Explain Methods of Heat Transfer

COOKING AND BAKING require the use of heat energy. However, heat energy comes in numerous forms. The manner in which heat energy is transferred from the heat source to the food varies. Therefore, understanding the heat transfer methods may enable you to manipulate and improve the results.

Objective:

Explain the ways heat energy moves from the heat source to the food.

Key Terms:

conduction
convection
heat
heat source
heat transfer
heat transfer medium
induction
infrared energy
microwaves
molecules
radiation
temperature
thermal conductivity
thermal energy

Forms of Heat Transference

Heat is a combination of kinetic (movement) energy and temperature (a measurement of heat). It can be created using various methods for different purposes, with varying results.

HEAT TRANSFER

Heat transfer is a form of energy that moves heat to food. In general, heat is transferred from one material to another in one of three ways: conduction, convection, or radiation. When foods are heated, their molecules begin to vibrate and bounce into one another. These collisions cause heat to transfer.

Heat or Thermal Energy

Heat (or **thermal energy**) is the relative amount of energy present in matter (more energy equals more heat), and **temperature** is a measurement of that energy (how fast the molecules of an object are moving; the faster they move, the higher the temperature). **Molecules** are the microscopic particles that make up all matter. Heat always emanates from a **heat source**—a unit generating energy—such as charcoal, a gas burner, an electric coil, radiation, or the sun. Whether the object is a steak or a living room, adding heat means adding energy.

Effects of Heat on Food

The effects of heat on food are to make food palatable and easier to digest. Heat results in these actions: fats melt; water evaporates; starches gelatinize (swell, thicken); proteins coagulate (become firm, harden); and sugars caramelize (brown). Heat is transferred to food by means of a heat transfer media: air, liquid water, steam, and/or fat.

THREE PRIMARY METHODS OF HEAT TRANSFER

The majority of people use conduction, convection, and radiation to transfer heat while preparing meals.

Conduction

Conduction is the transfer of heat directly from one source to another—direct physical contact. Heat through conduction is demonstrated as simply as putting a pan on a stove and turning on the flame (or coil). The heat (or energy) from the stove physically touches the pan. The heat moves from the bottom of the pan, through the pan, and into the food in the pan. So conduction is heat traveling through food. Conduction is by far the most commonly used method of heat transfer in commercial kitchens. In general, anything cooked on a stovetop or in an oven uses conduction heat transfer.

FIGURE 1. Conduction heat transfer is simply displayed here as a flame (heat source) sending thermal energy upward into the pan, which then sends the heat upward into the food.

Induction

The newest and most energy efficient form of conduction cooking is through induction cook tops or ranges. **Induction** is the process of releasing magnetic currents (generated by a high-frequency induction coil) that react only with certain ferrous (containing iron) metals that allow the heat energy to pass into the metal and then into the food. Induction heat only works if the pan used responds to magnetic energy. For example, aluminum does not respond to magnets and simply will not pass the energy into the food. No flame or red coil can be seen, and the "burner" surface produces no heat of any kind. Induction is pure energy.

Thermal Conductivity

Thermal conductivity is the extent to which a material absorbs and transfers heat. Unlike induction heat transfer where only special metals will absorb and pass along the heat magnetic energy, most matter absorbs and passes along thermal energy (heat). Some do it far better than others. For instance, aluminum transfers (or conducts) heat better than glass. The medium is directly related to thermal conductivity. A **heat transfer medium** is the actual "material" the heat is moving through: a pan, air, water, oil, etc. The medium has a direct effect on how rapidly a food cooks. For example, a chicken breast will cook faster in oil (deep frying) than in an oven's hot air medium, even if the temperature is the same.

Convection

Convection energy is the bulk movement of heat, not just the conduction of it from point A to B to C. Convection heat transfer can be natural (warm air rises, cool air falls) and/or mechanical (fans, stirring) movements; the heat travels in the air or through a fluid (liquid or gas). Because convection energy requires motion, it results in faster and more even cooking. Common in professional cooking equipment, convection ovens use standard heat and a fan inside the oven, blowing the heat around the food—moving the air—rather than just having hot air rise from the bottom of the oven. On a stovetop, while water is heating to a boil, the water on the bottom of the pot is hotter than the water at the top before reaching the boil. If the water is stirred, the heat will transfer more rapidly throughout the water. The physical movement of the water to transfer heat from the bottom of the pot is the use of convection heat

FIGURE 2. Convection ovens cause hot air to circulate around the foods (horizontally), causing the food to cook and brown more evenly. Notice the fan at the back of this oven. Convection ovens cook food 25 percent faster at a temperature 25 percent lower than a conventional oven.

transfer. Typically, convection energy is used along with conduction energy to heat food because the two together are more effective than either alone.

Radiation

Unlike conduction and convection energy, **radiation** is a type of heat transfer that occurs by moving energy waves of heat or light through molecules. No heat transfer medium is needed when using radiation heat transfer. In fact, a medium (e.g., pot, pan, or grill) would only get in the way by blocking the rays that emit the energy. Cooking with radiation requires that the rays be "beamed" directly into the food, where the food absorbs the raw energy.

Microwaves

Microwaves are short electromagnetic radiant (photon) energy waves emitted from a magnetron tube. The tube spins around and showers the food inside the oven with microwaves. The ovens are designed to keep the waves inside the walls of the oven and not emit energy when the door is open.

FIGURE 3. Notice that the clips on the microwave oven door ensure that the door cannot accidentally open while the oven is in operation.

Cooking occurs when water molecules in the food absorb the microwave energy. As the water molecules begin to move, the food cooks from the outside to the inside by simple conduction. As microwaveable foods are being heated and cooked by water molecules, they generally do not brown or crisp without special sleeves or cookware. This is the same reason glass, china dishes, paper towels, etc. do not burn in a microwave oven. If cookware feels hot when removed, it is because heat was transferred from the food to the cookware, not from the microwave. The waves pass harmlessly through nonporous cookware, but they will bounce off, spark, and react violently when they hit tin, aluminum, or similar metals.

Infrared Energy

Infrared energy is electromagnetic (e.g., a microwave) light energy that causes organic food molecules to vibrate and cook. It is their light energy that causes food molecules to vibrate and cook. Infrared waves are sent directly to the food without the use of a medium. Broilers and heat lamps are examples of infrared cooking devices. Infrared waves are not visible as "red" rays, though the source may (or may not) glow red. The rays penetrate the food from the outside in and are more readily absorbed by all molecules (rather than just water as in a microwave), making this energy form useful for browning the surface of foods, such as meat and cheese.

Keep in mind that the transfer of thermal energy is not limited to a single direction or form no matter what energy source is used. By cooking food in a microwave, the heat that builds up in the food due to microwaves will spread to the plate or food container through conduction if that food container is a good thermal medium. In addition, food cooked in a glass dish in a microwave oven will cool faster (after being removed) than the same food cooked in a plastic bowl in the microwave. Because glass is a better medium for heat transfer than plastic—the plastic holds the heat longer because it doesn't conduct heat well—the food cooked in the glass dish gets cold first.

FIGURE 4. Even though heat generally rises, the infrared energy coming from the glowing broiler coil above the food moves in all directions.

Summary:

Heat is the amount of energy present in a given object or environment. It is conducted or transferred in one of three primary methods: conduction, convection, or radiation. Conduction is the process of heat or thermal energy moving from one molecule to the next, passing along from the source, through the medium (e.g., air, water, oil, or metal), and into the food. Convection uses motion or fans to move energy from place to place.

Radiation uses energy waves to transfer heat in two forms: microwaves or infrared waves. Microwaves are emitted from magnetron tubes inside microwave ovens and are absorbed primarily by liquid molecules that heat the food and do not brown foods unless sleeves or special cookware are used. Infrared waves typically come from heat sources that glow: coils, bulbs, or burning coals. Broilers and heat lamps are infrared cooking devices that brown and crisp foods. Neither form of radiation relies on heat mediums or conductivity to work, but both can be impaired by mediums such as foil or other metal objects.

Checking Your Knowledge:

1. What form of energy transfer takes place when frying an egg on the stove?
2. Why don't microwave ovens brown or crisp foods unless the cook uses special cookware?

3. If heat rises, how can food be cooked in a broiler where the food is below the heat source?
4. Why does water that is boiling rapidly at 212°F cook so much faster than water that isn't moving at 209°F?
5. A cake baked in a glass pan takes much longer to bake than an identical cake baked in an aluminum pan. Why?

Expanding Your Knowledge:

Most homes and foodservices have a microwave oven. Regardless of what is cooked or heated, the only real warning for microwave usage is: Do NOT use metal in any form inside the oven. Glass, china, paper, and plastic are all acceptable containers, but what most people don't know is that there is a problem with plastic. Some plastic containers are labeled as "microwave safe," but those that do not carry that label seem to work just fine. The problem has to do with food safety and chemical contamination. Do some research to determine the dangers. What type of plastics should never be used to heat food in microwave? What are the dangers of eating foods heated in those containers? Should plastic wrap be used to heat food in a microwave oven? Make a PowerPoint based on your findings, and post it on MySpace or Facebook if you have an account. If you do not have an account, share your findings with your class.

Web Links:

Microwaving Food in Plastic
http://www.health.harvard.edu/fhg/updates/update0706a.shtml

Getting Food Hot
http://culinaryarts.about.com/od/cookingmethods/a/heattransfer.htm

How Stuff Works—Microwave Cooking
http://home.howstuffworks.com/framed.htm?parent=micriwave.htm&url=http://ag.arizona.edu/pubs/health/foodsafety/az1081.html

How Does Infrared Cooking Work?
http://www.ehow.com/how-does_4886541_infrared-cooking-work.html