VOLUME 3 FOOD PRODUCTS SERIES

MEAT and Meat Products

TECHNOLOGY, CHEMISTRY AND MICROBIOLOGY

Alan H. Varnam and Jane P. Sutherland

CHAPMAN & HALL

type of spoilage appears to be increasing in summer months, although occurrence is sporadic. This has been attributed to a higher incidence of high pH meat and the failure of the industry to appreciate that modern bacon, of relatively low NaCl content, requires storage at temperatures below 5°C.

Relatively little is known of the spoilage microflora of bacon in modified atmosphere packs. Available evidence suggests a similar pattern to vacuum-packed bacon, although spoilage due to *Providencia* appears to have been largely eliminated.

Lactic acid bacteria, especially *Lactobacillus* and *Carnobacterium* are dominant in spoilage of pre-packed sweetcure bacon and the involvement of other bacteria is rare. Initial numbers on sweetcure bacon are low, as few as 10^2/g being present on some occasions. The relatively low NaCl concentration and the lack of a pre-existing microflora mean that growth is usually relatively rapid, even when temperature is adequately controlled. On some occasions, however, a delay of up to 6 days has been observed during which little growth occurs. This delay is then followed by very rapid growth but the reasons for this phenomenon are unknown. Spoilage is by souring, with stickiness and slime formation.

Vibrio species are rare, but not unknown, in spoilage of sweetcure bacon. A particularly spectacular type of spoilage, which primarily affects bacon made with added sucrose, is due to dextran formation by some strains of *Vibrio*. This results in massive slime formation, rashers of bacon often being completely coated.

Members of the Enterobacteriaceae may also be involved in spoilage of sweetcure bacon. *Proteus* and *Providencia* are most commonly implicated, although cabbage odour does not appear to be a significant problem. The most common spoilage pattern is faecal odours and stickiness.

(c) Dry-cured hams

Dry-cured hams, when properly made, are a stable product with a long storage life. External mould or yeast growth is common and within industry has previously been thought to be of little significance, or to be indicative of correct ripening and good quality. It is now accepted that mould growth is undesirable and there is concern over the possibility of mycotoxin production. A link has been made between consumption of mould-spoiled hams and some types of cancer in the Adriatic region of the former Yugoslavia. A large number of mould genera have been isolated from dry-cured hams but *Aspergillus*, *Cladosporium* and *Penicillium* are dominant. Potassium sorbate sprays are permitted in the US and some other countries to control mould growth.

Yeast growth can also be a fault on dry-cured hams, alternate patches of yeast and moulds being present on heavily spoiled products. Species present are generally the same as those found on Wiltshire bacon and include *Candida*, *Debaryomyces*, *Rhodotorula* and *Torulopsis*.

Internal spoilage of dry-cured hams is rare in commercial practice and is usually associated with exposure to high temperatures before a sufficiently high concentration of NaCl and curing agents is attained in deep muscle. Internal spoilage is often attributed to species of *Clostridium*, although in modern practice this type of spoilage appears to be rare. A wide range of clostridia have been isolated from spoiled hams, including *Cl. bifermentans*, *Cl. putrefaciens* and *Cl. sporogenes*. In extreme cases gas production was sufficient to disrupt the structure of the ham, although the significance of these findings to current practice must be questioned.

Some investigations have suggested that a miscellaneous group of bacteria is responsible for internal spoilage of hams. The normal internal microflora, for example, is *ca*. 10^6 cfu/g and is dominated by lactic acid bacteria, especially *Lactobacillus* and *Pediococcus*, *Micrococcus* and *Staphylococcus xylosus*. Numbers of bacteria in spoiled hams are in excess of 10^8 cfu/g, with species described as 'coryneform' (*Aerococcus*, *Arthrobacter*, *Bacillus* and *Sarcina*) being present in significant numbers in addition to members of the normal microflora. On other occasions, the spoilage microflora is dominated by *Providencia* and, to a lesser extent, species of *Proteus*. In any case considerable variation may be expected even with hams produced at the same plant.

Internal mould growth is very rare in traditionally cured hams but can be a significant problem with more modern cures. Mould growth, usually involving *Aspergillus* or *Penicillium*, is a common problem in deboned hams, in the cavity remaining after bone removal. Internal mould growth is also a serious problem in restructured dry-cured hams and has limited development of this type of product (see page 189).

4.4.4 Microbiological analysis

(a) Routine analysis of Wiltshire and related immersion brines

Direct microscopic enumeration, using a counting chamber, permits gross changes in brine microflora to be readily detected and remedial action taken. The accumulation of debris can make direct counting difficult and phase contrast microscopy is preferred. Direct counting is a relatively crude method and should be supplemented by colony counts. Colony counts of high NaCl environments are beset by difficulties and there is a large discrepancy between microscopic and colony counts. Further, no single medium will recover all types of micro-organism in the brine. A medium containing 4–5% NaCl is most widely used and recovers halotolerant bacteria as well as those halophilic bacteria involved in bacon spoilage. Recovery of the dominant, more strongly halophilic bacteria requires a medium of higher NaCl concentration (*ca*. 20%) and special techniques which are not appropriate to routine monitoring.

Much of the current knowledge of the microbiology of Wiltshire brines and their technical management stems from the work of Dr Alan Gardner at the Ulster Curers' Association in Belfast. This work demonstrated the level of control possible by means of relatively simple techniques and suggested means by which more sophisticated control could be applied. A selective medium for *Vibrio* spp. was devised, crystal violet–kanamycin agar, which, although designed to indicate backwash contamination of brines, may well have a wider role as a predictor of brine instability and a short storage life of bacon. The value of other microbiological examinations of curing brines, such as counts for *Escherichia coli* I or *Pseudomonas*, appear less well defined and it is possible that

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* Halophilic bacteria can be highly sensitive to osmotic shock and it is necessary to 'think salt' whenever the organisms are handled. This means that not only must cultivation media contain NaCl at an appropriate concentration, but also a similar concentration must be present in dilution blanks, etc. Preparation of heat fixed smears for microscopic examination is also complicated by the need to make cell suspensions in a solution of NaCl rather than water. The smear must then be desalted, a procedure which makes the Gram stain difficult and more complex operations, such as flagella staining, virtually impossible.

control should be exerted through good manufacturing practice rather than through retrospective microbiological examinations.

(b) Bacon and other uncooked cured meats

Microbiological analysis is most commonly undertaken at pre-packing and usually involves colony counts on non-selective media containing 4-5% NaCl. Enumeration of lactic acid bacteria may also be made and can be useful, especially with sweetcure bacon. Low pH value selective media containing high levels of acetate are not suitable and a medium such as the MRS medium recommended for other meats should be used. The crystal violet-kanamycin agar used for enumeration of *Vibrio* in curing brines can also be used with bacon. Enumeration of *Vibrio* is of particular value in summer months, especially as a predictor of spoilage in high pH value Wiltshire joints. The analysis is not, however, considered worth while for sweetcure bacon. Examination for other microbiological parameters, including *E. coli* and yeasts, is not considered of value under normal circumstances.

Routine microbiological examination of ripened dry-cured hams is not considered necessary.

EXERCISE 4.1

The relationship between the age of the brine and the flavour of bacon has never been systematically investigated. Indeed, there are few opportunities since mature brines are only discarded under extreme conditions. Following the establishment of a small Wiltshire curing operation on a greenfield site, however, it was found that for the first 10–12 curing cycles (length 3–4 days), the bacon was of pale colour and, while recognizably bacon, had a rather insipid 'porky' taste. The brine at this stage contained no more than 10^3 bacteria/ml, which appeared to have been derived directly from the meat. The brine had a pH value of 6.6, was clear and of a yellow-green colour. The 'porky' taste disappeared over the next few curing cycles and the colour and flavour improved slowly until, after *ca.* 100 cycles, the bacon produced was considered to be of typical high quality Wiltshire flavour. At this stage, bacterial numbers in the brine had increased to 10^6/ml, most of which were halophilic Gram-negative rods. The pH value of the brine had fallen to 6.2, a moderate amount of suspended material was present and the colour had darkened to a light brown. Levels of NaCl, $NaNO_2$ and $NaNO_3$ had been controlled to similar levels throughout.

Discuss the relationship between changes in the brine and the properties of the bacon. On the evidence presented, do you consider that the development of a brine microflora is important in the curing of Wiltshire bacon?

Assume you are given the opportunity to study a greenfield curing operation more fully than that described, and draw up an outline plan to determine the effect of chemical and microbiological changes in the brine and the quality of the bacon.

EXERCISE 4.2

The relatively low levels of NaCl and NO_2 in sweetcure meats mean that vegetative pathogens, such as *Salmonella*, can survive for extended periods and may even be capable of growth. Although undesirable, this is of limited public health significance provided that cooking is adequate. Sliced sweetcure bacon, however, has been identified as being a potential risk product for *Listeria monocytogenes*. This stems from the resistance of *L. monocytogenes* to NaCl and NO_2, its ability to grow at low temperatures and the possibility of its surviving the light cooking often applied to thin sliced bacon. As far as is known, however, there are no epidemiological grounds for implicating sweetcure bacon in listeriosis.

Assess the basis for the identification of bacon as a high risk product for *L. monocytogenes*. To what extent do you consider the identification justified?

Develop a method by which the risk presented by sweetcure bacon can be analysed (quantitatively if possible). Apply this method to compare the risk presented by sweetcure bacon to that presented by pasteurized milk, cooked chicken (as a commercial product), Wiltshire bacon and cornflakes.

5

COOKED MEAT AND COOKED MEAT PRODUCTS

OBJECTIVES

After reading this chapter you should understand

- The various types of cooked meat product
- The basic technology of industrial-scale cooking
- The post-cooking handling of meat products
- The manufacture of specific types of cooked meat product
- The development of 'recipe' meals
- Quality assurance and control
- The physical structure of cooked meat products
- Chemical changes resulting from cooking
- Public health aspects of cooked meat products
- Microbiological spoilage of cooked meat products

5.1 INTRODUCTION

A very wide range of cooked meat products is available, from traditional products, such as pork pies and cooked sausages, to relatively recent developments, such as pre-prepared meat meals. From a socio-economic viewpoint, consumer convenience is the common thread linking these products and this may often be related to work patterns. Some of the earliest commercially cooked meat products, pies and pasties, were derived from the pastry-wrapped 'dinners' prepared for field workers, while modern 'ready-meals' are particularly popular in families where both adults work. It is notable, however, that while traditional products allowed manufacturers to make use of lower quality meat, and were accordingly cheap, ready-meals and other more recent developments tend to be premium cost products.

In industrialized countries, the continuing demand for convenience means that manufacture of cooked meat products is an increasingly important area of the meat industry. Performance in this sector is uneven. Sales of traditional products, including pies and cooked sausages, are static or slowly declining; such products are often perceived as old fashioned and even as 'food of the poor'. In contrast, sales of more recently introduced products are tending to increase rapidly. These include not only ready-meals but also pre-cooked meat joints of various types.

BOX 5.1 **The baker's oven**

Precooked meat joints are seen today as an area of considerable opportunity for the meat industry. The concept is not new. In earlier times, the lack of adequate oven space in working class homes and the high cost of fuel meant that, on special occasions when joints were available, home cooking was not practical. In many areas it was customary to arrange for the joint, as well as home mixed cakes and puddings, to be roasted at the local bakery. At busy times, such as Christmas, it was necessary to devise elaborate precautions to ensure that meat was reunited with its correct owner and accusations of swopping, followed by non-festive bouts of fisticuffs, marred many a happy Christmas.

5.2 TECHNOLOGY

Cooking is a process in which, due to thermal treatment, chemical, physical and microbial changes occur in food finally leading to a palatable product. The wide variety of cooked meats produced means that a correspondingly wide range of technologies must be employed. The underlying functions are, however, the same in each case: a heat treatment which must be sufficient to kill vegetative pathogens, in addition to meeting technological objectives; cooling to prevent outgrowth of surviving bacterial endospores; and protection of the cooked product from contamination. In some cases, there may be an apparent conflict between the need to process for safety and the production of desired organoleptic properties. Under such circumstances safety is of paramount importance and must take precedence over all other considerations.

A knowledge of physical, chemical and biological changes as a function of cooking time and product temperature is required to enable optimal thermal processing conditions to be applied. This permits the use of cooking processes which maximize the quality attributes of the end-product, while minimizing undesirable effects, such as shrinkage. A cook-value (C-value) analogous to the F-value used in sterilization has been proposed:

$$C = \int t_o 10^{[T(t) - 100/Z_c]} \, dt$$

where C = cook-value in equivalent minutes at 100°C, T = product temperature, t = cooking time, Z_c = necessary temperature rise (°C) needed for a 10-fold increase in reaction rate of a product property value.

The cook value concept is typically applied to a constant temperature environment. The Z_c concept can be modified for application to change in product property rather than change in reaction rate constant. Thus Z_p is the necessary temperature rise in °C needed for a 10-fold change in a property value.

5.2.1 Methods of cooking

(a) Hot air

Hot air is a traditional means of cooking, and the most widely used on a domestic and catering scale. Hot air cooking is also widely used on an industrial scale. Ovens may operate on a batch basis, but conveyer ovens in which the product travels through the oven on a moving belt are universal in large-scale production. Air at up to 200°C is used and is usually heated by electricity or by gas burners. Heat transfer is only moderate, but can be increased by humidifying the air.

* A widely used guide to the heat treatment required is the reduction of numbers of *Salmonella* through 7 log cycles. This involves internal time/temperature combinations such as 57.2°C for 37 minutes and 60.0°C for 5 minutes. Such treatments provide an adequate safety margin with respect to *Salmonella*, but there is concern that *Listeria monocytogenes* may survive. In the US, there is a tendency to accept this possibility and to propose addition of preservatives to control its subsequent growth. Some microbiologists consider the use of preservatives to be contrary to good practice in cooked meat production. There is no doubt, however, that while preservatives should not be used as a substitute for good practice, their use is likely to improve significantly the safety of 'minimally processed' cooked meats, which are highly dependent on refrigeration for stability.

Smokehouse cooking is effectively a specialist form of hot air cooking. In basic form, kilns of the type used for bacon smoking are employed, although the operating temperature is rather higher. Heat is supplied by hot air, smoke being produced in a separate generator or sprayed into the chamber as a liquid extract. Alternatively, a hot air oven fitted with a means of introducing smoke may be used. In either case, careful control of humidity is required to prevent excessive drying.

(b) Steam

Steam involves heating with saturated air at 100°C. Latent heat is given up at the meat surface as the steam condenses and heat transfer is therefore very good. The continuing presence of water at the surface, however, means that the temperature does not rise above 100°C and thus browning and other reactions associated with roast meat do not occur. Steam cooking can be used as the first part of a two-stage process for products of this type, the second stage involving radiant or hot air heating to impart the characteristic roast appearance and flavour.

Meat stews, soups and similar products of high water content can be heated by direct steam injection. This is an efficient process, but it is necessary to take account of the water produced by condensation. Heating by direct steam injection is also widely used in production of ultraheat-treated (UHT) soups and stews. In this case water of condensation is removed by flash cooling in a vacuum chamber.

Steam at pressures greater than atmospheric is generally associated with canning, but is also used in production of soups, stews, etc. Temperatures in excess of 100°C are obtained (typically up to 125°C), allowing for faster processing and shortening of the production cycle.

(d) Hot water

Hot water at temperatures up to 100°C has relatively good heat transfer properties and is an efficient means of cooking (stewing, braising). There can, however, be a leaching of constituents, including flavour compounds, and the method is generally used only where the water is ultimately to be consumed with the meat and other ingredients. This is the case with soups, stews and pie fillings, which are often cooked in large, jacketed vats, fitted with a stirrer to assist heat distribution. In such cases, water is the heating medium for meat and other solid constituents, but the product as a whole is heated by conduction through the metal walls of the jacket from steam, or circulating hot water. A similar situation exists where heat exchangers, usually of the tubular type, are used to heat particulate meat products.

Some use is also made of hot water for cooking sausages in plastic shrouds and joints of meat in plastic bags. Heat transfer is reduced by the relatively poor conduction of the plastic. A similar process is used for cooking pâtés in metal moulds. Baths are used where the entire process involves hot water, but hot water sprays can be used in conjunction with hot air, or other forms of heating.

(e) Hot fat or oil

Hot fat or oil are used for cooking (frying) at temperatures of 150–190°C and has very good heat transfer properties. The temperatures are sufficiently high for browning reactions to occur and there is absorption of the fat or oil used for heating. This imparts a characteristic flavour and texture to fried meats, which depends to some extent on the fat or oil used. Heated fats and oils rapidly become oxidized and off-flavours can readily be picked up by the meat being fried. It is usual practice to replace a part of the fat or oil at the end of each production cycle. Small-scale fryers operate on a batch basis, but large-scale production requires continuous frying.

(f) Radiant heating

Radiant heating (grilling) primarily involves the infra-red portion of the spectrum. Heat transfer is very good and high surface temperatures are attained, with rapid onset of browning reactions and charring. For this reason, use is restricted to thin pieces of meat of even cross-section, or to heating the surface of larger products. Radiant heating, for example, may be used to 'brown' the surface of joints cooked in steam ovens. Electrical elements or flames can be used as the heat source; some processes involve a short passage through flames to char the surface deliberately.

(g) Dielectric heating

Dielectric heating is a generic term which includes both microwave and radio frequency heating. For practical purposes, dielectric heating can be considered to be a volumetric process, which does not depend on heat transfer through a surface. This permits a significant improvement in heating rate by largely eliminating the temperature gradient.

Both microwave and radio frequency radiation are electromagnetic energy forms, with wavelengths between the audio range and the infra-red. Microwave is normally considered to be between 500 and 5000 MHz and radio frequency between 1 and 200 MHz. The major heating mechanism in microwave heaters involves the dipole effect, in which water molecules act as dipoles and oscillate in sympathy with the electric field reversals. This results in frictional heating, in proportion to the amount of water present in the food mass. A second heating mechanism, ionic conductivity, is of less importance in microwave heating but is of the greatest importance in radio frequency heating, especially at low frequencies. In either case, the ease with which heat can be generated is known as the loss factor and varies with a number of parameters including composition of the food, temperature and frequency of the applied field.

With respect to foods, the best known application of microwaves is the microwave oven, widely used domestically and in catering, primarily as a means of re-heating pre-cooked foods. Microwave heating is also used in industrial-scale food processing applications and has been used successfully, on a small scale, for cooking a wide range of meats, including sausages, pâté and bacon. There are doubts concerning uneven heating in heterogeneous products and in products of differing geometry. Despite this, a particularly valuable role is envisaged in the in-pack, post-cooking pasteurization of products such as ready-meals, where a high level of

* It is a common misconception that microwave ovens cook food from the inside outwards. The outer layers receive energy at the same rate as the inner mass and, provided that moisture content and other factors affecting heating are the same, will rise in temperature at the same rate. Immediate and significant heat losses can, however, occur at the surface through conduction and convection. This process continues after cooking is completed, resulting in a thermal gradient from the inner mass to the outer.

handling of cooked material is inevitable during manufacture (see page 253).

Radio frequency cooking has been most widely used for completing the baking of cereal products. More recently combination ovens have been developed which combine conventional heating with radio frequency heating in the same enclosure. Such ovens have applications with a number of meat products, including pies (see page 240).

(h) Extrusion cooking

Extrusion cooking cannot be applied to conventional meat products, but is seen primarily as a means of upgrading meat of very low quality. Basic extrusion cookers consist of a pitched screw, or two parallel intermeshing screws, rotating within a barrel. The barrel may be heated or cooled, according to requirements. The operating characteristics of single and twin screw extruders are different, the latter now being the more widely used in most applications, including meat processing. Screws may be counter- or co-rotating, the latter design being the most popular. Meat and other ingredients, including water, enter at one end of the barrel and are carried through by the screws. There is a constriction towards the end of the barrel to provide compression, where a combination of mechanical work and heat converts the discrete food particles into a viscous dough. The meat then passes through the constriction, with accompanying pressure release, cooling and moisture loss, leaving the barrel through a die. Where high temperature cooking is used, the product is puffed by steam production on pressure release. Heating is primarily through the mechanical energy input used to drive the extruder screw, this accounting for 50–100% of the total energy input. Steam injection into the barrel may be used to provide additional heat input and heat transfer may take place through the heated or cooled walls of the barrel.

Extrusion cooked meat is primarily used as an ingredient in other products but there is interest in using it as a basis for a new type of restructured meat.

5.2.2 Cooling

It is unfortunate that there can be a tendency to regard cooling as incidental to the main technological functions in cooked meat production. This attitude can undoubtedly lead both to risk to public health, due to growth of surviving pathogens, and to poor quality due to overcooking. A target temperature of 10–12°C within 6 hours is generally considered safe, provided that the temperature is below 30°C in 2 hours and 20°C within 3 hours. Some strains of *Clostridium perfringens* and *Bacillus cereus* are able to grow, albeit slowly, at 6°C and a final temperature of 4°C should be attained within 24 hours.

Cooling usually commences immediately after cooking. Either chilled water or air may be used and it is common practice, where feasible, to incorporate cooling facilities into the cooking apparatus. Water, where used, should be chlorinated and of potable quality to avoid risk of contaminating the cooked product.

5.2.3 Prevention of recontamination

Prevention of recontamination, either from raw material or from other sources, including food handlers, is a major aspect of the safe production of cooked meats. Strategies must be built into the process design and extreme precautions are required in industrial-scale operations, which effectively means operating two physically separated factories. Routes by which meat may be contaminated after cooking are summarized in Figure 5.1 and means of control summarized in Table 5.1.

One of the most important precautions is the planning of operations to minimize hands-on operations. In some cases, however, handling is inevitable. These include the rebagging of cooked joints and the assembly of ready-meals. A further trend in some countries is production of a basic bulk packaged cooked meat product,

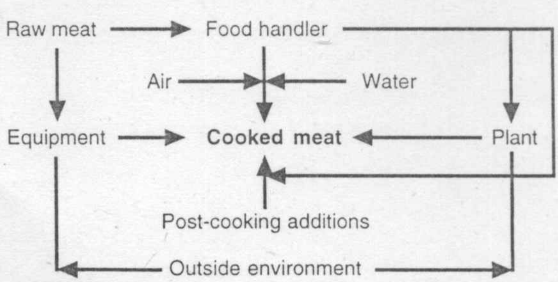

Figure 5.1 Possible routes of contamination of cooked meat.

Table 5.1 Precautions against the recontamination of cooked meat products

Source	Precaution
Raw meat	Ensure strict physical separation of raw and cooked meat.
Food handlers	Persons working with cooked meat must have no contact with area of plant where raw meat handled. **All** persons must meet appropriate medical criteria (Table 5.2). Clean protective clothing and footwear must be worn.
Post-cooking additions	**Either** ensure brought-in ingredients conform to agreed microbiological specifications, **or** apply processing sufficient to ensure safety at plant. Ensure added ingredients handled and stored correctly.
Equipment	Separate equipment **must** be used for handling raw (including fermented) and cooked meat. Equipment should be cleaned and sanitized according to a predetermined schedule with an allowance for emergency cleaning if required. Food contact surfaces must be maintained in a condition permitting effective cleaning.
Plant	The fabric of the plant must provide adequate protection for the food and must be cleaned and maintained to minimize the risk of its becoming a reservoir of micro-organisms. Contamination of food by condensation or splashes from floors must be prevented. Drains must be correctly cleaned and maintained and flow must be from cooked areas to raw. (*Ideally* the drainage system for each part of the plant should be separate.)
Water	All water used for cooling, cleaning, etc. must be of potable quality and chlorinated.
Air	The general air flow in the plant should be from cooked to raw areas. Local air flows should protect product from contamination. Filtered air should be used for cooling.
Outside environment	Entry of wild animals, birds and insects must be prevented. The environs of the plant must be kept clean and protected from contamination by flood water. Outside clothing and footwear must not be worn in the cooked meat part of the plant.