6

Principles of Smoking

Zdzisław E Sikorski and Izabela Sinkiewicz

Department of Food Chemistry, Technology, and Biotechnology, Gdańsk University of Technology, Gdańsk, Poland

6.1 Introduction

Treatment of a large variety of foods with wood smoke has been practiced for centuries — predominantly meats, poultry, and fish, but also scallops, cheeses, prunes, paprika, and the malt used to produce whiskey and some sorts of beer. The process usually includes salting and partial drying; it may also be coupled with heating. The aim is to increase the shelf life of the products, prevent food poisoning, and add a desirable smoky flavor. Smoking is applied at both an industrial scale in food processing plants and at the small scale of traditional home cooking. With the advent of canning, freezing, and the refrigeration chain, the preservative effect of smoking has gradually lost its importance. The process parameters required to obtain a very long shelf life through smoking are very severe and may decrease the nutritional value of a product and increase the health risks for the consumer.

6.2 Wood-smoke composition

Smoke develops from the charring of wood: beech, oak, alder, hickory, or maple, as well as fruit trees. Pinewood is used only seldom. To produce the desirable flavor that is characteristic of some products, juniper berries or pinecones are added to the smoldering material. The wood usually takes the form of shavings or sawdust. Today, these are available commercially in different assortments of standardized mesh size and moistness. In old-type kilns and friction-type generators, wood logs are also used.

The thermal decomposition of the woody material, followed by oxidation, generates hundreds of solid, liquid, and gaseous compounds, differing in boiling point, solubility, chemical properties, and the role they play in food smoking. These are mainly H_2O, CO, CO_2, alcohols, carbonyl compounds, carboxylic acids, esters, hydrocarbons, nitrogen oxides, and phenols. The yield of the various components depends on the species of wood and the smoldering parameters. Mixed with air, they form a complex aerosol. The mass proportion of the dispersing and dispersed phases of the aerosol depends on the chemical composition of the constituents and on temperature: heating increases the concentration of components in the gaseous phase, while cooling causes many compounds to condensate and so move the in form of tiny solid particles or liquid droplets to the dispersed phase.

The phenolic fraction, about 240 items, contains mainly guaiacol and its derivatives, phenol, 2,5-dimethylphenol, cresols, syringol and its derivatives, pyrocatechins, resorcinol, pyrogallol, hydroquinone, and hydroxy-dimetoxyphenylo-ketones. The composition of the phenolic fraction depends on the temperature of smoke generation. Increasing the temperature decreases the content of syringol and 4-methylguaiacol and the percentage of *trans*-isoeugenol. The highest yield of smoke phenols occurs in the temperature range 480 – 520 °C. The smoke aldehydes and ketones are also numerous. Formaldehyde is generated by the oxidation of methanol, one of the main products of the dry distillation of wood. The group of carbonyl compounds includes *inter alia* acetaldehyde, benzaldehyde, acetone, and furanone. The acid fraction contains mainly acetic acid, other components being various short-chain carboxylic and ketocarboxylic acids. Among the alcohols are a variety of low-molecular-weight aliphatic compounds. Several components have been identified also in the ester fraction.

The group of hydrocarbons comprises various aliphatic compounds and polycyclic aromatic hydrocarbons (PAHs). Wood smoke contains about 60 identified PAHs, differing in number of aromatic rings and structure, as well as in physical and biological properties. Among them are the following 16 potentially mutagenic and/or carcinogenic ones: cyclopenta[cd]pyrene, benzo[a]nthracene, chrysene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene (BaP), benzo[ghi] perylene, dibenzo[ah]anthracene, dibenzo[ae]pyrene, dibenzo[ah] pyrene, dibenzo[ai]pyrene, dibenzo[al]pyrene, indeno[1,2,3-cd] pyrene, 5-methylchrysene, and benzo[c]fluorene. The structure of these compounds determines their biological activity, because in the living organism they are activated on different routes, which are catalyzed by various enzymes. The concentration of PAH in wood smoke depends mainly on the temperature of the smoldering wood and on the access of air. Increasing the smoke-generation temperature leads to a larger proportion of the high-molecular-weight compounds in the total PAH. The content of PAHs in the smoke can be minimized by keeping the glowing temperature below 400 °C and removing the tar.

Wood smoke can be condensed and purified, yielding various preparations. These are used for smokeless smoking of meats.

Handbook of Fermented Meat and Poultry, Second Edition. Edited by Fidel Toldrá.

The concentration of PAHs in such preparations can be effectively controlled. According to EU Directive 2065/2003, the BaP content in smoke preparations must not exceed 10 ng/g (European Parliament, 2003).

6.3 The preserving effect

Smoking of foods can be regarded as "hurdle technology" (Figure 6.1). Smoked products are not sterile. The preserving effect results from the consecutive or simultaneous action of several of the following factors: thermal inactivation of the product's microflora, water activity, pH, antibacterial activity of additives used prior to smoking, concentration of antimicrobial and antioxidant smoke components in the product, barrier properties of the packing, and storage temperature. Therefore, the high-quality life and the practical storage time of various smoked foods extends from a few days in refrigeration conditions to several months at room temperature, depending on the kind, initial freshness, microbial contamination, and form of the raw material, on the parameters of salting and curing, on loss of water due to dripping or drying, temperature, duration, and smoke density in the smokehouse, and on the conditions of packaging and storage of the product.

Numerous components of wood smoke have antimicrobial activity in concentrations similar to those found in smoked meats. Among the most active are various phenols, especially guaiacol and its derivatives, cresol, pyrocatechols, and pyrogallol. The contents and distributions of the phenols and their derivatives in smoked meats are related to their solubility in the lipid and water phases of the products, as well as to the smoking conditions. Mini-salamis in sheep casings, 18–20 mm in diameter, smoked for 30 minutes at 22 °C with smoldering smoke from beechwood chips, contain from 30 to 72 μg/g of the sum of guaiacol, 4-methylguaiacol, syringol, eugenol, and *trans*-isoeugenol (Hitzel *et al.*, 2012), while hot-smoked frankfurter-type sausages contain 19.6–57.6 μg/g, depending on the process parameters (Pőhlmann *et al.*, 2012). Compounds with an additional aldehyde group in their structure are more effective antimicrobials than phenols. The sensitivity of different species and strains of microorganism towards various phenols may significantly differ in broth and in smoked meat products. The growth inhibitory concentration of some smoke phenols in broth towards *Listeria monocytogenes* is in the range of 10–100 μg/g. However, as yet it is not possible to predict exactly the concentration of total smoke phenols that is necessary for an inhibitory effect on, for example, *L. monocytogenes* or *Clostridium botulinum* in foods. Cold smoking may decrease the population of *L. monocytogenes* on the surface of the products, but might also lead to proliferation of these bacteria in meats cured with contaminated brine. The growth of *L. monocytogenes* has been shown in various ready-to-eat smoked products.

Smoke carbonyl compounds, especially formaldehyde, are also known to retard the proliferation of microorganisms. Smoked meats may contain up to 125 μg/g formaldehyde. Most sensitive are the vegetative forms of bacteria; molds and yeasts are more resistant. Many molds were isolated from fully ripened, lightly smoked Norwegian dry-cured meats, and the predominant species were found to belong to the genus *Penicillium* (Asefa *et al.*, 2009).

Generally, smoke components alone cannot protect lightly smoked foods from spoilage and microbial hazards for long. At the concentrations found in foods, the smoke constituents do not decrease the population of various pathogenic microorganisms by several log cycles, or efficiently restrain their growth. A significant antilisterial effect can be achieved by adding potassium lactate and sodium diacetate to the sausage formulation and by 2 minutes'

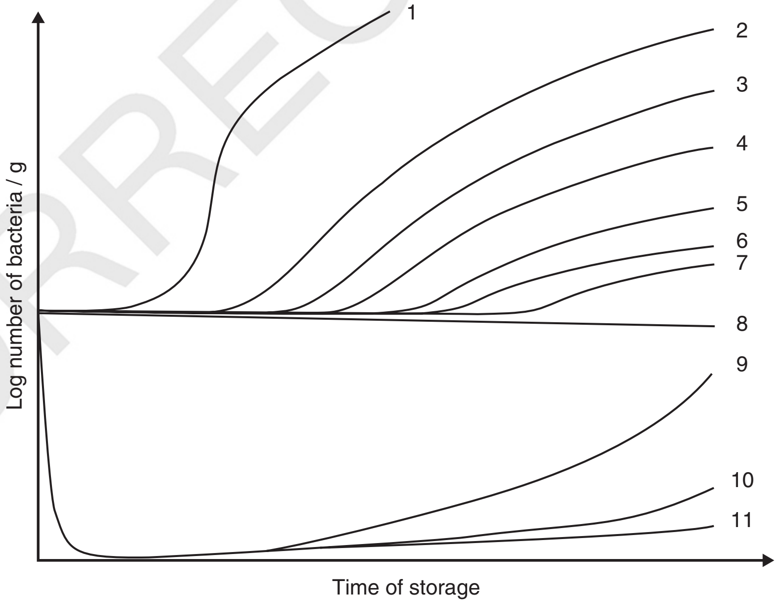

Figure 6.1 Effect of preservative treatments on the growth of bacteria in foods: (1) untreated food, room temperature; (2) refrigeration; (3) chemical preservation and refrigeration; (4) chemical preservation, modified atmosphere, and refrigeration; (5) drying or salting, room temperature; (6) marination or lactic acid fermentation, room temperature; (7) drying or salting and refrigeration; (8) freezing; (9) heat pasteurization, room temperature; (10) heat pasteurization and chemical preservation, room temperature; (11) heat pasteurization and refrigeration.

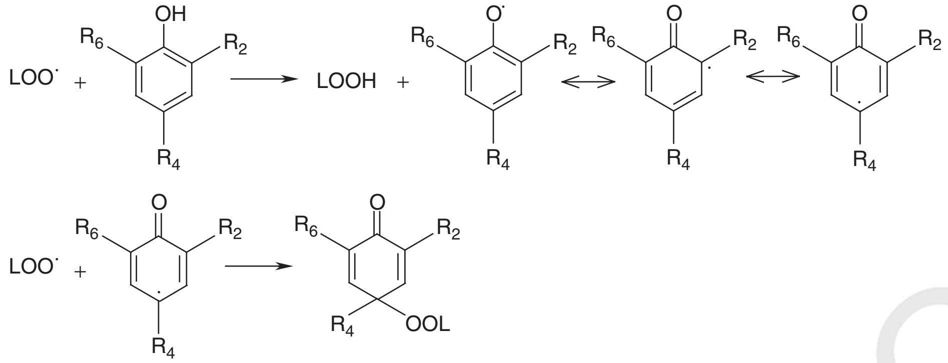

Figure 6.2 Mode of action of a phenolic antioxidant.

immersion of the smoked sausages in various antimicrobial solutions. Spraying frankfurters with liquid smoke of pH 4.25 – 4.85, containing in 1 cm^3 0.3 – 0.8 mg of phenols, decreased the surface population of *L. monocytogenes* during storage at 4 °C by several log cycles (Martin *et al.*, 2010). In a particular smoked product type, the effect on the bacterial population depends on all factors involved in the hurdle technology and on the implementation of the food safety management system.

Smoking also prolongs the shelf life of foods by decreasing the rate of lipid oxidation, mainly due to the antioxidant activity of various phenols. The phenolic antioxidants are capable of inactivating different free radicals present in the products by donating the hydrogen atom of the OH group and thus breaking the chain reaction of lipid autoxidation (Figure 6.2). A phenolic radical created by abstraction of the hydrogen atom has a lower reactivity than other free radicals, as a result of the resonance delocalization of the radical function in the aromatic structure. The activity of the phenol antioxidant increases with decreasing binding energy of the hydrogen atom in the OH group and decreasing energy of the created phenolic radical. Both of these characteristics depend on the structure of the compound, which explains why various smoke phenols differ in antioxidant effect. The activity of several smoke components exceeds that of the known food additives buthylhydroxyanisole (BHA) and buthylhydroxytoluene (BHT). The most effective are resorcinol, pyrogallol, 4-methylguaiacol, 4-vinylguaiacol, and *trans*-4-propenylsyringol. The protective action of smoking depends too on the presence in food of various compounds that decrease the activity of the antioxidants or act synergistically on the factors influencing the rate of formation of reactive oxygen species (ROS), as well as on the distribution of lipids in the product. Thus, complete arrest of lipid changes is not possible, and various compounds generated due to thee oxidation of polyenoic fatty acids occur in smoked meat, among them minute amounts of the cytotoxic aldehyde 4-hydroxy-2-nonenal.

6.4 The flavoring effect

The sensory properties of smoked foods depend on the type of product, its initial quality, the preparation of the raw materials prior to smoking, loss of moisture and thermal changes during processing, and the concentrations of various smoke components on the surface and in the deeper layers of the product. The color, flavor, and taste typical of smoked meats and fish are formed by the smoke compounds, while the texture, juiciness, and saltiness result from the properties of the raw material and the processing parameters.

6.4.1 Color

The color of the surface of smoked foods is a blend of the pigmentation of the raw material and that resulting from the action of the smoke components. The tint added by smoking extends from light lemon to dark brown, depending mainly on the kind of smoldering wood and the time/temperature regime of the process. It is especially visible on the carcasses of poultry and the originally whitish or silvery belly parts of fish, while on many sausages and other meat products a red coloration predominates.

The color added by smoking is a result of the deposited colored smoke components, their changes during heating and storage, and their interactions with the surface material of the product. The chemical changes involved comprise mainly polymerization of phenols and the Maillard reaction; their rate increases with temperature. Thus, raising the smoke temperature promotes darker colorization of the products. Most important is the amount of deposited smoke components. Heavily smoked goods — that is, those kept in a dense smoke for a long time — turn very dark brown. This color can also develop on surfaces containing no components capable of interacting with the reactive smoke compounds. The tint is also affected by the characteristics of the sawdust taken for smoke generation; using beech, maple, ash, sycamore, or lime tree shavings favors a golden-yellow color, while oak, nut, and alder smoke cause yellow-brownish coloration, and meats treated with smoke from coniferous wood have a dark coloration. Consumer preferences regarding the color of various smoked meat products are not equal in different regions.

6.4.2 Flavor and taste

The smoky flavor is created mainly by the smoke components deposited on the product, predominantly the phenols. The compounds that contribute to the formation of the desirable flavor are mainly syringol, 4-methylsyringol, 4-allylsyringol, guaiacol, 4-methylguaiacol, and *trans*-isoeugenol. Carbonyl compounds, furans, and other smoke constituents play a role as well, although the exact proportions of the concentrations of different smoke components in the creation of various flavor notes have not been disclosed.

Smoke phenols, aldehydes, and acids interact with different food components. This may affect the sensory qualities of the products.

6.5 Benefits and risks

The intended, desirable effects of smoking comprise first the formation of the typical sensory properties of the products — attractive features are added to smoked foods, which are highly valued by many consumers — and second, the prolonged storage life of the product, brought about by the prevention of the growth of some microorganisms, including pathogens, and by the delay of lipid oxidation.

Smoked foods may contain microbial toxins carried through from the raw material or generated by microflora that survive the processing and are active in the product during storage. They may also harbor excessively large populations of pathogenic microorganisms. The hazards that can be caused by pathogenic microflora depend on the initial contamination of the raw materials, on the lethal and growth-inhibitory effects of the processing procedure, and on the handling and storage parameters of the products.

Further risks are caused by certain smoke components deposited on the meats and the effects of their interactions with the product constituents. Most smoke compounds would not be allowed by law to be added to foods in pure form; however, as their toxicity and concentration in these products are very low, smoking is generally regarded as safe (GRAS), in accordance with the common-law principle *De minimis non curat lex*.

6.5.1 PAHs

The smoke components that are hazardous to consumer health and whose content in smoked foods is limited by law are the PAHs. The mutagenic/carcinogenic activities of ingested individual PAHs, as well as their concentrations, are different in different smoked foods. Thus, it is very difficult to predict the degree of health hazard caused by these compounds in smoked foods. Various PAHs have been proposed as indicators of carcinogenicity. Until recently, BaP was regarded as such, since it is a very potent mutagenic and carcinogenic compound. This indicator is, however, not generally accepted anymore, as some smoked goods contain a large number of other highly carcinogenic PAHs and no BaP. On the other hand, the content of BaP in many different smoked meat products has been found to be highly correlated with that of most other carcinogenic PAH (Lorenzo *et al.*, 2011). According to a statement by the European Food Safety Authority (2008), a more adequate index of the carcinogenicity of smoked foods is the sum of the concentration of BaP, benzo(a)anthracene, benzo(b)fluoranthene, and chrysene (PAH4) (Figure 6.3), or else the concentration of eight carcinogenic PAHs (PAH8): the PAH4 plus benzo[k]fluoranthene, benzo[g,h,i]perylene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pirene. However, because most earlier published data on PAHs in smoked foods looked at the content of BaP, Commission Regulation (EU) No. 835/2011 (European Commission, 2011) decided to keep the maximum level of this indicator in smoked meat and meat products at 5 ng/g until August 2014, and at 2 ng/g afterwards. Additionally, an upper limit of 30 ng/g for PAH4 has been introduced until August 2014, and 12 ng/g afterwards.

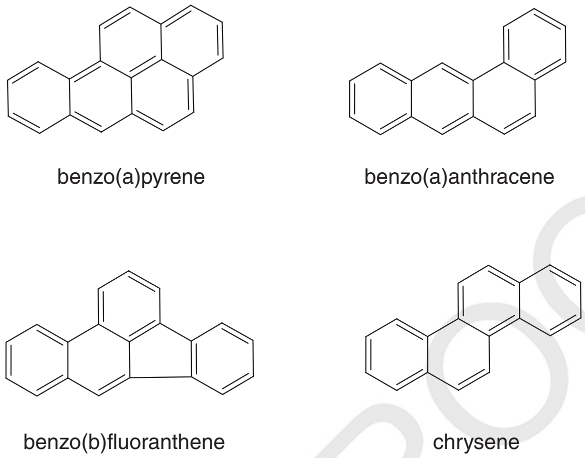

Figure 6.3 The four polycyclic aromatic hydrocarbons (PAH4) treated as an index of the carcinogenicity of smoked foods.

The content of PAHs in smoked meat products available on the market is usually well below the maximum level set by the EU. The limits of quantification of individual PAHs achievable by contemporary analytical procedures range from 0.009 to 0.030 ng/g (Jira *et al.*, 2008). Various assortments of smoked meats usually contain no more than 1 ng BaP/g, although very heavily smoked products may reach up to 50 ng BaP/g. Meat products manufactured by traditional Swedish “sauna” smoking involving direct exposure to hot smoke generated by a flaming log fire were found to contain 6.6 – 36.9 ng BaP/g (Wretling *et al.*, 2010). Market samples of smoked meats in Kuwait contained 0.97 – 1.20 ng BaP/g, 3.26 – 7.45 ng PAH8/g, and 82.9 – 110.0 ng total PAH/g (Alomirah *et al.*, 2011). According to different published data on about 600 smoked meat products, the contents of BaP, PAH4, and PAH8 were about 0.20, 1.5, and 1.8 ng/g, respectively. The concentration of 16 PAHs in 22 samples of smoked ham ranged from below 0.01 to 19 ng/g, with the median for BaP being below 0.15 ng/g (Jira *et al.*, 2008). In the raw-cured Spanish pork sausages androlla and botillo, smoked 8 – 10 and 7 – 15 days, respectively, in traditional kilns and ripened for several months, the mean contents of the 16 potentially mutagenic and/or carcinogenic PAHs were 36.5 and 29.4 ng/g, respectively, in which the BaP content ranged from 15 to 17% (Lorenzo *et al.*, 2010).

The accumulation of PAHs in different smoked meat products is related very significantly to the parameters of smoking and the kind of wood used for smoke generation. Assortments of sausages made of various raw materials, although having the same mass to surface ratio and being smoked in identical conditions, contain different amounts of PAH (Roseiro *et al.*, 2012). In traditionally smoked sausages, the PAH content even depends on the location of the product in the kiln, which affects the temperature and flow rate of the smoke. Meat products treated with smoke made from the wood of apple tree and alder contained about 10 times less total PAH than samples smoked in the same conditions with spruce smoke (Stumpe-Vīksna *et al.*, 2008). Generally, the PAH contamination of products smoked in strictly controlled conditions in modern smokehouses with external smoke generators is significantly lower than that of meats processed in old-type kilns with smoldering chips or burning wood logs directly under the hanging rows of sausages. The inner parts of the products are less contaminated than the surface layers, although during storage this difference gradually diminishes. The skin is an effective barrier for PAHs; this applies for various smoked fish, especially eel, and has been shown to hold for bacon smoked with skin versus that without (Djinovic *et al.*, 2008).

The concentration of PAHs in smoked products changes during storage. Being hydrophobic, they accumulate in fatty tissues at a rate controlled by the parameters of diffusion. They may also be absorbed by low-density polyethylene packaging films and there partially destroyed by UV radiation (Chen & Chen, 2005; Šimko, 2005). The photochemical changes induced by UV involve oxidation of peripheral carbons, leading to aromatic alcohols, ketones, and ethers.

6.5.2 Other hazardous compounds

The reactions of various smoke constituents with the components of foods may result in the formation of different groups of hazardous compounds. Smoking, as applied in the manufacture of the smoked dry-cured ham prosciutto di Sauris (2–3 days at 20 °C), has been found to have only a very limited effect on protein hydrolysis and the accumulation of biogenic amines in the meat (Martuscelli *et al.*, 2009).

Several heat-treated foods may contain nitropolycyclic aromatic hydrocarbons in concentrations of up to about 30 ng/g. In smoked sausages, the contents of 1-nitropyrene, 2-nitronaphtalene, and 2-nitrofluorene have been found to be in the range of about 4–20 ng/g

N-nitroso compounds, most of which are carcinogenic in laboratory animals, may be formed in smoked foods by the reaction of smoke aldehydes with cysteamine and cysteine, yielding various thiazolidine precursors that can be easily nitrosated. In various smoked meat and poultry products, the contents of *N*-nitroso compounds may reach up to several hundreds of ng/g.

Heterocyclic aromatic amines, known to be generated in pyrolytic reactions of amino acids and proteins and in non-enzymatic browning, are present in very heavy smoked goods in amounts lower than 1 ng/g.

In various smoked foods, β-carboline alkaloids are also found. These may be formed in the reaction of *L*-tryptophan with formaldehyde or acetaldehyde (see Figure 6.4).

The concentration of these compounds increases with temperature and duration of smoking, and depends on the accumulation of formaldehyde with the smoke. In sausages, 1,2,3,4-tetrahydro-β-carboline-3-carboxylic acid (THCA) is found in concentrations of 0.01–14.80 μg/g. The outer surfaces of smoked products may contain up to eight times more THCA than the core (Papavergou & Herraiz, 2003).

6.6 Food engineering approach

6.6.1 Mass and heat transfer

The aim of meat smoking is to achieve a desirable product quality through the action of the smoke and heat and the loss of moisture. The smoke constituents settle on the meat, driven by gravitational and centrifugal forces, and are absorbed in the thin film of water on the surface. The rate of deposition of various compounds depends on whether they are in the dispersing or dispersed phase of the aerosol at the given temperature and on the condition of the surface layer (Miler & Sikorski, 1990). Therefore, the temperature, humidity, and flow rate of the smoke significantly affect the efficiency of the sorption phenomena. These factors control the absorption of smoke components in conventional smoking, as well as in smokehouses supplied with dispersed, atomized smoke preparations. If the preparations are used in the form of dips, the process is governed by the laws of diffusion. In electrostatic smoking (Figure 6.5), the decisive factor is the electrostatic force, which drives the electrically charged smoke particles towards the product and creates an electric wind to carry the uncharged components of the aerosol in the same direction.

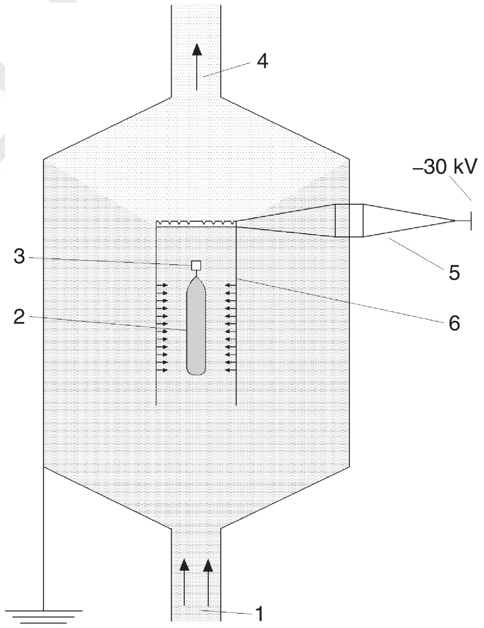

Figure 6.5 The principle of electrostatic smoking: (1) smoke inlet; (2) smoked sausage; (3) metallic, grounded conveyer chain; (4) smoke outlet; (5) insulator; (6) ionizing electrode. Source: Reproduced by permission of Łucasz Wiśniewski.

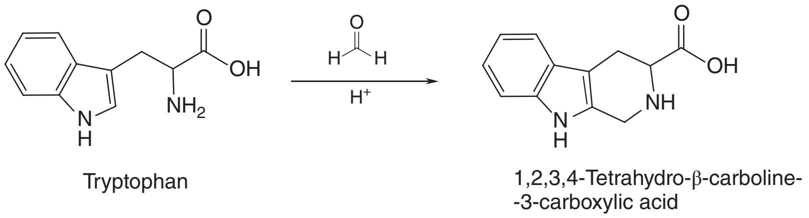

Figure 6.4 Formation of β-carboline alkaloids.

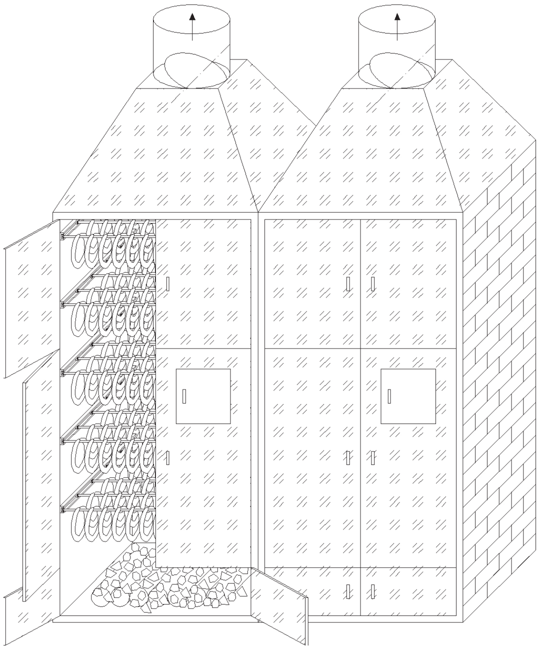

Figure 6.6 Traditional smoking kiln. Source: Reproduced by permission of Łucasz Wiśniewski.

The temperature, humidity, and flow rate of smoke/air also influence the rate of loss of moisture from the smoked meats, as well as the heat transfer by convection and by condensation of water vapor on the cool surface of the product in the early stage of smoking.

6.6.2 Equipment

In artisanal manufacturing of smoked foods, the sensory, nutritional, food-safety, and economic requirements are fulfilled by a trained craftsperson, who knows by experience how to process a given raw material using the available wood and equipment at the prevailing atmospheric conditions. Artisan smoking usually takes place in kilns, in which logs of wood burning on the floor and smoldering shavings or sawdust supply the necessary heat and smoke (Figure 6.6). The meat to be smoked is hung on racks at different heights above the fireplace. The conditions prevailing in various locations in the kiln differ significantly; therefore, it may be necessary to reverse the racks of sausages during the process. The temperature, density, and humidity of the smoke are controlled to some degree by the operator, by way of the proper use of the moist or dry woody material and by opening and closing the vent and doors.

In order to produce high-quality smoked meats at commercial scale, contemporary requirements regarding the standard of the raw material, precisely defined and strictly applied processing parameters, proper equipment design, and proper organization of the manufacturing line should be observed. Furthermore, procedures eliminating health risks should be introduced, such as the hazard analysis and critical control points (HACCP) system.

In modern smokehouses containing production lines, food engineering principles are applied to implement rational parameters of mass and heat transfer and to achieve organizational and economic goals.

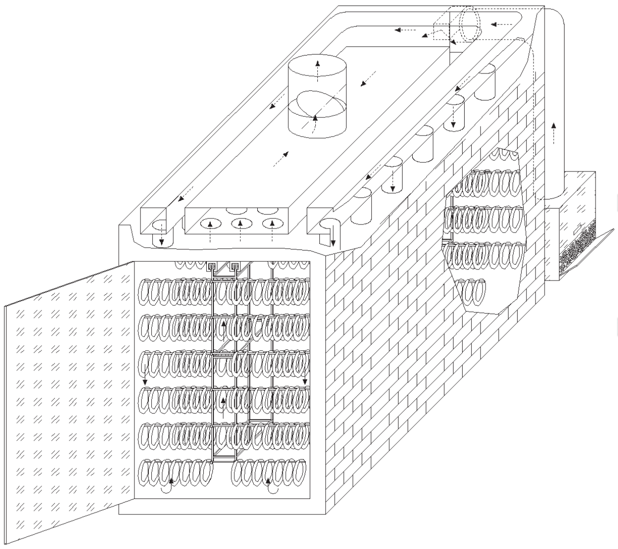

Figure 6.7 Modern smokehouse. Source: Reproduced by permission of Łucasz Wiśniewski.

Wood smoke is produced in outside generators, often filtered to separate the tar and soot, and directed into the smokehouse by ducts. Mostly smoldering-type units are used, in which the woody material is fed automatically on an electrically heated plate or grate. The temperature in the smoldering pile of sawdust can be kept at a level of about 600 °C by changing the flow rate of the air and the humidity of the woody material.

Less common are various types of machine in which the smoke develops from heat generated as a result of friction from a wood log pressed against a rotating metal ring or disk. By adjusting the pressure exerted on the log or the rotation rate of the disk, the temperature at the friction interface can be controlled; it is usually kept at about 400 °C. An asset of this type of generator is that smoke develops immediately after the drive engine is switched. They are noisy, however.

Several other types of machine can produce smoke at relatively low temperature. In one such unit, the smoke is developed by treating the woody material with overheated steam at about 250–390 °C.

Modern smokehouses are usually built in the form of kilns, tunnels, or towers (Figure 6.7). They work either periodically or continuously. The smoke is distributed evenly and circulated at controlled velocity by the action of fans and shutters. Smokehouses used to treat meats with smoke preparations are additionally equipped with nozzles or evaporating heated plates to turn the liquid preparation into an aerosol. The necessary heat is supplied by steam, gas, or electricity. The smoke temperature, density, and humidity and the smoking time are adjusted according to a program set for the particular product to be processed. In the manufacture of many types of smoked sausage, the smoking phase is followed by a period of cooking under a hot-water shower or by steam. The sausages to be smoked are hung on rods and transported into the smokehouse on trolleys, moving either on the floor or on an overhead track. In tower smokehouses, the goods are moved vertically on a chain transporter.

The spent smoke leaving the smokehouse carries many atmospheric pollutants and should be cleaned. This can be done by various different kinds of filter or afterburner. To avoid accumulation of tars, which contain more PAHs than smoke, and to prevent the outbreak of fire, many smokehouses have automatic cleaning systems.

6.7 Smoking procedures

A number of smoking procedures have been developed in the last several centuries, suitable for treating various commodities. They differ in the mode of preparation of the raw material and in the parameters of treatment in the smokehouse — mainly smoke humidity and temperature, as well as the duration of the process.

Smoking usually constitutes one of a chain of several unit operations and unit processes in the manufacture of a meat product. Depending on the intended characteristics of the product, a suitable raw material and pretreatment are selected, cold, warm, or hot smoking is applied, and different methods of heating are used (e.g., warm air, steam cooking, or cooking in water). Cold smoking, at a temperature of 12 – 25 °C, lasts from a few hours to several days. It is typical in the manufacture of raw fermented sausages made of cured meat, some assortments produced from variety meats, and pork belly. The parameters of fermented sausage smoking should promote the proliferation of lactic acid bacteria (LAB), ensure the predetermined loss of moisture, and lead to specific, rheological properties in the product. Warm smoking, at 25 – 45 °C (i.e., in conditions under which the fats in the batter change their consistency but no protein denaturation occurs), usually lasts up to a few hours. It is normal in the manufacture of baked or scalded sausages, pork back fat, and hams. Hot smoking is carried out at 45 – 90 °C. Depending on the assortment of sausage, it may be applied at several stages of the manufacturing process, and it can last from a few hours up to 12. It leads to the development of smoky sensory characteristics, thermal denaturation of proteins, and a predetermined yield of product.

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