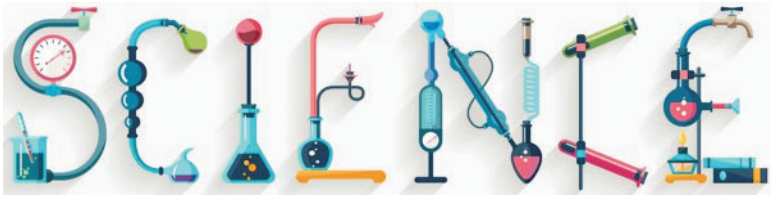
Icings and Glazes: Ingredients and Preparation



BAKING is a science. Numerous physical changes and chemical reactions are necessary to prepare perfect icings and glazes. Icing and glaze mixtures use relatively few ingredients: at a minimum all use some type of sugar and some types of liquid. Yet the processes that transform these limited ingredients into luscious coatings is not completely understood. However, we do know that foam creation, absorption, emulsions, and caramelization play key roles in the process. First, understand the science involved in creating icings and glazes, then experiment with new ideas for unique coatings.

Objective:

Analyze physical changes and chemical reactions that occur in icing and glaze preparation.

Key Terms:

absorption
alkaloid
antioxidant
caramelization
chemical reaction
coagulate
coagulation
colloids
colloidial dispersion
condensation
conduction
convection
denature
denaturation
emulsion
endothermic reaction
exothermic reaction
evaporation
firm-ball stage
foam
hard-ball stage
hard-crack stage
heat transfer
homogenous mixtures
hydrolysis
hygroscopic
immiscible
invert sugar
lecithin
physical change
radiation
soft-ball stage
soft-crack stage
surface tension
suspension
thread stage
Tyndall effect
viscosity

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The Science of Icings and Glazes

Baking is a science. Many scientific actions occur when preparing icings and glazes: numerous physical changes and chemical reactions are necessary to prepare the perfect icing or glaze. The difference between a chemical reaction and a physical change is composition (structure).

A **chemical reaction** is a permanent change in the chemical composition of a substance in which molecules are broken apart and rearranged into new molecules. For example, fresh eggs that are fried cannot become fresh eggs again: the protein in the egg is permanently changed and the appearance is very different. When dough and batter are heated in an oven, a chemical reaction occurs and new bonds are formed. Heat creates chemical reactions: exothermic and endothermic reactions. For example, heating sugar and liquid produces an endothermic chemical reaction that changes basic ingredients into "icing or glaze." An **exothermic reaction** produces heat. An **endothermic reaction** absorbs (takes in) heat.



FIGURE 1. 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. And, it's possible for the steam gas to return to a liquid state. However, when vinegar is added to baking soda, the gas produced is a new substance called carbon dioxide (CO_2) and it is not possible to turn this new solution back into vinegar and baking soda: it's an example of a chemical reaction.

A **physical change** is the transformation of a substance that does not alter its chemical properties: it's just a physical phase change. The change involves a difference in the way the substance displays: appearance (color or shape), texture, temperature, smell, or a change of state of the substance (e.g., frozen or melting or boiling). Melting, boiling, and freezing are examples of a physical phase change: an ice cube (frozen water) that melts is still water (liquid 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.]

PHYSICAL CHANGES AND CHEMICAL REACTIONS

Physical Changes

Absorption is the act of attracting (taking up) particles of gas or liquid into a liquid or solid substance. (Absorption can be physical or chemical.) For example: During icing and glaze preparation, liquid is absorbed in the following ways:

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- Sugars are hygroscopic; including granulated sugar, confectioners', honey, brown sugar, and molasses. **Hygroscopic** is the ability of a chemical to absorb water from its surroundings. Sugar attracts water keeping icings and glazes moist and soft.
- Fat/sugar mixtures, such as buttercream icing types, absorb liquid.
- Gelatin, used in some whipped cream icings, absorbs liquid during the "blooming step" (soaking gelatin in liquid).



FIGURE 2. Gelatin powder, granules, or sheets soak for 5 minutes without stirring until the cold liquid is absorbed and the mixture looks translucent. Stabilized whipped cream icings may add gelatin.

Condensation is the conversion (a physical change) of a vapor or a gas to a liquid: the reverse of evaporation. Condensation develops on the pans of cooked icings as steaming liquid gathers on the rims of the pan or double boiler and becomes droplets. Condensation can develop on iced cakes especially those covered with rolled fondant icing.

Evaporation is the conversion (a physical change) of a liquid to a vapor at a temperature below the boiling point. The rate of evaporation increases with the rise in temperature. Evaporation is used in many culinary processes to concentrate a solution (e.g., "cooking down" pan sauces to thicken and intensify the flavor, simmering tomatoes to release moisture and thicken a pasta sauce, cooking sugar and water to evaporate water and concentrate the sugar, etc.).

An **emulsion** is a semi-liquid and stable mixture in which one liquid is suspended in another: a mixture of two or more ingredients **immiscible** (unmixable) unless combined in an emulsion. Emulsions are uniform mixtures: **homogeneous mixtures** have a uniform composition and the same properties throughout. Eggs contain protein, fat, and natural emulsifiers. The fats and emulsifiers in eggs work like starch, stabilizing the bubbles in icing. Typical emulsions include a fat or oil and a liquid. Emulsions can be water dispersed in fat or fat dispersed in water. Natural emulsions include butter (water dispersed in fat) and homogenized milk and cream (fat dispersed in water).

French buttercream icing is thickened with egg yolks: a fat dispersed in water emulsion. Egg yolks contain **lecithin**, a protein substance found in egg yolks that attracts both water and fatty substances and aids in forming emulsions. [NOTE: Solid butter, should be 60° to 70°F and whole eggs, egg whites, and egg yolks must be at room temperature to whip to their maximum volume.]

In contrast to an emulsion, a **suspension** is a heterogeneous mixture (a non-uniform composition such as sand and water) of fluid and solid particles in which the components are mechanically dispersed and eventually settle out. In an oil and water mixture, shaking the mixture causes it to temporarily "suspend" the heavier water in the oil.]

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Heat transfer is the physical process of a food coming into contact with a heat source and becoming hot: the exchange of thermal energy between two objects. The action that occurs during heating is food molecules absorbing energy, vibrating quickly, and bouncing off each other. Each collision produces heat, which is transferred to the food: cooking. Cooked icings use the science of heat transfer. There are three methods of heat transfer:

Radiation is heat transmitted as infrared rays. The stovetop burner or unit produces radiant heat to prepare cooked icings.

Conduction is heat passed between objects by direct contact, by the collision of molecules. For example, stovetop burners conduct heat to pots and pans and pots and pans transfer or conduct heat to the icing and molecules collide. For example, grilling a steak or a hamburger is an example of conduction heat transfer. Also, cake pans transfer heat, by conduction, to the baked good.

Convection is heat transferred by circulating warm air around food. In a convection oven, a fan blows hot air over and around the food.

Chemical Reactions

Foam is air (in the form of bubbles) that is incorporated and trapped in a protein film by whipping: the act of whipping egg whites causes bubbles to form and be trapped in a protein film. (Source: Food Science: The Biochemistry of Food and Nutrition). For example, visualize a child blowing a bubble with a wand or straw dipped in a soapy solution or with bubble gum: these are types of foams. All foams are a type of **colloidal dispersion** (a suspension) in which air is dispersed without dissolving. Not all ingredients foam. For example: to foam, a liquid must have a low surface tension.

Surface tension is a property of a liquid that allows the liquid 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: surface tension.) Warm temperatures lower the surface tension of liquid eggs, making it easier for bubbles to form. Egg foams develop the volume and lightness of icings due to their ability to foam and the innate (natural) surface tension of liquid eggs.

Natural proteins, at the molecular level, are shaped like coils or springs. When exposed to



FIGURE 3. Foam is air (in the form of bubbles) that is incorporated and trapped in a protein film by whipping: the act of whipping egg whites causes bubbles to form and be trapped in a protein film. All foams are a type of colloidal dispersion (a suspension) in which air is dispersed without dissolving. The stiffly beaten egg whites in this image are a type of egg foam: a colloidal dispersion.

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heat, salt, or acid, they **denature** (unfold) and the coils unwind. Foams form when the protein liquid of eggs is whipped: the foam forms a film around the air pockets and denatures the protein. When proteins denature, they **coagulate** (bond together and form solid clumps). When heated, the protein in the egg white (ovalbumin) coagulates (clots, thickens) and gives the foam structure. The egg white bond must be denatured and the bond loosened to coagulate. **Coagulation** is the changing of a liquid to a semisolid or solid mass.

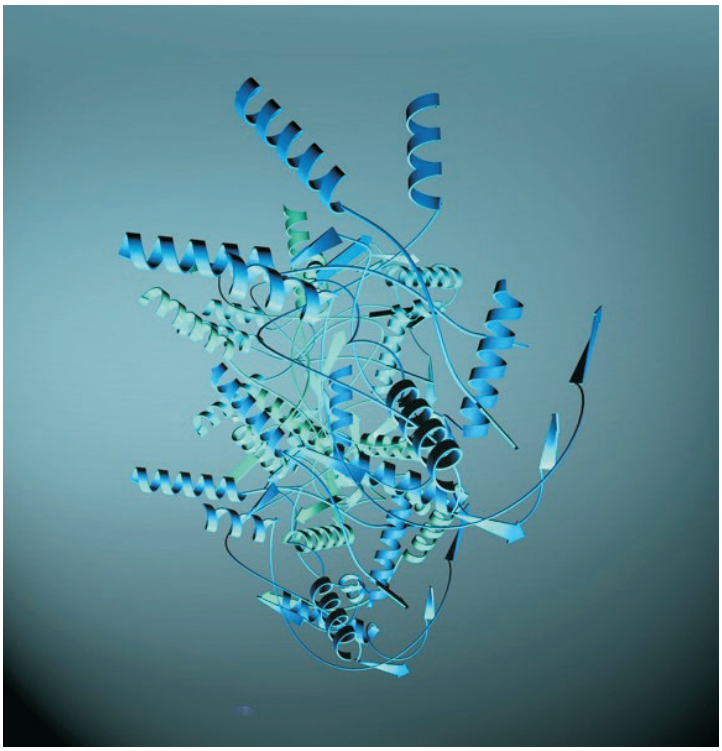


FIGURE 4. Natural proteins, at the molecular level, are shaped like coils or springs. When exposed to heat, salt, or acid, they denature (unfold) and the coils unwind. Foams form when the protein liquid of eggs is whipped: the foam forms a film around the air pockets and denatures the protein in the egg. When proteins denature, they coagulate (bond together and form solid clumps).

Denaturation is a chemical reaction that changes the shape of a protein molecule by loosening the hydrogen bond that originally formed coils and springs and turns it into a long, shapeless chain. Denaturation usually happens during heating or by the addition of an acid, but in the case of egg whites it happens due to physical whipping that causes the proteins to unfold. Denaturing breaks the hydrogen bond and makes a loose, less compact structure. Egg whites' **viscosity** (resistance to flow), due to their large protein molecules, makes them easily denatured by whipping. In contrast, milk does not retain the foam that forms when it is whipped because milk contains less protein than eggs and is less viscous (contains more water than eggs).

Colloids are mixtures of small, insoluble particles found in solutions and in suspensions that are evenly distributed without "settling out." Milk and cream are examples of colloidal dispersions: mixtures of colloid particles in a dispersing medium.

The elastic tendency of a liquid (surface tension) allows the molecules on the surface to push together and form layers (e.g., liquid fat and water). Emulsions break the surface tension and allow two liquids or a liquid fat and another liquid to mix. Egg yolk (a liquid and fat) and sugar syrup are emulsified in French buttercream by breaking the surface tension.

Colloids and suspensions are different primarily because the suspension components eventually settle out. Colloids are also different than solutions due to the **Tyndall effect**: a beam of light passing through a true solution, such as air, is not visible, however the particles in colloids are large enough to deflect the light.

Caramelization is the oxidation (browning) of sugar, a process used extensively in cooking for the resulting nutty flavor and brown color: a chemical reaction. (Source: Science of Cooking) Meringue icing is an example of caramelized sugar that is browned with a propane

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EXPLORING OUR WORLD...

SCIENCE CONNECTION:
Use Pasteurized Fresh Egg Whites in Royal Icing

To prevent the possibility of foodborne illness, use pasteurized fresh egg whites or meringue powder in your royal icing, instead of fresh egg whites. Royal icing got its name because the British royal families used it to cover their traditional fruitcake-based royal wedding cakes. Royal icing is also the glue or mortar that holds gingerbread houses together. For more information about the safe use of egg whites in royal icing, see The Barefoot Baker website article, "Egg White Royal Icing Recipe & Egg Safety," at https://thebearfootbaker.com/2015/04/egg-white-royal-icing-recipe/. Then, see The Spruce website article, "Royal Icing Recipe—Gingerbread House Glue," at https://www.thespruce.com/royal-icing-recipe-gingerbread-house-glue-1136167.



Look closely; can you detect the outline yellow outline on these cutout cookies? This baker traced the perimeter of the cookie using royal icing in a pastry bag fitted with a plain decorating tip, allowed the royal icing outline to dry slightly, and then "flooded" the outlined space to create a smooth icing. Once these cookies dry completely, they can be packaged and/or stacked without causing damage to the icing.

or butane torch or placed under the broiler before serving. Caramelization occurs when sugars are heated and each sugar type caramelizes at a different temperature.

- Fructose caramelizes at 230°F (110°C).
- Sucrose caramelizes at 320°F (160°C).

As sugar syrups cook, water boils away, and the concentration of sugar in the solution increases. As a result the temperature of the sugar syrup increases. The name of each stage of cooked sugar syrup indicates what the syrup is like when cooled.

- **Thread stage** is a sugar syrup measurement reached between 230° and 235°F in which the sugar concentration is about 80%. The syrup still contains a lot of water. When this syrup is dropped into cool water it forms a thread but does not create a ball. USES: Syrup for ice cream or pancakes.
- **Soft-ball stage** is a sugar syrup measurement reached between 235° and 240°F in which the sugar concentration is about 85%. This syrup, when dropped in cool water, forms a soft, flexible ball. It flattens in your hand when removed from the water. USES: Fudge, pralines, and fondant.

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- **Firm-ball stage** is a sugar syrup measurement reached between 245° and 250°F in which the sugar concentration is about 87%. When this syrup is dropped into cool water is forms a firm ball that does not flatten when removed from the water. It will flatten when squeezed. USE: Caramel candy.
- **Hard-ball stage** is a sugar syrup measurement reached between 250° and 265°F in which the sugar concentration is about 92%, a rather high concentration. This syrup, when dropped into cool water forms a thick, rope-like thread as it is poured and forms a hard ball after contact with the cool water. The ball does not flatten when removed from the cool water but it can be squashed to modify its shape. USES: Nougat, marshmallows, gummies, divinity, and rock candy.
- **Soft-crack stage** is a sugar syrup measurement reached between 270° and 290°F in which the sugar concentration is about 95% and the water content is very low. The mixture's bubbles become smaller, thicker, and closer together as the syrup boils. When dropped into cool water it solidifies into threads that are flexible but brittle (bend slightly before breaking). USES: Saltwater taffy and butterscotch candies.
- **Hard-crack stage** is a sugar syrup measurement reached between 300° and 310°F in which the sugar concentration is 99% and almost no water remains in the syrup. Dropping this mixture into cool water produces hard, brittle thread that break when bent. USES: Toffee, nut brittles, and suckers.



FIGURE 5. Caramelization is the oxidation (browning) of sugar, a process used extensively in cooking for the resulting nutty flavor and brown color. Caramelization occurs when sugars are heated. This image shows sugar and water cooking (bubbling). As the heat increases and evaporation of the water occurs, the sugar becomes darker and darker (more sugar molecules, fewer water molecules because the water is evaporating). The longer the sugar syrup cooks, the more concentrated it becomes with sugar molecules and caramelization occurs.

Hydrolysis is the splitting of a compound into smaller parts by the addition of water or another liquid. Hydrolysis occurs when cooked icings are prepared. For example: Sucrose + Water → Glucose + Fructose. The result of hydrolysis of sucrose is invert sugar. **Invert sugar** is equal parts glucose and fructose. Fructose is sweeter than sucrose. The heating of eggs and sugar prior to whipping allows time for the conversion of sucrose (table sugar) with moisture (from fat and egg) to begin.

Summary:

Baking is a science. Numerous physical changes and chemical reactions are necessary to prepare perfect icings and glazes. The difference between a chemical reaction and a physical change is composition (structure). A chemical reaction is a perma-

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nent change in the chemical composition of a substance in which molecules are broken apart and rearranged into new molecules. A physical change is the transformation of a substance that does not alter its chemical properties: it's just a physical phase change. The change involves a difference in the way the substance displays: appearance (color or shape), texture, temperature, smell, or a change of state of the substance (e.g., frozen or melting or boiling).

Many science terms are used to describe icing and glaze preparation. The science terms you will be asked to use repeatedly when preparing icings and glazes include: foam creation, absorption, emulsions, and caramelization.

Checking Your Knowledge:



1. Differentiate between a physical change and a chemical reaction.
2. Heating a water and sugar mixture to make a glaze causes evaporation of some or most of the water. How does water evaporation impact the "behavior" of the sugar syrup when cooled?
3. All foams are a type of colloidal dispersion (a suspension) in which air is dispersed without dissolving. What is an example of an icing or glaze that requires a colloidial dispersion?
4. Caramelization is the oxidation (browning) of sugar, a process that occurs when sugars are heated. What happens to the number of sugar and water molecules the longer the mixture cooks?
5. French buttercream icing is thickened with egg yolks. Is French buttercream an example of a "fat dispersed in water" emulsion or a "water dispersed in fat" emulsion?

Expanding Your Knowledge:



Learn more icing and glaze techniques and tips based on a coating's chemical makeup and/or how you wish the texture of the icing or glaze to appear on the dessert: smooth, crusty, textured, etc. Access the Craftsy website article, "A Comprehensive Guide to Different Kinds of Icing, Glazes, & Frostings," at https://www.craftsy.com/blog/2015/12/different-kinds-of-icing/.

Web Links:



How to Caramelize Sugar
https://www.youtube.com/watch?v=yWxuPDynKOY

Laws of Baking: Frosting/Icing/Glaze/Syrup
http://lawsofbaking.com/category/bakes/frostings/

Royal Icing
http://bigbaketheory.com/2011/12/14/royal-icing/

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