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COOKING WITH HEAT

Cooking food involves heat, whether it is roasting, baking, grilling, sautéing, or searing. Heat naturally moves from hot surfaces to cooler surfaces. The movement of heat is commonly referred to as heat transfer. There are three methods of heat transfer: conduction, convection, and radiation. The cooking of food usually uses a combination of these methods. Besides being aware of minimum internal cooking temperature for food safety, understanding what heat transfer is and how it works can help you better understand the science of cooking.

TYPES OF HEAT TRANSFER METHODS

Conduction

Conduction transfers the heat using direct contact; food is heated directly in a metal pan, in a liquid, or surrounded by air. Dropping an egg into a pan of boiling water is a good example. The heat from the water is transferred to the egg. As the outside of the egg becomes warm, the heat moves into the center of the egg, continuing inward until the entire egg is heated to the desired temperature. When sautéing a chicken breast, heat from the burner is transferred to the pan, where the molecules in the pan begin to vibrate, passing the heat onto the chicken breast. As the surface of the poultry becomes hotter than the interior, the heat transfers to the center of the breast via the food's moisture and fat content. Grill marks on a steak are also an example of conduction. The metal grates transfer heat from the grill to the steak.

Convection

Convection occurs by the movement of air, liquid, or steam around the food. For example, as a pan of soup heats up on the stove, heat moves from the bottom of the pan, rising so the cooler part of the soup moves down to replace it. This causes a circular motion to occur in the food. Stirring the food redistributes the heat from the bottom of the pan throughout the other ingredients, as well. Convection is also the reason frozen foods thaw more quickly when placed under cold running water. Convection can occur mechanically by means of a fan that circulates the air in an oven. An air fryer works through convection. A convection oven can reduce the cooking time by 25% over standard ovens. It also increases browning of the food because of the concentrated heat on the surface of the food.

Radiation

Radiation heat transfer occurs when microwave (light waves) or infrared energy (heat waves) are spread into the food. As the microwaves penetrate the food, they bump into molecules of water and fat, causing them to vibrate rapidly. This vibration creates friction, which creates the heat that cooks the food. The larger the piece of food, the more unevenly the microwaves penetrate, so microwave cooking has some limitations. Of course, microwaves are great for reheating, thawing (conduction of heat), or cooking food.

Induction Cooking

Induction cook tops have a coil wire under a ceramic glass surface. When the cooktop appliance is turned on, an electromagnetic current flows through this coil creating a magnetic field. When magnetic reacting cookware is placed over this magnetic field, the alternating direction of the magnetic field causes the molecules in the cookware to move and bump into each other. This causes heat to generate in the cookware. Induction cook tops heat up very quickly but are much cooler than gas or electric cooking surfaces.

FOOD SCIENCE OF HEAT TRANSFER

Proteins: Coagulation

Heat can cause plant and animal protein to denature and coagulate. The proteins change from a semisolid to a solid state during cooking.

- Temperature it begins: 140 degrees F

Examples:

- Heating an egg white causes the unfolded protein chains to become entangled and lump together.
- In meats, excessive heat will cause meat proteins to lose moisture and become tough.

Starches: Gelatinization

Heat breaks down the bonds that hold starches together. As the starch granules absorb water, they swell and then burst, leaking starch into the surrounding liquid. This causes a thickening of the product. The type of starch used to thicken influences the end result. Excessive or prolonged heat, not enough heat, inadequate dispersion of dry starch in melted fat or cold water, and excessive agitation may interrupt proper starch gelatinization.

Temperature it starts: 150 degrees F

Examples:

- Cooking pasta in boiling water, so it becomes soft and edible.
- The wheat flour in a roux sauce, causes gravy or other sauces to thicken.
- Adding cornstarch to soup thickens the soup without changing the color.

Sugars: Caramelization

Caramelization, or browning, occurs when sugar and proteins are combined and exposed to high heat. This applies to both natural sugars in food and sugar added to foods. Excessive caramelization may result in an unappealing dark color or burned flavor.

Temperature it starts: 320 degrees F

Examples:

- Making caramel sauce
- Toasting bread
- Frying potatoes

Water: Evaporation

Most foods contain water. As the water in foods reach 212 degrees F, heat causes the molecules to break bonds and turn into gas. Water turns to steam and evaporates into the air. Heat that is too high or prolonged cooking may dry out the product through excessive evaporation of moisture.

Temperature it starts: 212 degrees F

Examples:

- Cooling of hot tea.
- Cooking risotto causes the liquid to evaporate and concentrates the flavors.
- As steak cooks, the proteins coagulate, and moisture evaporates.

Fats: Melting

When heat is added to fats, they melt and become liquid. At room temperature, fats can be solid or liquid. Too much heat applied to fats will cause them to burn.

Temperature it starts: dependent on the type of fat

Examples:

- Butter melting in a pan.
- In baking, the fat surrounds air cells in the product, making it more tender.

In poultry, the fat melts at low temperatures and provides flavor.

Safe Cooking Temperatures

Food Minimum Internal Temperature

Beef, Pork, Veal and Lamb (steaks, chops, or roasts)
145 degrees F with a 3 minute rest time

Seafood (fish, shellfish, or crustaceans)145 degrees F

Ground Meats (beef, pork, veal, lamb)
160 degrees F

Poultry (whole or ground chicken, turkey, or duck; stuffed meat, seafood, poultry, or pasta)
165 degrees F

Eggs
Cook until white and yolk are firm

Egg dishes (frittata, quiche)
160 degrees F

Casseroles and Leftovers
165 degrees F

Plant, fruit, vegetables, grain, and legumes
135 degrees

COOKING METHODS

It is important to understand basic cooking methods to preserve the nutritional quality of foods and provide quality, good tasting foods. While there is a plethora of cooking method terminologies, here are some examples of healthier cooking methods.

Roasting is a dry-heat cooking method that uses hot air to conduct heat. The use of a baking sheet or roasting pan enhances the heat transfer to the roasting foods. Placing a rack inside the roasting pan will allow the melting fat to drip away from the food. Roasted vegetables are easy to prepare. With a drizzle of olive oil and a sprinkle of your favorite herbs, give a stir and bake at 350 degrees F for about 30 minutes.

Sautéing is a dry-heat cooking method that quickly cooks small pieces of food. A skillet or sauté pan, with small amounts of fat or oil, assists in browning the surface and cooking the food. Toss, turn, or stir frequently to brown and cook the food evenly. Sauté mushrooms in a small amount of olive oil and when almost done, add several handfuls of spinach until wilted.

Grilling can be done on an outdoor or indoor grill, over an open flame or indirectly by placing the food on a grill surface away from the heat source. Following the manufacturer's instructions will help you get the best quality from marinated or seasoned meat, poultry, fish, or vegetables. A little practice will have you grilling will have you grilling like a pro.

Broiling is a quick cooking method, as most foods are done in 5 to 10 minutes. To broil, place the food on a broiler rack below the heat element, usually in an oven. Broiling mainly cooks the outer surface of the food, so thin cuts of fresh vegetables or other tender foods are ideal for broiling. For a main dish in about 5 minutes, place shrimp on a foil-lined tray and sprinkle with your favorite herbs and melted butter. Broil about 4 minutes.

Searing allows the surface of the food to quickly brown at high temperatures. Heat a pan at high heat and use a small amount of olive oil. This can be used before roasting food to promote browning or to finish food off before serving. If a spice rub has been applied, sometimes this is referred to as blackening.

Steaming is a simple cooking method that uses a flavorful liquid or water to cook the food. Boiling liquid vaporizes to steam and contributes heat to the food. It is a healthier method with no added fat, and more nutrients are retained than in boiling. During boiling, the liquid is often discarded along with water-soluble vitamins. While Americans usually think of steaming vegetables, Asian cultures steam dumplings, and the traditional English plum pudding is a steamed cake.

Choosing the correct cooking method will determine the quality of the finished dish. In addition to quality, the color, flavor, texture, and nutrient content will also be affected by the cooking method chosen. The length of time that foods cook will depend on the cooking temperature, size, and shape of food, whether bone is present, the quality of the food itself, how much you are cooking at one time, and the degree of doneness desired.

CHOOSING COOKWARE FOR BEST HEAT CONDUCTIVITY

The most common materials used in cookware are copper, aluminum, anodized aluminum, cast iron, enamel, nonstick, and stainless steel. Each metal has a different reaction to temperature changes. When purchasing cookware for your kitchen, consider durability, weight, dishwasher-safety, ease of cleaning, price, and what you need to be successful in the kitchen.

Copper is the most conductive of available cooking materials but is coated with a nonreactive metal, such as stainless steel, to prevent the copper from being absorbed by food. Copper cookware provides fast and even cooking. However, copper cookware is expensive, dents easily, and must be washed by hand.

Aluminum is a lightweight, good conductor of heat that is reasonably priced. Heat can be maintained for a longer time. Aluminum is often combined with other metals, such as copper or stainless steel. Anodized aluminum was designed to coat the surface of pans to prevent flavor changes from aluminum absorption into food. The anodization process makes it darker in color and non-porous, improving the heat transfer process.

Stainless steel, because it is a cheaper metal, is found in more than half of all cookware tools. To improve its heat conductivity, it is almost always used in conjunction with copper or aluminum. Stainless steel is a good choice for browning and braising. It is durable, easy to clean, and does not react with food.

Cast iron is slow to heat, but holds heat once heated. It is the most durable of cookware, but it is really heavy and can be tough to clean. Enameled cast iron is available that heats slowly and evenly, which is perfect for stovetop-to-the-oven-to-the-table cooking.

Nonstick coatings allow for great versatility. Because no oil is needed, nonstick pans are a good choice for low-fat or nonfat foods, or to use for delicate foods, such as eggs and pancakes. Food does not brown as well in a nonstick pan, and metal utensils may scratch the surface.

The transfer of heat is the very basis of cooking. Understanding the types of heat transfer methods, the science behind how heat affects food, using healthful cooking techniques, and choosing the proper cookware for your kitchen, will help you have more success in the kitchen.

REFERENCES

American Heart Association (2015), Healthier Cooking Methods, https://www.heart.org/idc/groups/heart-public/@wcm/@fc/documents/downloadable/ucm_465750.pdf, accessed March 2022.

Consumer Reports (2021) Cookware Buying Guide, https://www.consumerreports.org/cro/cookware/buying-guide/index.htm, accessed March 2022.

Culinary Institute of America, Techniques of Healthy Cooking, Professional Edition, 4th Addition, Wiley: 2013, ISBN-13: 978-0470635438.

National Restaurant Association Educational Foundation (2019), Time and Temperature Control, https://www.servsafe.com/ServSafe/media/ServSafe/Documents/Time-and-Temperature-Control.pdf, accessed March 2022.

Texas Tech University (2011), Healthy Cooking Habits, https://www.depts.ttu.edu/hospitality/pdf/SmartChoices2011_Cook.pdf, accessed March 2022.

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