develop the volume and lightness of custards due to their ability to foam, and the innate surface tension of liquid eggs.

K. PH SCALE: When working with foods, ***pH*** is the level of acidity or alkalinity (a.k.a. basicity) of a given substance. The ***pH scale*** is a system of numbers used to measure the pH levels of a water-based liquid, with seven being neutral. The scale is a linear measure from 0 to 14. Neutral (neither acid nor alkaline) is a pH of 7 (water). Acid is a pH of less than 7 (lower numbers on the pH scale). Alkaline is a pH greater than 7 (high numbers on the pH scale). Alkaline substances release higher levels of hydrogen when mixed with water. Acids neutralize alkali and vice versa. Acidity is important when dealing with gelatins. Gelatins can break down in acidic atmospheres. [NOTE: For more information about pH and the pH scale, see the MYcaert lesson about pH and cooking.]

L. GELATINIZATION: ***Gelatinization*** is process of a liquid becoming gelatinous. It turns a colloidal system from a temporary suspension into a permanent suspension. Gelatinization is a chemical reaction involving a starch or gelatin with moisture and heat.

1. *Gelatinization of Starch:* There are physical changes that occur during gelatinization of starch—color, viscosity, and texture. Hydrogen bonds form between starch and water molecules, causing the starch granules to swell and absorb water. The more amylose in a starch molecule, the more the mixture will gel. The thickening properties of starch depend on the ratio of amylose to amylopectin molecules in starch.
   a. Amylose and amylopectin: Amylose mixes easily in liquid—it can change paste into a gel. Amylopectin doesn't mix easily in liquid due to its branched form. Waxy starches are engineered to have no more than 10% amylopectin (they contain more amylose and gel better).
   b. Retrogradation: In one or two days, a pudding gel made from starch breaks down. ***Retrogradation*** is the movement back to an original position. In starch, it is the realignment of previously separated molecular chains. The amylose and amylopectin chains start to realign as the pudding cools. This "backward movement" returns amylose to a crystalline form that causes the pudding to assume a gritty texture.
2. *Gelatinization of Gelatin:* Gelatin has long, stretchy chains of amino acids (and a small amount of hydrogen). These chains are attracted to other chains, and stick on top of each other. When liquid and heat are introduced, they slide apart and absorb the liquid. The hydrogen bonds are weakened from the liquid. Different from starch, the cooling process actually causes the hydrogen bonds to reform and reattach the gelatin chains. This strengthens and reforms the gelatin with the liquid dispersed within, creating a fully gelatinized product. This is why puddings made with gelatin are great for molds and significantly thicker than custards.
3. *Weeping:* ***Syneresis*** is contraction and separation of liquid from a gel. This is the action responsible for weeping. Sometimes, a pudding used as a pie filling starts to weep a day or two after preparation. This is a result of liquid molecules being pushed out as the solid molecules pull (contract) back together.

Teaching Strategy: ***TAKE NOTE:*** *Two common baking examples may help students differentiate between a physical change and a chemical reaction:*

- *Adding vinegar to baking soda causes the mixture to fizz (a gas is given off).*
- *Boiling water produces steam.*

One of these examples is a chemical reaction and the other is a physical change. To be termed a chemical reaction a new substance must be formed. When water boils, liquid water changes into steam, but it's still water (in a gas form)—a physical change. It's possible for the steam to return to a liquid state; however, when vinegar is added to baking soda, the gas produced is a new substance, CO_2. It is not possible to turn this new solution back into vinegar and baking soda; therefore, it is a chemical reaction.

Use for VM–N to review and visualize viscosity using honey and Dijon mustard examples. Use VM–O to understand immiscible ingredients, oil-in-liquid emulsions, and liquid-in-oil emulsions. Use VM–P to illustrate caramelization as a chemical reaction. Highlight the evaporation of water (a physical change) that also happens during caramelization. Use VM–Q to review gelatinization and to show the absorption of water by gelatin granules.

Assign LS–B to have students conduct a starch-viscosity experiment. Use VM–R to introduce the linespread experiment procedures for LS–B. Use VM–S, the Food Science Laboratory Report Form, to record details of the viscosity experiment. Use VM–T, the "Linespread Viscosity Data Table: Starches," to record the experiment calculations and observations.

Note: The test over this material is longer than usual. Consider adding a matching list for any completion sentences. This may be helpful to students who are new to studying the scientific side of cooking.

NGSS AND FCS CLASSROOMS: *Students benefit from learning the biological and chemical basics of food and nutrition. Culinary Arts allows real-life applications to scientific principles. Introducing the science behind the skills gives students a head start in understanding scientific terms and reactions. Science in FCS (Family and Consumer Science, Home Ec) classrooms encourage students to develop scientific reasoning skills with a fun twist. Get students prepared for Next Generation Science Standards (NGSS). Be part of the conceptual shifts in science education. NGSS states, "K–12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world." (https://www.nextgenscience.org/) FCS classes already include problem solving, teamwork, and applying real-life concepts (including physical changes and chemical reactions). Adding science concepts in FCS classes is a continuation of what is already being taught. When teaching a skill, try to explain the science behind the skill. This will develop and prepare your students, giving them both a scientific and an artistic viewpoint.*

RESEARCH LINKS: *There are multiple benefits of teaching science in FCS classrooms. For details about teaching science in FCS, try using some of the following quick links.*

- *"Cooking Class Benefits Kids in Many Ways" on the US News & World Health Report site at http://health.usnews.com/health-news/diet-fitness/diet/articles/2011/11/10/cooking-class-benefits-kids-in-many-ways*
- *"Six Reasons You Should Study Food Science" on the Institute of Food Technologists website at http://sciencemeetsfood.org/6-reasons-why-you-should-study-food-science/;*
- *"The Top 5 Reasons to Teach Nutrition Education in Your Classroom" on the Dairy Counsel of California website at http://www.healthyeating.org/Schools/Tips-Trends/Article-Viewer/Article/521/Top-5-Reasons-to-Teach-Nutrition-Education-in-Your-Classroom.aspx.*
- *"High School Food and Nutrition Classes Serve Up Skills for Life," at https://www.usnews.com/education/blogs/high-school-notes/2014/06/16/high-school-food-and-nutrition-classes-serve-up-skills-for-life.*

TEACHING SCIENCE IN FCS CLASSROOMS: *For advanced information about emulsions, see the Stella Culinary website article, "FS 101: What is An Emulsion? A Cook's Guide," at https://stellaculinary.com/cooking-videos/food-science-101/fs-001-what-emulsion-cooks-guide.*

Review/Summary.

Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. If a textbook is being used, questions at the ends of chapters may also be included in the Review/Summary. Use the E-Unit as a textbook with sidebars, expanded information, and questions at the end.

Application.

Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

Evaluation.

Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

Answers to Sample Test:

Part One: Matching

1. f
2. d
3. b
4. c
5. g

6. e
7. a
8. i
9. h
10. j

Part Two: Multiple Choice

1. c
2. d
3. b
4. a
5. c
6. a
7. d
8. b

Part Three: True/False

1. T
2. F
3. F
4. F
5. T
6. F
7. T
8. T

Part Four: Completion

1. emulsion
2. Hygroscopic
3. physical change
4. retrogradation
5. gelatinization
6. syneresis
7. viscosity
8. surface tension
9. chemical reaction
10. lecithin

Sample Test

Name _____

Custards and Puddings

Part One: Matching

Instructions: **Match the term with the correct definition.**

a. cornstarch pudding
b. crème anglaise
c. crème brûlée
d. custard
e. flan
f. gelatin
g. panna cotta
h. pastry cream
i. pudding
j. stirred custard

_____1. A colorless, flavorless, collagen-based, water-soluble, edible substance

_____2. A creamy, light dessert or sauce made from boiling or baking an egg-and-milk mixture

_____3. a thin, lightly sweet, custard sauce

_____4. baked custard served under a crispy sugar-topped crust

_____5. An Italian, double-cream pudding made with gelatin and served cold

_____6. A Hispanic classic—baked custard served upside down (unmolded), usually in a sauce

_____7. A boiled pudding thickened with cornstarch

_____8. A creamy dessert or filling made from eggs, milk, sugar, flavorings, and a thickener (such as cornstarch or gelatin)

_____9. A stiff, creamy, stirred custard that is used as a filling

____10. A soft, creamy custard made on the stovetop

Part Two: Multiple Choice

Instructions: **Circle the letter of the correct answer.**

1. The most common custard is _____.

   a. stirred
   b. boiled
   c. baked
   d. gelatin

2. Stirred custards should be thick enough to coat the back of a wooden spoon, leave a track when running a finger across the mixture, and reach an internal temperature of _____.

   a. 125°F
   b. 140°F
   c. 160°F
   d. 175°F

3. Adding a small amount of hot milk to beaten eggs while stirring constantly is a technique called _____.

   a. curdling
   b. tempering
   c. blooming
   d. mincing

4. To test the doneness of baked custard, gently shake the cup or baking dish and if the custard _____, it is done.

   a. jiggles all at once in the center
   b. jiggles in the center and edges all at once
   c. has a cracked skin
   d. forms bubbles

5. To prevent a skin from forming on a cornstarch pudding place _____ directly on the surface of the warm pudding.

   a. waxed paper
   b. paper toweling
   c. plastic wrap
   d. aluminum foil

6. Water baths prevent custards from becoming _____.

   a. unevenly cooked
   b. mushy
   c. dried out
   d. curdled

7. Naturally occurring starches contain two types of structures—_____ and _____.

   a. amylose, root starch
   b. tapioca, grain starch
   c. arrowroot, waxy starch
   d. amylose, amylopectin

8. When a starch solution is heated, its granules soak up the liquid, swell, and pop. When the granules pop, starch moves quickly into the liquid to _____ it.

   a. expand
   b. thicken
   c. dry
   d. color

Part Three: True/False

Instructions: **Write *T* for true or *F* for false.**

_____1. Crème anglaise and baked custard are prepared with the same ingredients but the cooking methods are different.

_____2. When a recipe calls for scalded milk to be mixed with beaten egg yolks, the standard practice is to add the milk all at once.

_____3. Perfectly baked custards are golden brown in color.

_____4. Panna cotta is a type of cornstarch pudding.

_____5. Gelatin puddings are often molded for specialty dessert presentations.

_____6. When making stirred custard in a double boiler, the top pan should rest in the boiling water for even heat.

_____7. The function of eggs in custards and puddings is to add color, add flavor, and coagulate the mixture.

_____8. Too much sugar or acid added to a custard or pudding mixture may prevent it from gelling properly.

Part Four: Completion

Instructions: **Provide the word or words to complete the following statements.**

1. A semi-liquid, stable mixture in which one or more liquids are suspended within another is a/an _____.
2. _____ is a term relating to the ability of a substance to absorb water from its surroundings.
3. The transformation of a substance that does not alter its chemical properties is a/an _____.
4. The backward movement that returns amylose to a crystalline form and gives pudding a gritty texture is called _____.
5. A chemical reaction involving a starch or gelatin with moisture and heat is called _____.
6. The scientific cause for weeping is _____.
7. An item's resistance to flow is called its _____.
8. A soap bubble is an example of a liquid property that allows it to resist external forces. This is called _____.
9. Fresh eggs that are fried cannot become fresh eggs again. This is a/an _____.
10. The substance found in egg yolks that attracts both water and fatty substances for binding is _____.

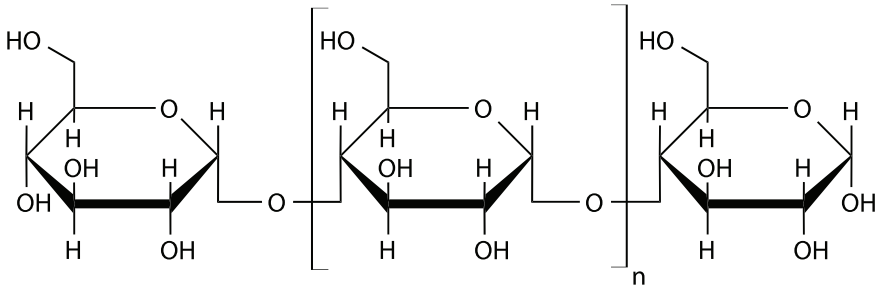
AMERICAN PUDDING AND CUSTARD

American puddings and custards are similar in consistency and ingredients. In general, puddings are a thick, jiggly, less-eggy version of a custard. Due to egg content, custards are more flexible in their uses. They can become a sauce, a cream filling, a baked filling, or a frozen dessert! Pictured are a flan (a combination of a custard and pudding), pudding made in a mold, a custard pie, and a classic créme brûlée.

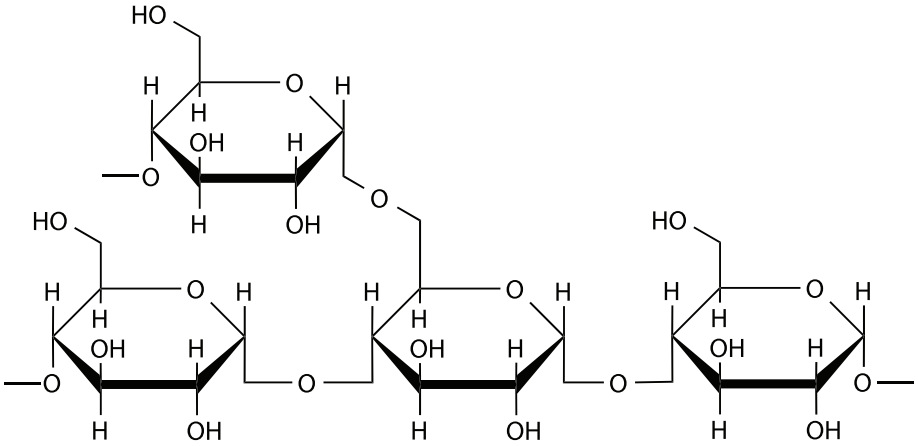



STARCHES: AMYLOSE AND AMYLOPECTIN

Starch is a complex carbohydrate, a polysaccharide of bonded carbohydrate molecules found in plants. The plants' molecules are tightly packed into small granules. Complex carbohydrates are composed of three or more sugar units. Starches are found in seeds, fruits, tubers, roots, and the stems of plants. The starch molecule contains long chains of glucose that form two types of structures, a long, straight-chain starch called amylose and a short, branched-chain starch called amylopectin. Starch molecules contain both amylase and amylopectin.



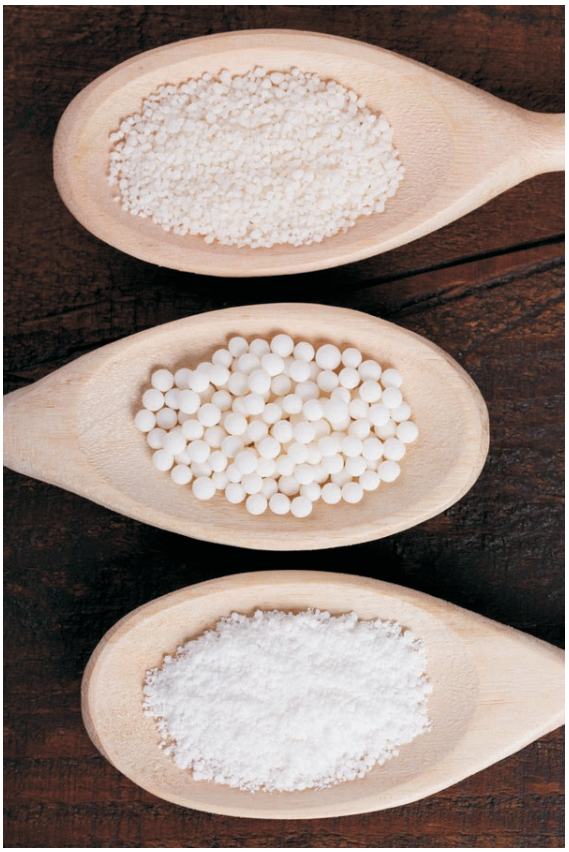
Amylose



Amylopectin

STARCHES: HOW DO THEY WORK?

All starches work by absorbing liquid into individual starch grains. The amount of liquid a starch grain will absorb (and how concentrated the grains are in the liquid) affects how thick the mixture becomes. Some starches will completely "set" a liquid (as in a molded gelatin salad). When a starch solution is heated, the liquid molecules begin to move around quickly and bump into the grains of starch. Then, the starch granules soak up the liquid, swell, and pop. Illustrated here are the ways you can find tapioca. In food preparations, it can be used in pearl, crushed, or powdered form. Which tapioca starch is used to thicken and bind the pudding shown here?



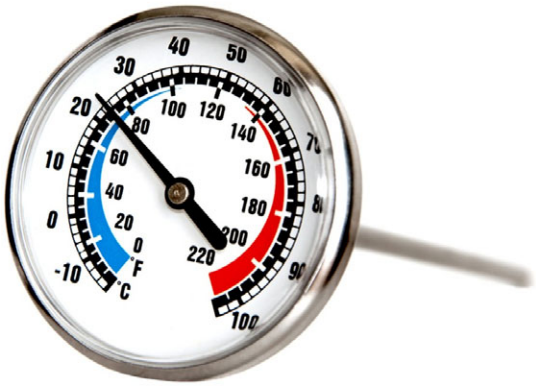
BASIC CUSTARD AND PUDDING INGREDIENT FUNCTIONS

For the best custard and pudding results, use high-quality eggs, milk, cream, and sugar. Measure and weigh accurately, and closely following recipe instructions.

Ingredient	Functions
Starch	Structure, thickening, and sometimes flavor
Eggs	Volume (when beaten), moisture, color, flavor, texture, and thickening (coagulation of protein)
Liquid	Moisture, Volume (with starches and gelatins), flavor, color, steam [Usually milk or a milk-like product]
Gelatin	Structure and thickening
Sugar	Flavor, color (caramelizes), and moisture retention
Salt	Enhances the sweetness and flavor of custard and pudding, while heightening the flavor of other ingredients
Fat	Flavor and richness, emulsification
Flavoring	Enhances or fundamentally changes the taste of custard and pudding

CUSTARD AND PUDDING EQUIPMENT AND TOOLS

Identify each tool and piece of equipment used to make custard and pudding.



(https://creativecommons.org/licenses/by/2.0/deed.en)

STIRRED CUSTARDS: PASTRY CREAM AND CRÈME ANGLAISE

Custard is a creamy, light dessert or sauce made from boiling or baking an egg-and-milk mixture. Custards are of two types—stirred or baked. They are used as desserts, sauces, bases for other desserts, and some savory dishes, such as a quiche or a frittata. ***Stirred custard*** is a soft, creamy custard made on the stovetop. It is softer in texture than baked custard. Pastry cream and crème anglaise are two of the most versatile stirred custards. Note the creations made with these two variations on custard. Can you name which is the pastry cream and which is crème anglaise?

BAKED CUSTARDS: FLAN, CRÈME BRÛLÉE, AND CRÈME CARAMEL

The most common custards are baked. **Baked custard** is a light, slightly eggy, custard that has been cooked in the oven. Ingredients include eggs, granulated sugar, salt, steaming milk, and flavoring. These custards typically retain the shape of their container and are relatively solid. Preparing baked custard is a simple process, in which the ingredients are whipped together, strained through a fine sieve, poured into custard cups or pie/tart shells, and baked in a water bath. Can you identify which dessert is a flan, crème caramel, or crème brûlée?

BAKED CUSTARD: QUICHE, FRITTATA, AND SOUFFLÉ

Quiche lorraine is a savory custard pie from the Lorraine region of France. The asparagus frittata shown here was baked; however, a frittata can be prepared on the stovetop (often in a cast iron pan). A soufflé can be prepared as a sweet dessert or a savory, creamy pie—raspberry and cheese soufflés are shown here.

BOILED PUDDINGS: CORNSTARCH

In the United States, the most common puddings made with cornstarch. **Cornstarch pudding** is a boiled pudding thickened with cornstarch. Generally, this dessert is a mixture of milk, sugar, cornstarch, and sometimes eggs that are cooked until thickened into a smooth, shiny, creamy consistency. The cornstarch puddings illustrated here are lemon meringue pie, chocolate pudding cup, and a butterscotch-and-vanilla parfait with mixed fruit.

BOILED PUDDINGS: GELATIN

Chilled, gelatin pudding has ample levels of cream and eggs. Gelatin puddings can have a higher liquid content, since the gelatin can has a stronger gel strength than cornstarch. Common ingredients include milk, cream, gelatin, granulated sugar, heavy cream, flavorings, and added fruits or fruit juices. The resulting desserts may be kept under refrigeration for several days (or frozen). Classic Italian panna cotta is pictured here with a strawberry sauce. This bavarian cream is very simply accented with shaved chocolate. A charlotte russe is another classic dessert. The one pictured here is a raspberry pudding molded with ladyfingers.

STIRRED CUSTARD LINKS FOR LS–A

Pastry Cream Recipes:

1. Allrecipes: “Pastry Cream” at http://allrecipes.com/recipe/76043/pastry-cream/
2. Bon Appètit: “Cream Puffs with Vanilla Pastry Cream” at http://www.bonappetit.com/recipe/cream-puffs-vanilla-pastry-cream
3. Cookie Madness: “Scratch Boston Cream Pie” at http://www.cookiemadness.net/2013/12/scratch-boston-cream-pie/
4. Genius Kitchen: “Éclairs with Vanilla Pastry Cream” at https://www.geniuskitchen.com/recipe/cream-puffs-or-eclairs-with-vanilla-pastry-cream-203416
5. Joyofbaking.com: “Fruit Tart” at http://www.joyofbaking.com/FruitTart.html
6. Food Network: “Lemon Curd” at http://www.foodnetwork.com/recipes/ina-garten/lemon-curd-recipe/

Crème Anglaise Recipes:

1. Epicurious: “Crème Anglaise” at http://www.epicurious.com/recipes/food/views/creme-anglaise-4984
2. Baking Bites: “Homemade French Vanilla Ice Cream” at http://bakingbites.com/2011/01/homemade-french-vanilla-ice-cream/
3. Callebaut: “Chocolate Mousse for Pastries” at http://www.callebaut.com/en-US/chocolate-video/technique/mousse-sauce#group-items-wrapper
4. Epicurious: “Lemon Chiffon Pie with Gingersnap Crust” at http://www.epicurious.com/recipes/food/views/lemon-chiffon-pie-with-gingersnap-crust-235364
5. Food Network: “Floating Island” at http://www.foodnetwork.com/recipes/floating-island-recipe0

BAKED CUSTARD LINKS FOR LS–A

Baked Custard Recipes:

1. CDKitchen: “Best-Ever Baked Custard” at http://www.cdkitchen.com/recipes/recs/838/Best-Ever-Baked-Custard82351
2. The Spruce Eats: “Easy Old-Fashioned Baked Custard” at https://www.thespruce.com/easy-old-fashioned-baked-custard-3059894
3. The Spruce Eats: “Classic Custard Pie with Nutmeg” at https://www.thespruce.com/classic-custard-pie-with-nutmeg-3052755
4. Genius Kitchen: “Authentic Mexican Flan” at https://cooking.nytimes.com/recipes/1018487-flan-de-leche
5. Betty Crocker: “Crème Brûlée” at http://www.bettycrocker.com/recipes/creme-brulee/67864cdb-de54-48b0-adca-02b9839ba033
6. Easy French Food: “Crème Caramel” at http://www.easy-french-food.com/creme-caramel-recipe.html
7. Martha Stewart: “Quiche Lorraine” at http://www.marthastewart.com/338286/quiche-lorraine

PUDDING LINKS FOR LS–A

Cornstarch Pudding Recipes:

1. Cooks.com: “Grandma’s Cornstarch Pudding” at http://www.cooks.com/recipe/259q973t/grandmas-corn-starch-pudding.html
2. Martha Stewart: “Vanilla or Chocolate Pudding” at http://www.marthastewart.com/314077/vanilla-or-chocolate-pudding
3. Better Homes & Gardens: “Best Cream Pie Recipes” at http://www.bhg.com/recipes/desserts/pies/cream/cream-pie-recipes/
4. Rachael Ray: “Black-and-White Pudding Parfait” at http://www.rachaelraymag.com/recipe/black-and-white-pudding-parfait
5. Once Upon A Chef: “Warm Lemon Pudding Cakes” at https://www.onceuponachef.com/recipes/lemon-pudding-cakes.html
6. Joyofbaking.com: “Lemon Meringue Pie Demonstration” on YouTube at https://www.youtube.com/watch?v=7TGtdzFs1eE

Gelatin Pudding Recipes:

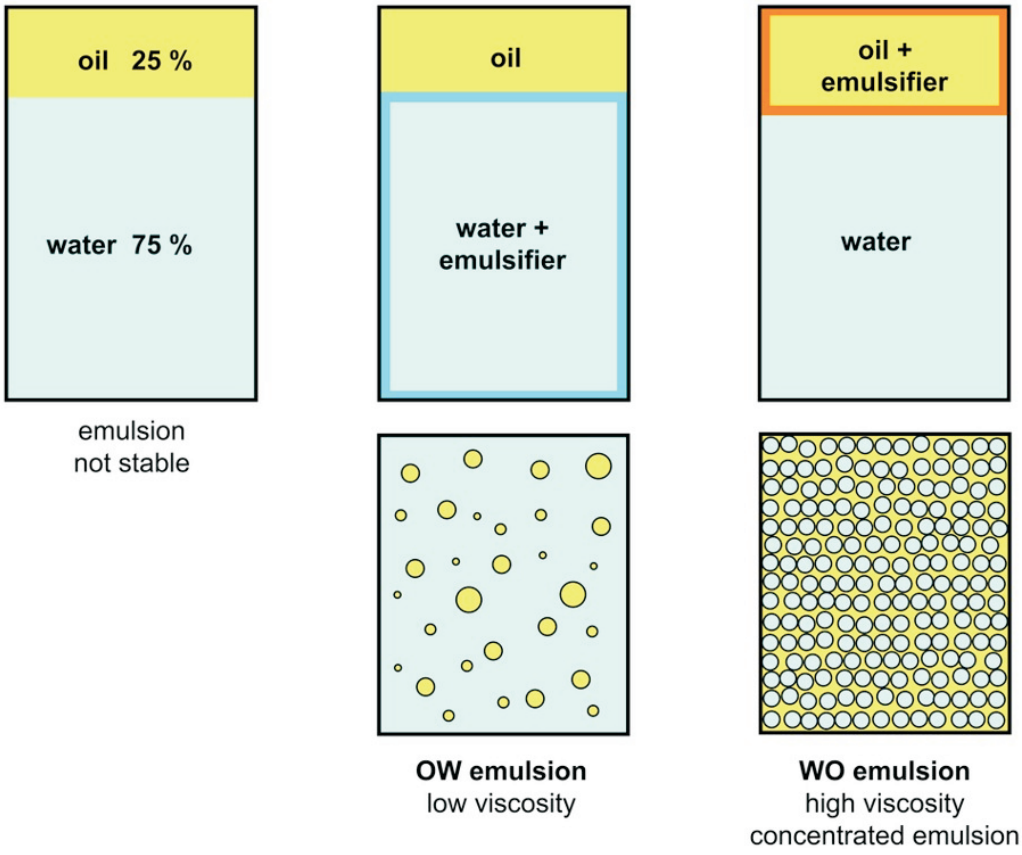
1. Italian Chips: The Italian, Original Recipe for Panna Cotta at http://www.italianchips.com/recipe-for-panna-cotta/
2. Rock Recipes: “Spanish Cream” at http://www.rockrecipes.com/spanish-cream/
3. Epicurious: “Bavarian Cream with Raspberry Coulis” at https://www.epicurious.com/recipes/food/views/bavarian-cream-with-raspberry-coulis-235956
4. cookeryskills.com: “Vanilla Bavarois” at http://www.cookeryskills.com/recipes/dessert-recipes/vanilla-bavarois/
5. Food Network: “Charlotte Russe with Raspberries” at http://www.foodnetwork.com/recipes/alexandra-guarnaschelli/charlotte-russe-with-raspberries-recipe-1973426
6. The Modern Gelatina: “Mrs. Molesley’s Prize-Winning Rose Blanc-mange” at https://themoderngelatina.com/category/blancmange/

PHYSICAL CHANGE: VISCOSITY

Viscosity is a measure of thickness, or resistance to flow. Each starch has different physical properties related to viscosity—less or more thickening power that affects the viscous nature of puddings and stirred custards. Observe these two ingredients—honey and Dijon mustard. Which has more viscosity? What other foodstuffs are "resistant" to flow?

PHYSICAL CHANGE: EMULSIONS

An **emulsion** is a semi-liquid, stable mixture in which one or more liquids are suspended within another. An emulsion can have two or more **immiscible** (unmixable) ingredients. While emulsions are immiscible, **homogeneous mixtures** are a mix of ingredients that have a uniform composition (the same properties throughout). Emulsions can be "liquid dispersed in fat" or "fat dispersed in liquid." For example, natural emulsions include butter (liquid dispersed in fat) and homogenized milk and cream (fat dispersed in liquid). Custards and puddings thickened with egg yolks are a fat dispersed in liquid emulsion. The egg yolk thickens the milk.



CHEMICAL REACTION: CARAMELIZATION

Caramelization is the oxidization (browning) of sugar, or the natural sugars in fruits and vegetables, in order to get a sweet, nutty, brown sauce or coating. Caramelization is the last chemical reaction to occur during baking. It only occurs when sugars are heated. The flavors of caramelization occur after 356°F is reached. Custards baked at 350°F have no caramelized flavor, but may develop a small amount of surface caramelization. Each sugar type caramelizes at a different temperature. Crème brûlée is an example of sugar that can be caramelized with a torch (or broiler) immediately before serving.

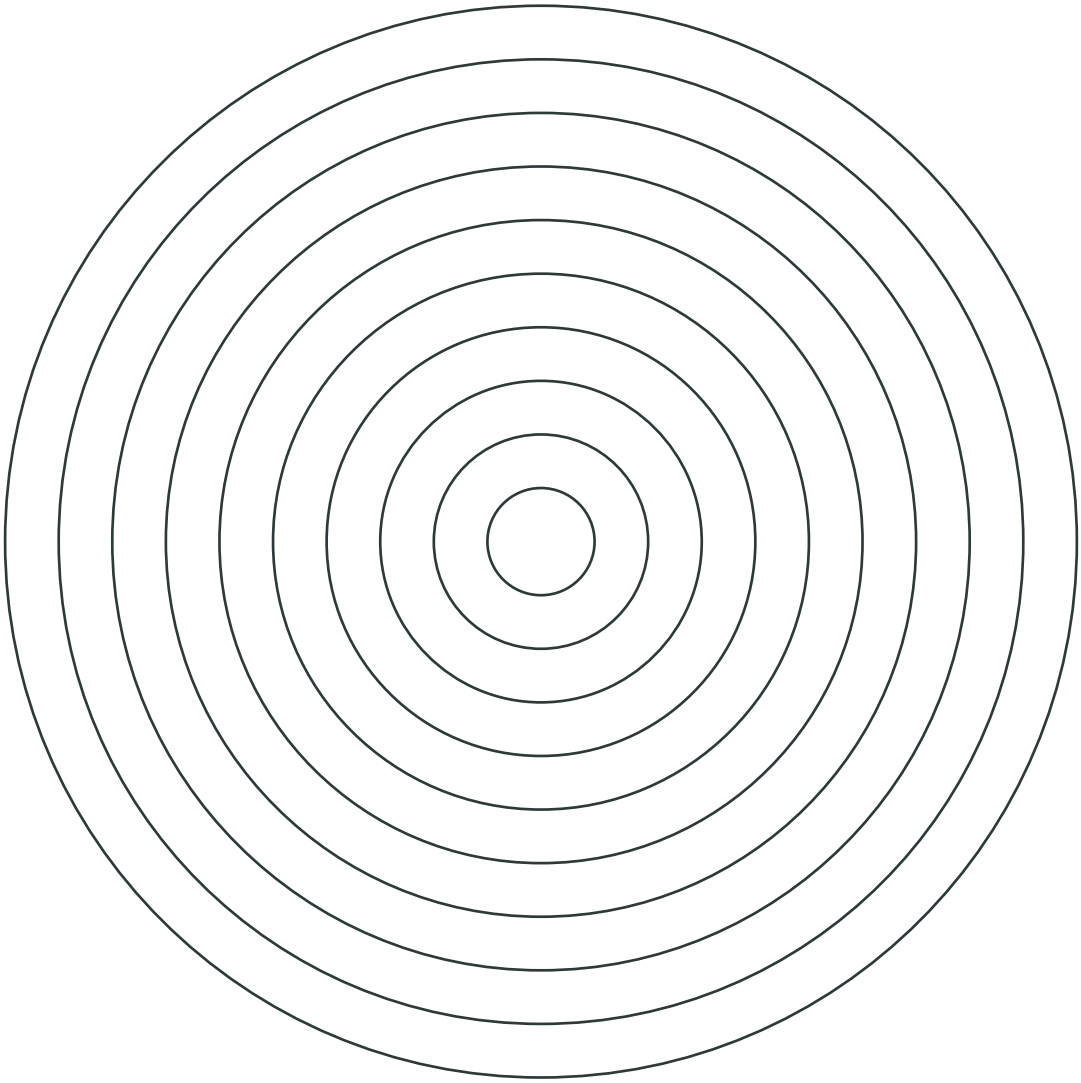
CHEMICAL CHANGE: GELATINIZATION

Gelatinization is process of a liquid becoming gelatinous. It turns a colloidal system from a temporary suspension into a permanent suspension. Gelatinization is a chemical reaction involving a starch or gelatin with moisture and heat.

There are physical changes that also occur during gelatinization of starch—color, viscosity, and texture. Hydrogen bonds form between starch and water molecules causing the starch granules to swell and absorb water. The more amylose in a starch molecule, the more the mixture will gel. The thickening properties of starch depend on the ratio of amylose molecules to amylopectin molecules in starch.

LSA: LINESPREAD VISCOSITY EXPERIMENT

The linespread test of viscosity is a quick, inexpensive, and reliable test for comparing the relative viscosities of various ingredients and mixes. [NOTE: For more information, see the Home Economics blog at http://cbs-he.blogspot.com/2005/07/linespread-test.html.]



Linespread Test Sheet:

1. TEST CYLINDER: The open circle in the center is the location for the test cylinder. It is the location for each test sample.

2. LABELED CIRCLES: From the test cylinder location, the next concentric circle is 1 cm from the test cylinder and is not labeled, concentric circle two is labeled "2," the third concentric circle is not labeled, yet the fourth concentric circle is labeled "4." Repeat this process.

3. MEAN AVERAGE CALCULATION: Divide the linespread test sheet into quarters with dissection lines from north to south and west to east. Record the "spread number" of each starch sample in all four directions (north, south, east, and west). Then, sum the four numbers and divide that sum by 4. Record the mean average calculation on the Data Table. [NOTE: Taking these 4 measures compensate for a completely level surface.]

FOOD SCIENCE LABORATORY REPORT FORM

Name: _____

Class Period _____ Lab Partners: _____

Experiment Name: _____ Total Points: _____

I. PRE-LAB (Complete before lab.) Experiment Date: _____

A. **Safety**: List safety precautions for this lab. _____ points

B. **Purpose** (in your own words): _____ points

C. **Procedure** (reworded and simplified): _____ points

D. **Hypothesis** (State your educated guess about the results.): _____ points

II. CONDUCT LAB (Complete and attach data table) _____ points

E. **Observations** (Watch and record the experiment): _____ points

F. **Data Summary** (Summarize the data table entries.): _____ points

G. **Evaluation** of lab completion and cleanup: _____ points

III. POST LAB: (Complete this section following the experiment.)

H. **Questions/Calculations**: _____ points

I. **Scientific Conclusion**: _____ points

LINESPREAD VISCOSITY DATA TABLE: STARCHES

Name: _____

Starch Name: _____

[NOTE: Attach Data Table to the Food Science Laboratory Report Form. Add the names of all starches used in the experiment. Add more rows if needed.]

Starch Name	Hot Linespread Average	Cold Linespread Average	Refrigerated Sample Appearance	Thawed Sample Appearance
Cornstarch				
All-purpose Flour				

LS–A

Name _____

Custard and Pudding Comparison Rating Lab

Purpose

The purpose of this lab is to practice custard and pudding preparation techniques and rate the final products.

Objective

Prepare, describe, and rate custard and pudding variations.

Materials

- lab sheet
- device with Internet access
- VM–K, VM–L, and VM–M
- lab equipment as needed
- ingredients as needed
- paper plates
- pen or pencil
- calculator (optional)

Procedures

1. Review your class notes and e-unit about custards and puddings.
2. Divide into lab groups. Each lab group will prepare a different custard or pudding variation. Select a recipe from VM–K, VM–L, or VM–M. List your selection in the table provided.

Custard and Pudding: MY SELECTION

Category	Recipe Name	Group Members
Pastry Cream		
Crème Anglaise		
Baked Custard		
Cornstarch Pudding		
Gelatin Pudding		

a. Review your recipe selection with your instructor.
b. Complete a grocery list and the instructor-required food preparation lab plan. Discuss time schedule with instructor.
c. Submit grocery list and lab form to instructor as directed.

3. PREPARATION:

a. Read the recipe carefully. Clarify any steps before beginning preparation.
b. Gather all ingredients, equipment, and tools (mise en place).
c. Measure ingredients accurately (mise en place).
d. Prepare the recipe according to instructions, video, and/or class demonstration. Use safety and sanitation standards.

4. DISPLAY & DESCRIBE: Present the final product to the entire class. As a lab group, describe your dish to the class.

5. EVALUATION: Cut sample pieces (pieces should reflect the number of lab groups plus one for your instructor) of your custard or pudding.

a. Place each sample on a separate paper plate with the category name and the recipe title at the top. Then, provide each lab group (and instructor) with a sample.
b. The lab group divides the sample into smaller samples for each member.
c. Individually, evaluate your own product in four categories: flavor, consistency, texture, and color using the "Custard and Pudding: My Assessment" data table.
d. Next, tally the scores for each category. This will in include the scores of the samples you try.
e. CALCULATE THE MEAN (AVERAGE) RATINGS: Next, calculate the mean average for the lab group of each category. (Add together all totals for "My Average" (from each group member) for each product. Divide each number by how many students are in the lab group. This is the average score. Do the same for the class. Add lab group totals and divide by the number of groups for each category.

Custard and Pudding Data Table: MY ASSESSMENT

	Pastry Cream Variation	Crème Anglaise Variation	Baked Custard Variation	Cornstarch Pudding Variation	Gelatin Pudding Variation
Flavor					
Mouthfeel					
Texture					
Color					
Overall TOTAL					

[Rating Scale: 1=Poor, 2=Fair, 3=Good, 4=Excellent]

Custard and Pudding: GROUP ASSESSMENTS
LAB GROUP AVERAGES

Lab Group	Pastry Cream Variation	Crème Anglaise Variation	Baked Custard Variation	Cornstarch Pudding Variation	Gelatin Pudding Variation
Flavor					
Mouthfeel					
Texture					
Color					
Overall TOTAL					

CLASS AVERAGES

Class	Pastry Cream Variation	Crème Anglaise Variation	Baked Custard Variation	Cornstarch Pudding Variation	Gelatin Pudding Variation
Flavor					
Mouthfeel					
Texture					
Color					
Overall TOTAL					

[Rating Scale: 1=Poor, 2=Fair, 3=Good, 4=Excellent]

6. REPORT RATINGS: After you have documented all of the averages, answer the following.

   a. Which variation(s) scored highest in your group evaluation? Describe what made that product the winner.

   b. To what degree did your individual ratings match those of your lab members' ratings? (1 = low, 4 = high) For example, *"I rated the baked custard highest because it was very creamy. My group did not rate it as highly because they didn't like the eggy taste as much as I did."* Describe any discrepancy between your individual ratings and those of your group.

   c. To what degree did your ratings match the class ratings? (1 = low, 4 = high) Describe any discrepancy between your group's ratings and the class averages.

7. Turn in your completed lab sheet to your instructor.

Name _____

Linespread Viscosity Experiment: Starches

Purpose

The purpose of this activity is to assess the viscosity of various starches.

Objective

Compare and contrast the viscosity and weeping qualities of different starch samples.

Materials

Individual Equipment

- lab sheet
- device with Internet access
- VM–R Linespread Viscosity Experiment: Starches Overview
- VM–S Food Science Laboratory Report Form
- 1 VM–T Linespread Viscosity Data Table: Starches
- one or more starch sample per group
- pen or pencil

Equipment per lab group:

- 1 linespread test sheet
- 1 test cylinder
- 1 fine line permanent marker

- 1 liquid measuring cup
- 1 tablespoon measuring spoon
- 1 wooden spoon
- 1 layer cake pan (8 × 8-inch square or 8-inch round)
- 1 medium saucepan
- 1 range or hot plate
- 1 small metal/plastic cylinder approximately 1.5" to 2" in height and diameter (or prepared with small disposable plastic cup and scissors)
- 1 stop watch or clock with second hand
- 1 clear glass pie plate
- 2 muffin tins
- 2 paper muffin liners
- 2 labels or small papers and tape

Procedure

1. **Lab Procedures Review:**
   a. As a class, review VM–R. Access and read the suggested website information. Ask questions about the procedure before beginning the linespread viscosity experiment.
   b. With your instructor, review VM–S "Food Science Laboratory Report Form" and requirements.
   c. Divide into lab groups (two to four each). Each lab group is assigned one or more types of starch for the experiment. [NOTE: Your instructor will identify which starch samples are being tested. If more starch samples are needed, two lab groups may be assigned different measurements of the same starch.]
   d. Complete the Pre-Lab portion of the "Food Science Laboratory Report Form" individually. Submit the Pre-Lab data to your instructor.
2. **Lab Preparation:** Mise en place
   a. Collect one test cylinder (either metal or plastic) approximately 1.5 to 2 inches in height and diameter.
   b. Collect all equipment and materials necessary for your lab group's experiment on a tray.
3. **Conduct Experiment:**
   a. Obtain starch sample(s). Record the starch name(s) on Data Table.
   b. Measure 2 tbsp. starch. Place in clean medium size saucepan.
   c. Place 1/3 cup of cold water in the saucepan, and stir the starch until all lumps are gone. Then, add an additional cup of cold water to the saucepan and cook over

medium heat, stirring constantly, until mixture boils. Boil the mixture for 1 minute. Remove the saucepan from the heat.

d. Place a clean, dry, glass pie plate atop the linespread test sheet (plastic wrap or a velum paper will work as well). Place the test cylinder on top of the glass pie plate and in the center of the linespread sheet.
e. Place 1/4 cup of the hot mixture from saucepan into the test cylinder. Lift the ring and allow the mixture to flow for 1 minute. Note the line number on four points (north, east, south, and west) to allow for leveling the surface. Total the numbers and divide by 4. Record your calculation in the "Hot Linespread Average" column on the data table.
f. Cool the remainder of the starch mixture to room temperature by placing the saucepan in a cake pan filled with cold water and ice (to speed the cooling process).
g. When the starch mixture reaches room temperature repeat the linespread test (from above) and record that calculation in the "Cold Linespread Average" on the data table.
h. Prepare two labels that state your name, type of starch, and the amount of starch added to the liquid. These labels will be placed in the muffin tin liners. Next, labels two muffin tins as "Refrigerator" and "Freezer." (If necessary, share muffin tins with one or more lab groups.)
i. Place 1/4 cup cooled mixture each into the two paper muffin tin liners.
j. Place the appropriate muffin tins into the refrigerator and the freezer to be left overnight.
k. Clean the lab area, and ask your instructor to inspect for cleanliness.

4. **Compare and Contrast Starch Samples:** On the following lab day, remove the freezer sample to thaw on countertop.

a. Inspect the thawed and the refrigerated samples for weeping due to retrogradation and syneresis. Record your observations of each starch sample:
   - Refrigerated:

   - Frozen:

b. Share your data with the class.
c. Compare and contrast each starch sample. Explain which starch, if any, would be the best choice for preparing the following.
   - Molded pudding cup:

   - Refrigerated cream pie:

- Stirred custard:

- Frozen/thawed cream pie:

d. What explains different starches producing different results?

e. Clean the lab area and have your instructor inspect for cleanliness.
f. Complete the "Food Science Laboratory Report Form." Submit this lab sheet and all data to instructor as directed.

Linespread Viscosity Experiment: Starches

1. Create test cylinders. (Prepare metal or plastic (PVC) cylinders approximately that are 1.5" to 2" in height and diameter. Other options include biscuit cutters or plastic drinking cups cut to specifications. To use plastic cups, cut off bottom so that the edges sit evenly on the glass pie plate.)
2. Create the linespread test sheets:
   a. Position the test cylinder in the center of a sheet of 8½ × 11-inch paper. Draw "around" the test cylinder (PVC or other material). [NOTE: For additional information and a visual of the linespread test sheet, see the Oregon State University "Linespread Test" information and images at http://cbs-he.blogspot.com/2005/07/linespread-test.html. The open circle is the location of the test cylinder.]
   b. Then, draw concentric circles at 1-centimeter intervals from the test cylinder space using a compass. (Each concentric circle is located 1 cm from the last circle and is continued until the linespread diagram "fits" the glass pie plate.)
   c. From the test cylinder space, label every other line. The first line is known as 1cm already, so the next lines labeled will be 2, 4, 6, etc. Then, copy the diagram for each lab group. Divide the linespread test sheet into quarters with dissection lines from north to south and west to east. Student lab groups must record the "spread" number of each starch sample in all four directions: north, south, east, and west. [NOTE: Your school's science department may have linespread test sheets available for your use. The linespread test sheets can also be purchased from science resource catalogues.]
   d. See the SciDoc Publishers article, "Rheology of Muffin Batters by Line Spread Test and Viscosity Measurements," at https://scidoc.org/articlepdfs/IJFS/IJFS-2326-3350-05-901.pdf. This study relates information about the viscosity of muffin batter and additional mathematics calculations that could be added to your experiment. It also gives good visual displays of a linespread test.
   e. This viscosity experiment is worth the time it takes to evaluate differences in thickening agents. Students are able to see retrogradation and syneresis firsthand. They are able to participate in scientific testing using supplies and equipment available in a food lab. [NOTE: Emphasize that numerous experiments, found on web searches use this same technique to measure starch viscosity. This experiment is adapted from *Food Science: The Biochemistry of Food and Nutrition*, "Chapter 15," by Mehas Rogers.]

3. A food science laboratory report form can be printed two-sided to save paper. This same reporting format may be used for any scientific labs performed in class. Print one copy per student:

   a. Linespread Test of Viscosity: Thickening Agents
   b. Food Science Laboratory Report Form
   c. Linespread Viscosity Data Table: Starches
   d. Linespread Test Sheet (this could be one per group)

4. For the experiment, you may substitute "waxy wheat starch" with a 3:1 mixture of flour to cornstarch.

5. Starch options include cornstarch, all-purpose flour (wheat), cake flour (wheat), instant flour (Wondra®), potato starch (or instant potatoes), rice flour, arrowroot starch, or a waxy starch.