Science of Smoking Foods

SMOKING is a method of curing (preserving) meat. Smoked foods are cooked "slow and low" to prevent flare-ups and charring of the meat—a potential health hazard. There is so much science in the art of smoking foods. Barbecue pork sandwiches are one of the most popular smoked foods. Let's learn the science behind a barbecue pork sandwich or a smoked chicken.

Objective:

Summarize smoked foods as well as the process and the science of smoking foods.

Key Terms:

brining
carcinogen
collagen
curing
elastin
fast-twitch muscles
glycogen
HCA
kippers
myoglobin
PAH
pastrami
rub
silverskin
slow-twitch muscles
smoke
smoking
USDA

Understanding the Science of Smoking Foods

Smoking is a dry-heat cooking method that uses exposure to smoke from burning or smoldering plant materials (often wood) to cook, flavor, and/or preserve food. Smoking injects a characteristic smoky flavor (e.g., the distinctive mesquite wood flavor). It is a method of cur-

ing meat. Temperature variations and length of cooking differentiate smoking, barbecuing, and grilling.

- Smoking uses low heat for one hour to two weeks. Smoke penetrates the interior and flavors the meat with smoke without drying it.
- Barbecuing uses low indirect heat for a few hours, and the smoke cooks the meat.
- Grilling uses high heat for several minutes. It sears the surface of the meat and creates a smoky caramelized crust.

FIGURE 1. This Spanish barbecue includes ribs and sausages. Barbecuing uses low indirect heat for a few hours. The smoke cooks the meat.

SMOKING TECHNIQUES AND PROCESSES

Smoking techniques and processes vary based on the meat being used, the desired end result, and the substances or time available.

Smoke Curing

Curing is a process of using salt and sodium nitrite alone or with other flavorings or sugars to preserve food. Smoking cures food by using burning or smoldering plants (typically wood) to give foods a characteristic smoky flavor. Some types of wood used for smoking are apple, hickory, and mesquite. Corncobs are also used in smoking. The most popular woods for smoking are sometimes regional or cultural. For example:

- Europe: Alder and oak are the most popular woods.
- United States: Hickory and mesquite are the most popular woods.
- Iceland: Sheep dung is an unusual smoking material used to smoke fish.
- Ireland: Peat (cut, dried, and compacted turf) is used to smoke barley malt.

FIGURE 2. Peat is cut and dried before burning. Notice the peat "bricks" piled at the top of the dig site.

Tips

Tips for smoke curing include:

- To get the desired flavor, select wood (or plant cellulose—tea leaves, herbs, etc.) based on the desired smoky flavor.
- To prevent bitterness, soak hickory wood chips for 1 to 2 hours before use.

Types of Smoking

Hot smoking, cold smoking, pit barbecuing, and liquid smoke are the types of smoking.

Hot Smoking

Hot smoking is a method to conserve and/or preserve food. Burning woods or electric kilns are used to slow-cook the food, usually with indirect heat at 150° to 160°F. The meat cooks as it is smoked, and this shortens the smoking time. As with any potentially hazardous food, hot smoked items should be kept under refrigeration when the process is complete.

Cold Smoking

Cold smoking is a method to dry meat with cooled smoke. This process eliminates the moisture that, in turn, inhibits the growth of bacteria. The process uses a technique that smothers wood (at a temperature of approximately 85°F) and takes 12 to 24 hours to smoke. Other than cold smoked salmon, many types of meat are salted or cured before they are cold smoked. Because this method allows food to remain in the temperature danger zone (40°F to 140°F), the FDA recommends cooking the meat to 160°F before eating it.

Pit Barbequing

Pit barbequing is a dry-heat cooking method in which food is placed in a large, level hole in the earth. The pit is filled halfway with coals from wood that has burned down. Getting these coals ready may take up to 4 hours. Then cooking can take up to 12 hours, depending on the thickness of the meat. Meat thermometers are used to determine doneness—to ensure a safe internal temperature—as the exterior cooks at a different rate than the interior.

Liquid Smoke

Liquid smoke is an additive that gives food a consistent smoky taste without using burning wood or cellulose or smothering smoke.

SMOKED FOODS

Throughout history, smoked foods provided people with a way to store items prior to refrigeration.

Protein Foods

Protein foods for smoking include beef, pastrami, pork, poultry, fish, game meat, cheeses and tofu.

Beef

Traditional beef jerky is lean beef strips cured by salting and smoking. Beef jerky is used as a snack food and as a hiking or camping food option. Beef brisket is a primal cut of beef in the chest area that contains a high level of connective tissue. The most popular beef brisket cooking method is rubbed and smoked. A rub is placed on the surface of the meat to be smoked. A **rub** is a spice and/or herb mix used to flavor meats. A typical southern barbecue rub contains a set proportion (based on regional tastes) of paprika, salt, sugar, garlic, black pepper, and chili pepper.

Pastrami

Pastrami is a brisket (or other cut) that has been cured in a mixture of sugar, spices, and garlic and then smoked before cooking. Pastrami is often brined, rubbed, and smoked. It is a standard choice for deli sandwiches.

FIGURE 3. Pastrami is a brisket cured in a mixture of sugar, spices, and garlic. Then it is smoked before cooking. Notice the color of the brined and smoked pastrami slices. The outside edge contains a rub.

Brining

Brining is wet curing or immersion curing; foods are submerged in brine. Lean meat—such as turkey and pork loin—is brined before cooking to increase the moisture content of the meat fibers. Brining solution is typically the addition of salt to water. Sometimes sugar or nitrite are added to brine. The meat must be completely immersed in the brine solution. The percentage of sodium in the brine and the thickness of the meat determine the amount of time required in the brine solution.

Pork

Pork is one of the most popular types of smoked meat. In addition, ham and bacon are the most popular cured and smoked pork products. They are used in sandwiches, main dishes, and

FURTHER EXPLORATION...

ONLINE CONNECTION:
Are Commercially Smoked Meats with Added Sodium Nitrates Safe?

A number of commercially smoked meats contain sodium nitrates. Read "Sodium Nitrite: Essential to Food Safety" on the Pork and Health Organization's Web site at http://www.porkandhealth.org/filelibrary/PorkAndHealth/freebies_SodiumNitriteFactSheet.pdf. Review the paper, and note a controversy over sodium nitrates used in cured meats causing cancer. In 2012, a University of Wisconsin study found that 93 percent of one's total daily intake of nitrite comes from saliva.

Nitrate is NO_3, and Nitrite is NO_2. Both are chemical compounds found in some foods and are used as food additives. Nitrates can be converted into nitrites by bacteria in the mouth. When nitrates react with amines (NH_2), nitrosamines can form. Nitrosamine is a potentially carcinogenic compound.

Read more about the nitrates in saliva and vegetables in The American Journal of Clinical Nutrition article, "Nitrate in Food: Harmful or Healthy?" at http://ajcn.nutrition.org/content/90/1/11/. The article looks at problems of sodium nitrite and discusses the carcinogenic effect of nitrites. Compare the two articles. Make three generalizations or statements about sodium nitrates in foods.

seasonings. Barbecue pork ribs are popular and are available in a variety of styles, including country style. Other styles are more closely associated with cultures and cities, such as Chinese, Kansas City, Memphis, and Saint Louis. Other smoked pork products are ham hocks, pork butt, pork chops, whole pork shoulders or Boston butt.

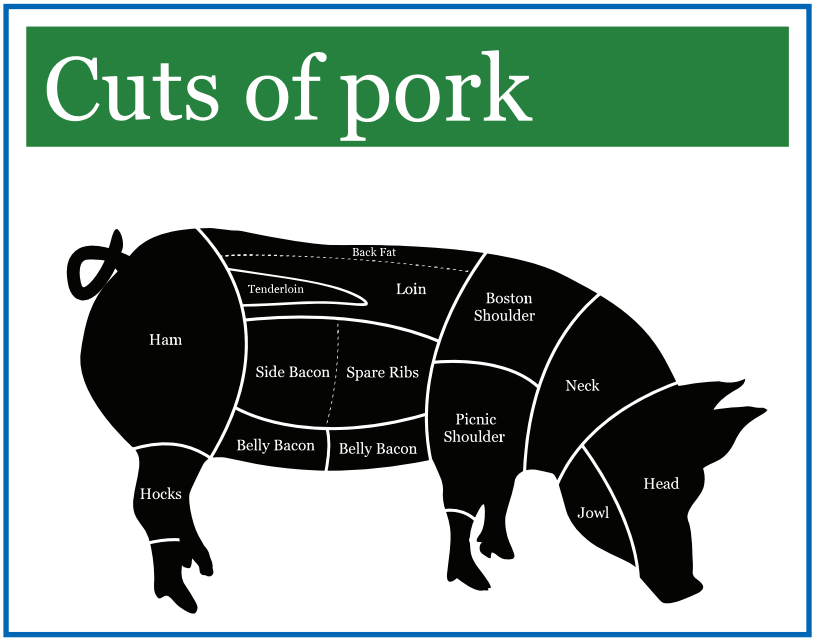


FIGURE 4. Pork wholesale cuts are divided into the retail cuts consumers purchase. Ham and bacon are the most popular cured and smoked pork products.

Poultry

Smoked turkey and chicken are popular options at barbecue restaurants. Turkey is often brined prior to smoking. "Beer can" chicken is a grilled favorite. A whole chicken is stretched over a can of beer or another liquid. Then the chicken is smoked to produce a moist product. Other smoked poultry includes capon, Cornish hen, duck, and pheasant.

DIGGING DEEPER...

UNCOVERING ADDITIONAL FACTS: Smoking Alaskan Fish

Smoking fish is an Alaskan tradition. The University of Alaska-Fairbanks Cooperative Extension Service provides a bulletin about "Smoking Fish at Home." The bulletin discusses the types of smoking techniques, fish smoking food safety, and the brining step before smoking. Learn more at http://www.uaf.edu/files/ces/publications-db/catalog/hec/FNH-00325.pdf.

Fish

Smoked salmon is the most popular smoked fish in the United States. It is used in main dishes and sandwiches as well as appetizers. **Kippers** are smoked herring—whole herrings (gutted, salted, pickled, and cold smoked). They are eaten for breakfast in some countries, such as Norway and Finland. Cod, haddock, and sardines are popular smoked fishes in other countries.

Game Meat

Game meat is any animal hunted for sport or food. Meat includes bear, boar, deer (venison), elk, pheasant, rabbit, and wild turkey. Game meat is commonly braised, grilled, or smoked.

Cheeses and Tofu

Smoked cheeses include Gouda, cheddar, and Swiss. Processed cheese spreads and dips are also smoked. Tofu (bean curd) is coagulated soymilk pressed into a block. Tofu is a low-calorie, high-protein food used in many Asian and vegetarian dishes. It may be smoked or sold in the silken (soft tofu) or regular tofu forms.

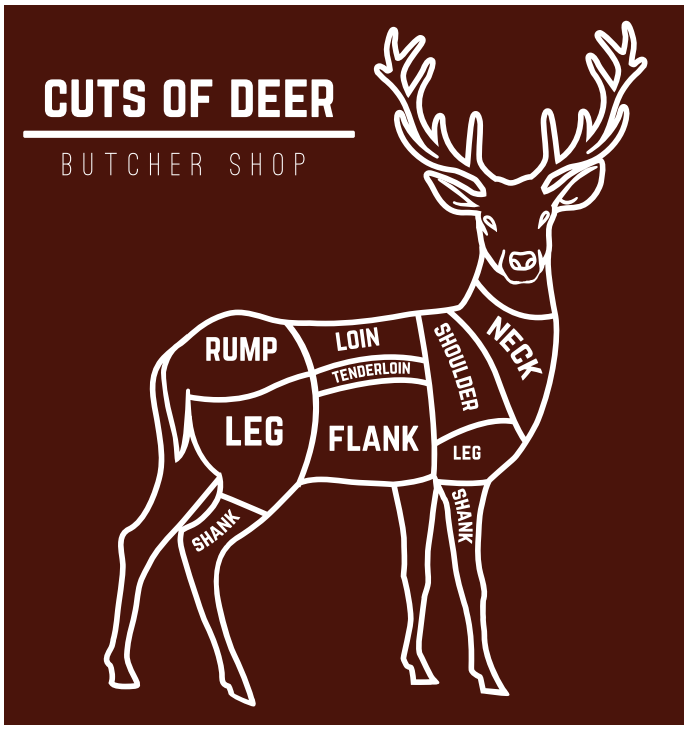


FIGURE 5. Braising, grilling, and smoking are common cooking applications for game meats.

Other Smoked Foods

Smoked almonds, cashews, macadamia nuts, pecans, peanuts, and walnuts are popular commercial snack foods. Recipes are available for smoked, barbecued, smoked, and spiced nuts. Popular smoked spices include paprika and salts.

Smoked beverages include:

- Lapsang souchong tea (smoked with pine or cedar)
- Malt (to produce smoked whisky)
- Rauchbier (a type of smoked beer)

SCIENCE OF SMOKING FOOD

Various critical steps are necessary to safely smoke food.

Smoke

Smoke is the flavor derived from a combination of small airborne particles, water vapor, and gases created by combustion (burning) of fuel and oxygen: typically smoke from a smoldering plant material. Common plant materials used for smoking are alder, apple, cherry, hickory, maple, and mesquite. Other plant materials used for smoking are corncobs, peat (organic debris used for fuel), and dung (manure).

Wood from conifer trees should never be used to smoke foods because of the levels of the tar and resin in the wood fiber. Conifers are evergreen trees and shrubs that typically bear cones and have needles (e.g., cedar, fir, pine, redwood, and spruce).

Smoking Process

The smoke should be in constant movement and should be surrounding the meat, cheese, nuts, etc. Surrounding the meat with smoke helps the smoky flavor penetrate the meat. Stagnant (unmoving, still) smoke may build up creosote (a wood preservative distilled from coal tar) that causes a bitter taste in smoked foods.

Selecting Meats for Smoking

Meats with a high amount of fat and collagen are best for smoking. Fat is the source of flavor in the meat. As the fat heats, it melts and lubricates the muscle portion of the meat that becomes tougher as it cooks. **Collagen** is a fibrous protein found in connective tissue. It

DIGGING DEEPER...

UNCOVERING ADDITIONAL FACTS: Smoke Flavor Chart

Each wood's smoke gives food a different flavor. Some wood smoke flavors are better with certain meats and vegetables. For more information, research the Wood Smoking Flavor Chart at http://www.deejayssmokepit.net/Downloads_files/SmokingFlavorChart.pdf. The Web site also discusses herb blends used to flavor smoke and woods that should never be used in smoking foods.

breaks down in slow cooking and changes to a gelatin state, which in turn, lubricates the meat. **Elastin** (gristle) is a rubber band-like protein in connective tissue that shrinks and becomes tougher when cooked. **Silverskin** is white or silver-colored connective tissue that encases (wraps around) muscles and is an example of elastin. Silverskin is often removed from spare-ribs before cooking.

Slow-Twitch Muscles

Slow-twitch muscles are muscles used for extended periods of activity, such as standing or walking. These muscle fibers require a constant energy source and contain more myoglobin. **Myoglobin** is a protein that stores oxygen in muscle cells, and these muscle cells use that oxygen to extract the energy needed for constant activity. When cooked, slow-twitch muscles have more moisture and flavor. Dark meat chicken—legs and thighs—is an example of slow-twitch muscles. Beef round steak is another example.

Fast-Twitch Muscles

Fast-twitch muscles are muscles used for quick bursts of activity (e.g., running from danger or sprinting). These muscle fibers obtain energy from glycogen, which is stored in the muscles. **Glycogen** is a polysaccharide, which is a main form of carbohydrate storage in animals. Fast-twitch muscles contain less myoglobin than slow-twitch muscles. Fast-twitch muscles cook quickly but have less moisture and fat and are not easy to smoke without brining. White meat chicken—breasts and wings—is an example of fast-twitch muscles.

Tips for Smoking Food

- When smoking, cook "slow and low" to allow time for the smoke to flavor (penetrate) and tenderize the meat.
- Use two thermometers when smoking foods. For instance, use one thermometer to identify the temperature of the smoker and the other to identify the internal temperature of the meat. The smoker should register 200 to 220°F.
- Most meats should register 145°F internal for safety reasons. Cook poultry to an internal temperature of 165°F. Cook tender barbecued meats, such as a pork shoulder, to an internal temperature of 180°F.
- Large pieces of smoked meat may take hours to achieve an internal temperature of 150° to 165°F. During this time, the meat loses moisture and keeps the internal temperature down. Tender pork shoulder barbecue requires time to reach 180°F. Know the type of meat being smoked because collagen begins to melt at 160°F.

FIGURE 6. Use two thermometers when smoking foods. Use one to identify the temperature of the smoker and the other to identify the internal temperature of the meat.

FURTHER EXPLORATION...

ONLINE CONNECTION: USDA Barbecue and Food Safety

Find out more about food safety issues relating to barbecue and smoking at http://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/barbecue-and-food-safety/CT_Index. Read the short informative paragraphs, including From the Store: Home First, Thaw Safely, Marinating, Safe Smoking, and Pit Roasting.

Food Safety

Standard sanitation procedures must be used to keep the food safe. Smoking alone may not reduce bacterial growth for long-term storage. If you plan to store smoked meats for a long period of time, consider:

- Curing with a brine or dry salt prior to smoking
- Freezing the smoked meat in a vacuum seal

IS SMOKED FOOD HEALTHY?

Is smoked food healthy? The United States Department of Agriculture or **USDA** is the organization that oversees the farming industry, with duties such as price support subsidies and inspecting food for consumption. The National Cancer Institute and the USDA offer information on the issue of cancer-causing substances related to grilled and smoked meats. For instance, HCA and PAH are known carcinogens. A **carcinogen** is a substance capable of causing cancer in living tissue.

HCA and PAH

HCA is an abbreviation for heterocyclic amines and is present in beef, pork, fish, and poultry when cooked at a high temperature with open flames and flare-ups. HCAs are formed when amino acids (building blocks of protein), sugars, and creatine (an organic acid found in the lean portion of meat) are heated at a high temperature. The presence of HCA becomes a health concern when meats are charred or burnt.

PAH is an abbreviation for polycyclic aromatic hydrocarbon and forms when cooking exposes meat to smoke or charring. PAH forms when fat drips into the fire and causes

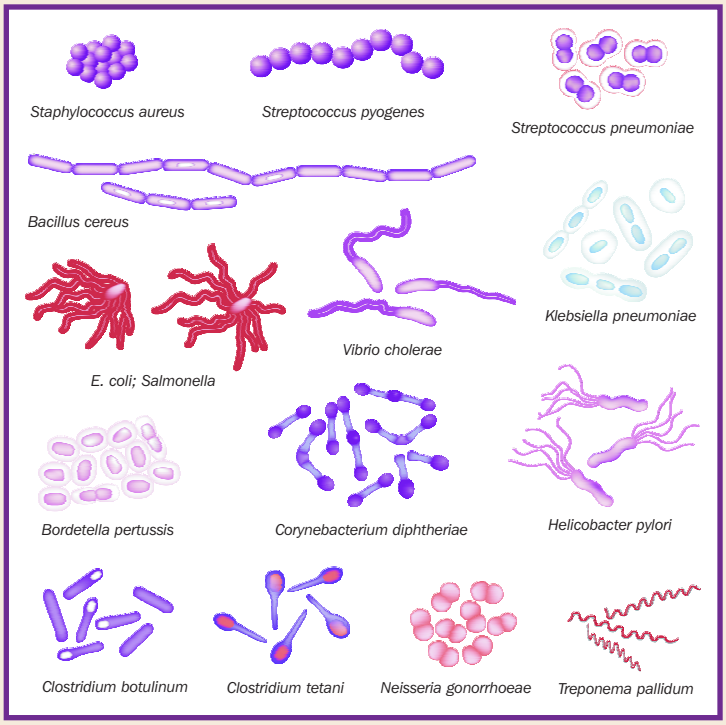
FIGURE 7. In terms of your health, what is "wrong" with the method of cooking these sausages?

EXPLORING OUR WORLD...

SCIENCE CONNECTION: Food Safety and Bacteria

Are you interested in the food safety in cured and smoked meats? See section 5 of the National Center for Home Preservation Guide and Literature Review Series for information about food safety of cured and smoked meats at

http://nchfp.uga.edu/publications/nchfp/lit_rev/cure_smoke_fs.html



Identify the common bacteria discussed in the article. What shape is staphylococcus aureus?

flames. The PAH formed during that drip and flare-up process "sticks" to the surface of the meat. Smoking and charring meat increases the formation of PAH. Also, PAH is found in cigarette smoke, environmental pollution, and car exhaust fumes.

Cooking Methods

Cooking methods that might cause meat to form HCA and PAH are:

- Broiling
- Deep-Fat Frying
- Grilling
- Pan frying above 300°F
- Smoking (possible formation of PAH)

Carcinogenic Formations

The American Cancer Institute indicates the following ways to avoid the formation of HCA and PAH:

- Do not cook meat at high temperatures.

- Use a thermometer, and do not overcook meat.
- Avoid open flames and flare-ups.
- Microwave meat prior to grilling or smoking. Immediately completing the cooking process on a grill or in a smoker reduces the time for HCA and PAH formation.
- Turn meat often to reduce HCA formation.
- Remove charred meat and fat; do not ingest. Do not use charred pieces in sauces or gravies.
- Place food in the center of the grill, or use indirect heat methods.

Research Findings

Current research findings about the link between HCA and PAH exposure and cancer include the following:

- Population studies have not established a definite link between the way meat is cooked and cancer.
- In "Does Grilling Pose a Cancer Risk?", the USDA explains there may be a cancer risk related to eating food cooked by high-heat cooking techniques (e.g., grilling, frying, and broiling). Yet research suggests "eating moderate amounts of grilled meats cooked without charring to a safe temperature does not pose a problem." The USDA does not mention smoked meats, as they are not charred.
- The American Cancer Institute states, "Exposure to high levels of HCAs and PAHs can cause cancer in animals; however, whether such exposure causes cancer in humans is unclear."
- Research continues on the link between HCA and PAH exposure and cancer. For more information on current research, visit the National Institutes of Health (NIH) National Cancer Institute's Web site at http://www.cancer.gov/cancertopics/causes-prevention/risk/diet/cooked-meats-fact-sheet.

Summary:

The science of smoking involves understanding the techniques and smoking medium used. A variety of foods are smoked. Pork is a popular smoked meat. To smoke meats effectively and safely, you must understand food safety, the science of smoke, and meat composition. Presently, regulatory agencies consider smoked and grilled foods, without charring or burning, safe in moderate amounts.

Checking Your Knowledge:

1. What is smoking? How does it differ from barbecuing and grilling?
2. Describe the three types of smoking. How does liquid smoke differ from the other two?

3. List five categories of smoked food.
4. What are five ways to avoid risks of HCA and PAH in smoked and grilled food?
5. What do the USDA and the American Cancer Institute say about the safety of smoked and grilled foods?

Expanding Your Knowledge:

In 1912, French scientist Louis-Camille Maillard discovered the browning reaction called the Maillard reaction. This biochemistry reaction is between sugar (carbohydrate) and amino acid (protein) being side-by-side in the meat. When heated, the chemical reaction causes the meat to have a caramelized color on the surface and gives it a savory taste and smell. Research the Maillard reaction.

The protein structure in meat is shaped in coils and springs. Protein denatures (loses structure) when cooked, salted, or placed in an acid (e.g., a marinade). The proteins bond together (coagulate), making them easier to digest. You can see denatured protein when watching an egg cook. When heat is applied, the egg loses its thick liquid state and becomes more solid. Denaturing also releases moisture from the protein. Some moisture loss is reversible. This is important in roasted meats. Large pieces of meat should rest 15 to 20 minutes before carving to allow the juices that have been "squeezed out" of the protein time to reabsorb. Meathead Goldwyn (writer's pen name) believes you should not let meat rest. Find out why by reading this opinion at http://amazingribs.com/tips_and_technique/mythbusting_resting_meat.html.

Web Links:

Juiciness and Debunking the Resting Meat Rule
http://amazingribs.com/tips_and_technique/mythbusting_resting_meat.html

Basic Meat Science for Cooks
http://amazingribs.com/tips_and_technique/meat_science.html

The Chemistry Behind BBQ
http://www.ift.org/Knowledge-Center/Learn-About-Food-Science/Food-Facts/The-Chemistry-Behind-BBQ.aspx

Denaturing Proteins
http://chefsblade.monster.com/training/articles/216-food-science-basics-denaturing-proteins

The Maillard Reaction
http://www.wisegeek.org/what-is-the-maillard-reaction.htm#