SMOKED FOODS

PRACTICAL ACTION
Technology challenging poverty

technical brief

Smoking was originally used to preserve protein-rich foods such as meats and fish for long-term storage at room temperatures. These traditional products are still produced in some countries, but now the main reason for smoking foods in many countries is to change their flavour and colour, and these smoked foods are preserved by refrigeration. Smoking is a relatively low-cost process that can add value to foods and is highly suitable for small-scale processing.

The most commonly smoked foods are fish and seafoods (e.g. tilapia, mackerel, trout, black cod, sturgeon, tuna and mussels); meats and meat products (e.g. duck, venison, game birds, pork, sausages, bacon, ham and pastrami (pickled, spiced and smoked beef brisket)); and many types of smoked cheeses. Other smoked foods include vegetables such as chipotles (smoked jalapeño peppers) and nuts (e.g. cashews and macadamia nuts, hickory smoked almonds).

There are three types of small-scale smoking processes:

1. Cold smoking, below 33°C in which the food is not cooked. This process is typically used for salmon, salamis, hams, frankfurters and cheeses.
2. Warm smoking at around 30-40°C, used for bacon, sirloin and some types of sausage (e.g. Mettwurst and Teewurst).
3. Hot smoking at 60-80°C, which cooks the food and destroys contaminating micro-organisms. This process is used for meats, some types of sausage (e.g. kielbasa, mortadella) and fish such as herring, Nile perch or eel.

A fourth process involves dissolving smoke chemicals in water to make smoke concentrate or 'liquid smoke' and spraying it onto foods, but this is rarely done at a small scale.

The smoking process

Smoke from burning wood is a mixture of gases and vapours together with tiny particles of smoke. Some of the particles are deposited onto the surfaces of foods, but this is of little importance for the smoking process: the important chemicals are the gases that are absorbed into the foods, which give the characteristic colour and flavours. Shavings, sawdust or logs made from hardwoods (e.g. oak, beech, chestnut or hickory) produce the best flavours and colours in smoked foods. Sometimes aromatic woods, such as apple, juniper or cherry, or aromatic herbs and spices are also used to produce distinctive flavours. All wood should be free from wood preservatives or saw lubricants. Softwoods, especially pine and fir, are not suitable for smoking because they contain resins that produce harsh-tasting flavours when burned.

There are more than 300 chemical compounds in hardwood smoke: some have sweet, flowery and fruity aromas, whereas others have spicy, pungent, smoky flavours and aromas. The wood also contains small amounts of proteins that produce roasted flavours when it is burned. The types of flavours in the smoke depend on both the temperature of the fire and the moisture content of the wood: the best results are obtained using lower temperature, smouldering fires with a restricted air supply and dampened or soaked wood. These produce dense smoke and the desirable smoke flavours. High-temperature fires break down the flavours in smoke to produce unpleasant tasting compounds.

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The amount of smoke that is absorbed by a food depends on the density of the smoke, its humidity and temperature: the higher the smoke density, the more is absorbed. If the smoke is moist, it increases the amount of flavour compounds that are absorbed. Colour and flavour development also depend on the moisture content of the food and there needs to be a balance between smoke temperature and the surface moisture of foods: low surface moisture is needed for colour formation, but if the surface is too dry, there is less penetration of the smoke flavours into the food. Balancing these different factors makes smoking foods an art as much as a science.

Traditional hot-smoking

Hot-smoked foods are heated to a temperature that is high enough to destroy micro-organisms and cook the food (Table 1). Hot-smoked products can be stored without refrigeration for several weeks. Curing with salt or brine is optional for these foods. If they are dry-salted they should be soaked in fresh water to remove most of the salt before consumption. Smoking produces a strong smoky taste, a golden brown to black colour and a silky sheen on the food surface. An example is traditional West African hot-smoked pork shoulders, feet, head or offal, which have well-developed smoky flavours and are used in soups or stews.

There are minimum temperatures and times needed for hot-smoking to destroy the particular types of food poisoning (or 'pathogenic') bacteria that are likely to be found on the food: for example, fish requires a process that gives an internal temperature of 60°C for at least 30 min to destroy *Listeria monocytogenes.* However, most smoking times are much longer than this to allow colour and flavour development (e.g. up to eight hours at 60-85°C) and all hot smoking processes normally kill pathogenic bacteria. Preservation of hot-smoked foods is due to a complex series of factors, including drying the surface of the food, the antimicrobial effects of salt and heat, and the antioxidant and antimicrobial action of the chemicals in the smoke.

Type of food	Smoking time at a smoke temperature of 107-121°C	Final product temperature (°C)
Beef	3.3 h/kg	82
Beef ribs	3	79
Chicken (legs, wings)	1.5	75
Chicken (quarters)	3	75
Chicken (whole)	4	75
Maize cob	1.5	-
Pork	3.3 h/kg	79
Potato	2	-
Mussels	0.5-1	75
Sausage	3	71

Table 1. Smoking times for selected foods (Adapted from Phillips, undated)

Cold or warm smoking

Foods that are cold- or warm-smoked are not heated to a high enough temperature to destroy micro-organisms and they need to be treated with salt ('cured') to prevent the growth of food poisoning bacteria. In traditional methods, dry fine-grained salt with optional potassium nitrate (saltpetre) is rubbed into all surfaces of the meat or fish before they are smoked. In

more modern processing, pieces of meat are 'tumbled' with the salt mixture for 30-60 min in a tumbling machine. The pieces are stored in a cool place for up to four days to allow the liquid extracted by the salt to drain away. They are then hung in air to dry the surfaces before smoking.

Dry-salting has higher labour costs and less uniform salt penetration into the food than using brine, but it is still widely practised in artisan tropical fish processing. In 'Kench' salting, grains of salt are rubbed into the surface of split fish and the fish are stacked with a sprinkling of salt between each layer. Care is needed in tropical climates to make sure that the fish are fully covered by liquid pickle because any fish that are not covered are susceptible to spoilage and insect attack. It is not possible to make good quality smoked fish from spoiled fish: if fish spoil in the centre before the salt can penetrate, it produces 'putty fish' that have a very soft texture that is unpalatable. Exposure to air also increases the risk of rancidity and can give rise to discoloration and off-flavours. If fish are salted at a lower temperature (e.g. 5°C), spoilage is dramatically reduced because salt can penetrate into the fish before spoilage occurs. In many countries, large fish are split before salting to reduce the thickness of flesh that the salt has to penetrate and so avoid this problem. The liquid pickle that forms is allowed to drain away before smoking.

Fish may also be covered with saturated brine (360g salt per litre of water) as quickly as possible after catching and kept covered until curing is complete. In tropical climates, this is preferable to dry salting to avoid spoilage. A brining tank may be constructed from watertight wooden or plastic barrels, stainless steel or food-grade plastic tanks, or concrete lined with ceramic tiles and waterproof grouting. They should be fitted with lids that are weighted down to hold the fish beneath the brine. The brine strength falls as water is removed from the fish and salt should be added to maintain the strength of the pickle. Curing times vary from a few hours to two weeks. Once curing is completed, the brine should be discarded and a new batch prepared.

In industrialised countries, curing most commonly uses brine that contains 25 kg salt, 3 kg sodium nitrate and 50g sodium nitrite per 100 litres of water. Foods absorb salt more uniformly from weaker brines, but the curing time is longer. Stronger brines can cause the salt to crystallise on the surface of foods after smoking to create unsightly white patches. There may be optional sugar, herbs and spices (including juniper berries, nutmeg, cloves, peppercorns, rosemary or bay leaves) added to give particular flavours. The aim is to have a salt concentration of more than 3% in the finished product. Fish or de-boned cuts of meat are submerged in a tank of refrigerated brine (below 5°C), turning them occasionally. The brine strength is checked daily using a brine hydrometer (Figure 1) that is calibrated to measure the concentration of salt in brine. Depending on the result, curing salts are added to maintain the brine strength. (Note: salinometers that are available to measure the salt in seawater are not suitable because they only measure low concentrations of salt). If a salt hydrometer is not available, brine of the correct strength will allow a fresh egg or a freshly peeled potato to float in it (if it is too weak the egg or potato will sink). Other equipment to measure salt strength in brines, such as a refractometer, are much more expensive.

Figure 1: A salt hydrometer to measure the strength of salt in brine. Photo: Pete Fellows

More rapid curing of meats can be achieved by injecting the meat with brine before curing in a tank. This brine contains 30 kg salt per 100 litres of water and the same amount of sodium

nitrite/nitrate as tank brine above. The meat should be injected in about 20 places, deep into the flesh. At larger scales of operation an electric injection pump with 5 - 10 needles can be used.

After curing, foods are cold- or warm-smoked for 6 - 24 hours to produce the required flavours and colour. The texture remains mostly unchanged and products have a milder taste than hot-smoked foods. These foods are preserved by refrigeration and are either cooked (e.g. bacon or frankfurters) or eaten without cooking (e.g. ham, salmon).

Smoking equipment

Micro-scale smokers use a grill mounted above a smoky fire: meat or fish pieces are turned regularly for 6 - 10 hours to ensure uniform heating and smoking. A traditional method for smoking salted fish is to tie them in pairs and leave them hanging in air overnight to dry the skins. They are then hung in a steel drum or a wooden barrel containing a hardwood fire and sealed with a lid to create a hot, humid smoky fire without flames. They are smoked for an hour and the heat and thick smoke produce a strong smoky taste and aroma.

Small-scale smoking equipment should allow the controlled development of flavour and colour in foods, with low levels of environmental pollution caused by the smoke. Smoke can be either generated within a kiln or smokehouse, or it can be produced by a separate smoke generator (Figure 2). Smoke generators add to the cost but give better control over the temperature, humidity and density of the smoke. A simple smoker can be constructed from an old refrigerator by removing the compressor, cutting a vent in the top of the cabinet and fitting an adjustable air vent in the bottom of one side. The smoke generator is a brick or metal cabinet that contains the fire and has a vent to control the amount of air entering the cabinet. A pipe is connected from the smoke generator to the vent in the side of the refrigerator.

Figure 2: Smoker with separate smoke generator.
(The Old Smokehouse at www.the-old-smokehouse.co.uk)

Smokehouses are larger than kilns and can be constructed from wood, concrete blocks, bricks or galvanised iron. More sophisticated smokehouses have fans to evenly distribute smoke in the smoking chamber. In small kilns, fillets of fish or meat and small products such as shellfish or cheese are placed on wire mesh trays or hung from hooks, with space between the pieces to allow smoke to penetrate all sides. In larger smokehouses, trolleys that have hanging rails or mesh trays are wheeled into the smoking chamber. Whole fish are hung so that the backs face the flow of smoke. Smoke from a smoke generator is passed into the base of a kiln through a pipe, with or without the use of a fan.

Efficient smokers have low fuel consumption compared to the output; high capacity; and ease of control without requiring constant attention. Examples include the 'Altona' design developed by the Food and Agriculture Organization and the Chorkor smoker (Figure 3). The

last design has high fuel efficiency and circulates smoke inside the smoker, which reduces fuelwood consumption by more than 80% compared to traditional designs, and produces high quality smoked fish. It has a large capacity, with up to 18 kg fish per tray and 15 trays per smoker. Details of its construction are given by Brownell (1983) and Zinsou and Wentholt (1989).

Figure 3: Improved Chorkor smoker. Photo: from Jallow, 1994.

A note on safety of smoked foods

Smoked foods give rise to some health concerns because they contain dangerous chemicals that are absorbed from the smoke. These include PAHs (polycyclic aromatic hydrocarbons), nitrogen oxides and PCBs (polychlorinated biphenyls), and also nitrosamines that are formed by reactions between gases in the smoke and components of the foods. These chemicals increase the risk of gastrointestinal cancer where there is a high intake of heavily smoked and/or salted foods. There are legal or recommended limits for these chemicals in smoked foods in many countries. Using fires that have lower temperatures or reduced smoking times can reduce the levels of these chemicals.

Cold-smoked fish, shellfish or meat products have a high risk of contamination by bacteria and these foods require more stringent standards of hygiene and handling to avoid the risk of food poisoning. Safety measures include using very fresh fish or meat that is chilled to 2°C before smoking, and handling under strict hygienic conditions before and after smoking. After cold smoking, foods should be chilled to 3°C in a coldroom and they should be packaged and kept at chill temperatures during storage, distribution and retail display. These measures are described in Good Manufacturing Practice (GMP) and Good Hygienic Practice (GHP) guidelines (Anon, 1979; Anon, 2001) and are included in the food legislation in many countries.

In some countries, hot-smoked meats and fish are not packaged and are sold loose in markets. The main cause of spoilage is development of rancidity over several weeks due to exposure to air and sunlight. In humid climates, moulds may cause spoilage of unpackaged smoked foods and they should be packed in plastic bags to prevent moisture pickup.

In some countries, cold-smoked foods are packaged in vacuum packs or modified atmosphere packs. These packs contain low levels of oxygen and thus slow the development of rancidity, especially in fatty products such as cheese, meats or oily fish. However, the lack of air (or anaerobic environment) inside these packs can allow the growth of food poisoning bacteria, especially *Clostridium botulinum*: vacuum-packed smoked fish is one of the highest risk foods to cause botulism. Small-scale processors who wish to use vacuum- or gas-packing for smoked meats, fish or cheeses should be properly trained and have strict controls in place to avoid the risk of botulism. Many countries have laws or recommended practices to prevent the growth of *Cl. botulinum.* These include the use of temperature monitoring and time-temperature indicators to ensure low storage temperatures; the use of sodium or potassium nitrite with salt to cure foods; recommended smoking conditions (e.g. to give a core product temperature of 62.5°C for 30 min for fish that contains more than 2.5% salt); and storage at chill

temperatures below 3°C. Packaging materials are available that allow sufficient oxygen into the pack to prevent the development of an anaerobic environment. A typical type is a 'styrofoam' tray with an oxygen permeable film over-wrap. If these packs are used, it is important that retailers are trained not to stack the packs in such a way that would block the film over-wrap and reduce the oxygen permeability.

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