FOOD INDUSTRIES MANUAL

23rd edition

Edited by
M. D. Ranken and R. C. Kill

Published with the authority of the
Leatherhead Food Research Association

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Preface

It is a pleasure to be involved in yet another edition of the *Food Industries Manual*, and to know that the book remains in sufficiently high demand for a new edition to be necessary. The work of revision and updating has been rewarding to us and we hope that the result will be found at least equally helpful to those who use it.

In the five years since the last edition the growth of the chilled foods sector, in both quantity and quality—with much more refrigeration available and in use, with close control of refrigeration temperatures, storage times, storage temperatures, transport conditions and display conditions, and with better information on labels and elsewhere about shelf life and the handling of products—has been dramatic. Practical details of this are dealt with in a number of places throughout this edition, notably in a new chapter devoted to composite foods and ready meals.

Alongside and interconnected with this—encouraged by intense public concern over food poisoning and other food issues—we have seen a huge growth in legal and quasi-legal controls over all stages of food manufacture, especially the chilled foods sector. New provisions introduced in the UK Food Safety Act of 1990 are the clearest symbol of this development, accompanied by a host of Regulations and Codes of Practice to expand (and some of them intended to clarify) the basic provisions of the Act. In consequence also, we see a heightened awareness of the role and functions of the enforcement system and its officers, and the appearance of many more consultants, advisors and training specialists all claiming to assist manufacturers in the discharge of what are described as new and onerous duties. In reaction to all this, food manufacturers are learning so to order their operations that their reliability and their commitment to quality and good workmanship can be routinely demonstrated. The touchstone of this has become accreditation of the manufacturer's systems by an independent authority, for instance that they conform with the International Standard for Quality Systems, ISO 9000, or its British Standard equivalent, BS 5750. These and related matters are dealt with in another new Chapter, on Food Issues.

Of course, there have been many other technological developments among the processes of food manufacture, storage and distribution, and a few processes formerly important are now little used. These changes are all recorded here in appropriate places.

We have been most valuably helped by the Editorial Panel who advised us closely about new developments, provided information and checked all that we have compiled or written anew. Staff at the Leatherhead Food Research Association have also helped considerably with suggestions and extensive references from their information database. We wish to acknowledge our great indebtedness to them all.

M.D.R
R.C.K.

Editorial Panel

Contents

1 Meat and Meat Products

ACTIN

Actin is the major constituent of the thin myofilament, part of the contractile mechanism of muscles. The molecular weight is estimated to be about 43 000. It binds one molecule each of nucleotide (ATP or ADP) and divalent cation (calcium or magnesium). An unusual amino acid, *N*-methylhistidine, is found, as also in myosin, and may be used for the analytical determination of these muscle proteins.

AGEING

The object of ageing meat after slaughter is to make it more tender. When an animal dies, the adenosine triphosphate (ATP) in the muscle fibres, in the presence of magnesium, is decomposed by myosin ATP-ase. There is a large release of energy which is used up in contracting the muscle fibres: the actin filaments slide inwards between the myosin filaments, shortening the myofibrils. The heads of the myosin filaments then lock on to the actin, making the structure rigid. This is the well-known phenomenon of rigor mortis: opposing muscles contract and pull against each other and the whole carcass becomes stiff. If the meat is cooked when still in the rigor condition it is extremely tough and unacceptable.

When the meat is hung after slaughter the muscles gradually recover their extensibility and become considerably more tender. We say that rigor mortis has been resolved. The mechanism by which this occurs is not clear. Cracking of the muscle fibres occurs, probably a result of mechanical failure when the muscle was in the rigor state. Damage is also observed at the Z-lines of the muscle structure, where the individual fibrils are joined; this is probably caused by proteolytic enzymes including cathepsins and calpains. At ordinary ambient temperatures the approximate times for rigor mortis to commence and the times of hanging for adequate tenderization are:

	Time to onset of rigor	Time to resolution of rigor
Cattle	12–24 h	2–6 h*
Turkeys	1/2–2 h	6–24 h
Chickens	1/2–1 h	4–6 h

*Further slight increase in tenderness up to 14 d.

These differences in the hanging times necessary to achieve maximum tenderization are possibly due to different degrees of contraction of the myofilaments in bovine, porcine and avian muscles. Limited proteolytic changes have been observed in the sarcoplasm of the muscles but these do not appear to be the cause of the tenderization. Furthermore, very few micro-organisms are found deep within the intact meat after ageing, so neither the tenderizing nor the proteolysis is caused by bacterial action.

Accelerated ageing or conditioning

Ageing normally takes place after the meat is chilled but the process is greatly accelerated if chilling is delayed and the meat continues to be held at about 37°C. Undesirable bacterial and mould growth must be guarded against and there is an increased possibility of the production of pale exudative tissue. Beef carcasses held at 43°C become significantly tenderized in 24 h after slaughter but the meat becomes pale and exudative. Times for achieving satisfactory tenderness, in typical experiments, are of the order of weeks at 0.5°C, five days at 13°C, two days at 18°C and a few hours at 29°C. After accelerated ageing at higher temperatures, the meat should be cooled and stored as necessary at 2°C.

Cold shortening or cold toughening

If beef (to some extent) or lamb (especially) is chilled rapidly after slaughter the muscles may undergo extreme contracture or 'cold shortening'. When cooked this meat is very tough. Under similar conditions pork is almost unaffected. The cause of the

problem is that muscular contraction is triggered off by the cold conditions and it is mechanically possible because reserves of energy and of the energy-using ATP system still remain in the meat. Where the meat is cooled slowly these reserves become consumed and contraction is no longer possible when the meat is cold. The critical condition appears to be that if the temperature within the meat falls to 10°C (50°F) in less than 10 h then cold shortening is probable unless other precautions are taken—see below.

The 'tenderstretch' process

If the contraction of the muscles on a carcass can be prevented then cold shortening is unable to occur even if the meat is cooled rapidly after slaughter. In the 'tenderstretch' process, also called 'hip-hanging', beef carcasses are suspended after slaughter not in the usual manner by the hind legs but by brackets which secure them by the aitch bone. By this means the muscles of the loin and back are kept under tension by the weight of the animal, contraction is inhibited and the meat can be rapidly chilled without undergoing cold shortening and consequent toughening. It is however necessary after evisceration to change the suspension of the carcasses by moving them from the special brackets, which can interfere with the smooth flow of the slaughter line.

Because of their smaller size this process is less effective with lambs.

Electrical stimulation

When an electric current is passed through an animal carcass immediately after slaughter there is a considerable contraction of the muscles. The energy needed for this contraction consumes the remaining reserves of glycogen and ATP so that when the muscles relax on removing the current no further contraction can take place, so toughness from that cause, even if cooling quickly follows, can be eliminated. The process is effective both with cattle and lambs and is in widespread use wherever there are advantages in cooling rapidly after slaughter, for instance with lambs to reduce the holding time necessary before freezing, or with beef to permit hot boning.

High voltage stimulation (700–800V at peak) gives more rapid tenderizing than low voltage (80–100V at peak) but the latter is safer to use in the abattoir.

There is some danger of reduced colour stability in the meat, possibly because of damage to the protein part of the myoglobin pigment by muscle enzymes released during the electrical contraction.

ANALYSIS OF MEAT PRODUCTS

For most practical purposes in a meat factory quality control laboratory, the chemical analyses carried out on the products are for moisture, fat, protein, connective tissue and ash or salt. For cured meat products nitrite and nitrate determination will also be required. Rapid methods of carrying out these analyses are desirable.

Moisture may be determined rapidly by heating 5 g of the product for 30 min at 150°C (328°F).

Fat content may be determined by continuous extraction of the dried solids with mixed chloroform–petroleum ether (b.p. 40–60°C) in a Soxhlet extractor or in the Foss-Let or similar apparatus. In the latter method the sample is extracted with perchlorethylene which is then made up to a standard volume: the fat content is calculated from the refractive index of the solution. The proportions of saturated, unsaturated and polyunsaturated fatty acids may be determined by glc of the fat after hydrolysis and esterification with methanol.

Various methods of measuring protein content have been tested but modifications of the Kjeldahl process are still the most favoured. Semi-automatic systems are now in common use (e.g. Kjel-Foss, Kjel-Tec, Buchi) in which a first result may be available in 15–20 min from commencement and later ones at 3 min intervals.

Connective tissue may be determined by the method of Mohler and Antonacopoulos. After hydrolysis of 4 g of the meat product, the hydroxyproline in the hydrolysate is determined by oxidation with hydrogen peroxide to give a compound which on acidification gives a red colour on heating with Erlich's reagent. 8 times the hydroxyproline content is reckoned as collagen or dry connective tissue, 37 times is wet connective tissue.

The estimation of nitrogenous substances other than meat protein may present severe difficulties (see MEAT CONTENT).

Salt may be determined by titration with silver nitrate or mercuric nitrate. Multiple routine determinations may be done with a suitable calibrated salt probe or electrode. Salt in curing brines is commonly monitored by hydrometer.

Nitrite can be determined by the well-known diazo reaction followed by coupling with *N*-(1-naphthyl) ethylenediamine dihydrochloride (NED) to produce the water-soluble azo dye. Nitrates are usually determined after reduction to nitrite using

metallic cadmium. The test solution is treated either by shaking directly with precipitated cadmium or by passing it through a column packed with the metal. The total nitrite content of the reduced solution is determined, the original nitrite deducted and the remainder calculated as nitrate. Nitrite and nitrate determinations should be carried out routinely on curing brines.

Bacteriological tests

There is much variation in the tests done in different laboratories and the methods have not been standardized sufficiently for strict and enforceable bacteriological standards for meat and meat products to be laid down at international or, in most cases, national level. It is even considered by many that such standards are neither possible nor desirable. It is, however, common for large buyers to make their own microbiological specifications or guidelines and a supplier should of course follow these.

For raw meat, the following figures are a rough guide:

Microbial count, per g	
10^2	Excellent quality (laboratory conditions)
10^4	Good commercial quality
10^6	Rejection limit in many commercial contracts
10^8	Meat smells
10^9	Meat slimy

One recommended procedure for the examination of open pack meat products is as follows: make a plate count at 37°C, a presumptive coliform count at 37°C and follow if necessary with a faecal coliform count at 44°C. A staphylococcal count using the Baird Parker medium is also desirable. Salmonellae may be detected by enrichment in double-strength selenite F broth followed by plating on to a McConkey agar plate and a desoxycholate citrate agar plate. After incubation at 37°C, non-lactose-fermenting colonies are inoculated into peptone water. After 12 to 24 h at 37°C, inoculations are made into one tube each of Kohn's two-tube medium from the peptone water cultures. The Kohn's tubes may be read after 24 h at 37°C.

Clostridium perfringens screening tests may be carried out using litmus milk as in testing water; occasional false positives are obtained.

Four per cent agar counts are carried out on bacon brines.

The 'agar sausage' may be used as a simple means of checking the level of microbiological contamination of equipment. The exposed cut end of the sausage is pressed on to the surface to be sampled, a thin slice is cut off and incubated.

The commonly used microbial media are now available in prepared forms such as ready-poured plates or media-impregnated pads, which greatly simplify routine laboratory procedure. Inoculation and counting can be simplified and speeded up with the Spiral Plate Maker. For intensive routine work, automatic systems such as the Bactometer or the Malthus Growth Analyser are becoming commonly used.

Meat content

Since the protein and moisture contents of pure muscle are relatively constant, this fact may be used in the analytical determination of the meat content of meat products. In real meat, of course, the situation is complicated by the presence of variable amounts of fat and connective tissue along with the muscles in different cuts of meat.

(a) 'Meat content' calculated from standard values for the nitrogen content of meat In the UK the determination of the meat contents of products such as sausages is done using average factors for the nitrogen contents of lean meat, including the proportions of connective tissue and fat normally associated with the 'lean' meat.

The following factors (per cent nitrogen on the fat free basis) have been agreed between the Society for Analytical Chemistry, the Royal Society of Chemistry and others, and are used for control purposes in the UK:

Pork	3.45
Beef	3.55
Breast of chicken	3.9
Dark meat of chicken	3.6
Whole carcass of chicken	3.7
Ox liver	3.45
Pig liver	3.65
Liver of unknown origin	3.55
Tongue	3.0

The pork and beef factors are average values for all cuts of meat from the animal in question and may be incorrect for particular cuts whose composition (proportions of connective tissue and intermuscular fat) differs markedly from the average, as is the case with many of the cuts used for manufacturing. The following factors (per cent nitrogen on the fat-free basis) are recommended for use when the individual cut of pork is known. See over.

Of course, meat products may contain nitrogenous substances other than meat protein and the detection and estimation of these may present difficulties. The Stubbs and Moore calculation applied to the analysis of British sausages assumes that the non-meat solids present consist of rusk with a nitrogen content of 2% and the appropriate

	Lean and subcutaneous fat	Lean, rind and subcutaneous fat
Collar	3.35	3.50
Hand	3.35	3.60
Rib belly	3.45	3.70
Rump belly	3.45	3.70
Rib loin	3.60	3.80
Rump loin	3.60	3.80
Middle cuts	3.50	3.75
Leg	3.45	3.60
Whole carcass	3.45	3.60

deduction is made from the total nitrogen content before calculating an 'apparent meat content'. Soya, milk or other proteins may be estimated electrophoretically or by other means, provided the sample has not been strongly heated, and the appropriate corrections made. ELISA (enzyme-linked immuno-serum assay) methods can be used for cooked samples.

Attempts have been made to estimate meat contents directly by measurement of the content of 3-methyl histidine, an amino acid which is characteristic of meat protein, but this process is not reliable unless the species of meat is known, the 3-methyl histidine content of muscle being rather variable.

(b) Analytical control without calculation of 'meat content'. In countries other than Britain it is common for control purposes to refer the composition of meat products directly to the nitrogen or protein content of the dry, fat-free product, or to the water/protein or similar ratio. The analytical problems of determining the true meat nitrogen or protein content are of course the same.

From the figures considered on pages 16–17, the water/protein ratio in muscle meat is close to 77% water/23% protein = 3.35. This ratio is a pure number, independent of the fat content of the meat.

The Feder number as used in Germany is closely similar, being defined as the ratio of water to organic non-fat in a sample, or:

$$\text{Feder no.} = \frac{\text{water \%}}{100 - (\text{fat \\% + water \\% + ash \%})}$$

The organic non-fat consists of the protein of the meat plus other substances which are almost all nitrogenous; in practice this is close to the protein content as estimated from the nitrogen content.

In France the relationship HPD (humidité du produit degraissé or 'moisture of the defatted product') is used. For pure muscle, from our previous data, this value is 77%.

In the US regulations and in FAO/Codex recommendations a related ratio is used, 'protein on fat-free' or:

$$PR_f = \frac{100 \times \text{protein \%}}{100 - \text{fat \%}}$$

The limiting value of this expression is the protein content of fat-free muscle, or 23%.

The expression (100 − fat %) in both HPD and PR_f is not the protein plus water content of the sample but protein plus water plus ash. It may therefore be affected by differences in ash content, as will be found for instance in cured meats.

Under systems such as these it is usual to provide a maximum tolerance for the presence of rind, gristle and connective tissues, calculated from the collagen content. French standards are expressed in terms of the ratio of collagen to total protein, the German ones as absolute or relative BEFFE values. The absolute BEFFE value is the percentage content of connective-tissue-protein-free meat protein (Bindegewebeseiweiss-frei Fleischeiweiss). The relative BEFFE is the percentage of BEFFE in the total protein.

Of course, if non-meat proteins are present they will not be distinguished in these calculations and must be analysed for separately.

Meat species

The species of meat used in a given product, as long as the product has not been cooked, may be readily identified using immunological techniques. Simple test kits are commercially available.

With heated meats, immunological identification is very difficult but the species may still be determined by taking advantage of species differences in the composition of the muscle proteins, the myoglobin or certain enzymes including phosphoglucomutase. The individual components may be separated by gel electrophoresis with iso-electric focusing, then stained with Coomassie Blue. So long as mixed fats are not present, identification may also be possible from the fatty acid profile of the fat.

Rapid methods

To meet the increasing pressure from regulatory authorities for precise control of composition at the point of manufacture, and also in the manufacturer's own interest, a number of good and rapid analytical methods is now available. The initial cost of the equipment is high, but can be justified when large numbers of analyses lead to improved control of production. The systems presently available include those based on the following methods:

(a) Infrared spectroscopy of a prepared sample surface (e.g. the Infralyser). This process was first developed for dry materials such as flour but has been adapted for meat. The instrument requires careful calibration for each type of sample analysed, so it is convenient only for long production runs of the same product. Another infrared method is the Foss Super-Scan, where light in the fundamental infrared region (2.5 to 10 microns) is transmitted through the sample and the energy attenuation is measured. The system consists of an electronic balance for accurate on-line transmission of sample weights, a reactor for sample preparation, a measuring unit where the fat, protein, carbohydrate and water infrared absorptions are measured and a desk-top computer.

(b) X-ray methods—a large sample (e.g. 1–15 kg) may be required, but this may be an advantage as it makes it easier to ensure that the sample is representative; after analysis the sample may be returned to production without loss. The Anyl-Ray machine tests the sample by X-ray diffraction and gives a digital read-out of the fat content.

(c) Microwave drying and solvent extraction—rapid destructive analysis by physical and chemical methods, as in the CEM Meat Analyser, can provide results in under 10 minutes. The CEM system consists of two units, an electronic balance fitted inside a microwave drying cabinet and a fat extraction unit with automatic solvent extraction and solvent recovery. This is an AOAC approved method.

(d) Video image and optical methods—the Glafascan video image system is an on-line method for measuring the fat to lean ratio of fresh or frozen minced or diced meat. The system provides real time video measurement of the fat to lean ratio by continuously scanning the surface of the meat as it passes along a conveyor, calculating the fat content from the intensity and colour of the reflected light and displaying the accumulated results every 5 seconds. This information can be fed directly through suitable equipment to control subsequent manufacturing operations on the meat. An example of an optical method is the Lean Machine which consists of a hand-held optical device which is inserted into a meat sample; the device is linked to a microprocessor which gives a rapid calculation of the fat to lean ratio. Another optical method is the Trebor-99 Composition Analyser which is a laboratory-based instrument.

(e) Automated heat and digestion systems—a simple heating method called the Univex Hobart instrument consists of a heating element within which the sample, for instance of minced meat, is placed. The heated fat melts and is collected in a graduated tube which is calibrated to give a direct read-out of the fat content. The analysis takes 15 minutes. Although it appears rather crude, if the instrument is carefully calibrated it can provide accurate results.

(f) Chromatography—the Dionex ion chromatography method is in principle capable of measuring the content of chloride, phosphate, nitrate and nitrite anions in a sample of meat in under 30 minutes. The system will also detect fluoride, benzoate, bromide, malate, sulphite and sulphate.

(g) Electrical methods—the Dickie-John ground meat tester is a non-chemical method which relies on the generation of an electromotive force (emf) in a plug of meat; the emf generated is directly proportional to the lean meat content. A sample tube is loaded with approximately 750 g of meat and the instrument gives an immediate read-out of the fat content. The accuracy is somewhat lower than that of the chemical methods but is generally acceptable in a factory environment.

(h) Density methods—the specific gravity of fatty tissue is about 0.92 and that of lean tissue about 1.0. In theory therefore the fat content of a sample can be calculated if its density can be measured accurately. Machines have been designed to measure the density simply, for instance by compressing a known weight of minced meat and measuring the resulting volume, but they are not yet commercially successful.

The Foss-Let method uses automatic extraction of the fat from a sample of meat with perchlorethylene; this solvent has a specific gravity (s.g.) of 1.62, compared with about 0.92 for the extracted fat. Here the difference in s.g. is large and the s.g. of the solution of fat is easy to measure accurately; the Foss-Let instrument gives a reliable measure of fat content in meat. The results are available within 5 minutes and the method is AOAC approved.

ANTIBIOTICS

Antibiotics are chemical substances, usually prepared from micro-organisms, which interfere with the metabolic processes of other organisms and retard their growth. The use of antibiotics as preservatives is prohibited in most countries, partly

for the not very good reason that by checking spoilage they might reduce a major incentive towards good hygiene in processing factories. But public health considerations are more compelling.

In the late 1950s the authorities in a number of countries, including the Swann Committee (Joint Committee on the use of Antibiotics in Animal Husbandry and Veterinary Medicine) in the UK (1959), considered the dangers to human health posed by the carry-over of antibiotics from animals to meat, milk, etc. used as human food. Antibiotics may be administered to animals either for veterinary reasons (disease treatment) or as feed additives for growth promotion (achieved by suppression in the animal gut of bacteria which are harmful or which compete for the animal's food).

There is a double danger. The use of any antibiotic may be expected ultimately to lead to selection of resistant strains of the micro-organisms against which it will then be ineffective. If such micro-organisms from an animal were later to infect humans, causing disease, the illness would not be treatable with the same antibiotic. Furthermore, this property of drug resistance is transferable among micro-organisms—suppose that an animal is treated with antibiotic for a disease condition which is itself of no significance to human health, but that as a result of the treatment the bacteria responsible become resistant to the antibiotic—that resistance could then be transferred to other bacteria, for instance salmonellae, and if the salmonellae should cause human food poisoning then that illness would be resistant to treatment with the same antibiotic.

The Swann Committee therefore recommended that whilst the antibiotics used in human medicine might be used also in veterinary medicine, with care and under proper supervision, antibiotics used as feed additives should be restricted to those without application in human medicine. This means in practice that antibiotic residues should not appear in meat. In milk, which might contain residues of penicillin following veterinary treatment of the cows, absence of antibiotic is interpreted in UK laboratory practice as meaning that the content of penicillin, or its equivalent of other antibiotic, should be below 0.05 i.u./ml; a similar standard could be applied to meat.

See also PROBIOTICS.

ASCORBIC ACID AND ASCORBATES

Ascorbic acid is the well-known vitamin C, occurring naturally in fruits and vegetables. Its optical isomer erythorbic acid (D-iso ascorbic acid) has almost identical chemical properties but no vitamin activity, apparently because it is not physiologically absorbed by living cells. Both acids are manufactured synthetically and are readily available. The use of erythorbic acid and its salts in food is permitted in the USA but not in the UK or most of the countries in the EC. There are no known ill effects from the consumption of moderate or even large amounts of ascorbic acid or its salts.

It is usually better in manufacturing practice to use sodium ascorbate than the free acid. If the acid is used in solutions such as curing brines, containing nitrites, free nitric oxide will be formed: on contact with the air this immediately forms brown fumes of nitrogen dioxide which are unpleasant to breathe and highly toxic.

In uncured meat the presence of ascorbate delays the oxidative processes which turn the red colour of the meat into brown. It therefore prolongs the apparent shelf life; an increase of about 1 day at ordinary temperature is typical. In the UK and certain other countries it is considered that to do this is to deceive as to the true age of the meat and the use of ascorbate in butchers' meat for this purpose is therefore prohibited—see under NICOTINIC ACID. It is however permitted in manufactured fresh meat products such as sausages and burgers.

In uncooked cured meat products such as dried sausage or unpasteurized bacon, the formation of the cured red colour is accelerated by the use of ascorbate but this is not usually of commercial significance because the time normally available for colour development is more than adequate. On the other hand if 200 mg/kg or more of ascorbate is used and the product is exposed to the air, hydrogen peroxide may be formed by reaction of oxygen with the ascorbate. This can form green choleglobin or further breakdown products which are colourless, thus destroying the red colour completely. The use of ascorbates is therefore not advisable in these products.

The colour of cooked cured meats such as ham, pasteurized or hot-smoked bacon, luncheon meats and sausages of the frankfurter type is intensified and stabilized by ascorbates. There appear to be at least three different effects:

(a) the yield of cured colour from the nitrite available is increased in the presence of ascorbate: this effect is significant where the concentration of available nitrite is low, so the uniformity of colour is improved in meats where the nitrite itself is not uniformly distributed;

(b) the colour is formed more rapidly in the uncooked meat so that more is available to be fixed by the cooking process;
(c) the cooked colour is more stable to light, so long as some residual nitrite is also present.

In a period of intense activity in the early 1970s, American workers demonstrated the effectiveness of ascorbates in reducing the formation of NITROSAMINES (q.v.) in heated cured meats. The use of ascorbate was then required by the US authorities, at concentrations of 470 mg/kg (ascorbic or erythorbic acid) or 550 mg/kg (sodium ascorbate or sodium erythorbate).

Ascorbyl palmitate finds some use in proprietary mixtures as a fat anti-oxidant. It has the advantage of being both fat-soluble and water-dispersible. It can thus be added to a product by dispersion among the other water-soluble ingredients in order to perform its function in the fat phase in the product.

BACON

Bacon is cured pork. In the UK and in Europe generally it may be made from any part of the pig, but in North America the term usually refers specifically to cured pork bellies.

Wiltshire curing or tank curing

The original Wiltshire method of curing bacon has undergone many minor modifications but remains relatively unchanged in principle.

After slaughter and evisceration the pigs' heads are removed and the carcasses divided into halves. These are then chilled before curing. The curing process takes place in a curing cellar which is kept at a temperature round about 6°C (42°F). First the sides are pumped with a brine or 'pickle', by injection under pressure through a hollow needle connected with a reservoir of pickle. The sites of injection are carefully controlled to ensure uniform distribution, so far as possible, throughout the meat. Where any bones have been removed in the preparation of the side, for instance the shoulder blade is usually removed, the pocket which remains in the meat and which is a probable source of infection, is stuffed with dry salt as an additional aid to the keeping quality of the final product. Next the sides are carefully stacked into large concrete or tiled tanks, immersed in curing brine and wedged with wooden beams to prevent floating. Extra salt may be sprinkled on the sides so as to keep the salt concentration in the brine high despite the diluting effect of meat juices seeping out from the pork. This immersion stage usually lasts four to seven days. Finally the sides are removed from the tanks and stacked on the floor, skin side upwards, to drain, mature and, it is believed, to equilibrate further in composition. Traditionally, this stage might last a week but in recent times it has been shortened to only two or three days.

A typical Wiltshire brine as used nowadays in the curing tanks contains salt 24 to 25% by weight (a saturated solution contains, in theory, 26.3% salt at 0°–20°C), sodium nitrate or saltpetre 0.5% and sodium nitrite 0.1%. There is also a high concentration of soluble proteinaceous material derived from pork previously cured in the same brine, so that a 'mature' brine is a deep red colour. It has long been recognized that the proper management of this brine, to keep it in good condition, is essential to producing a satisfactory product. Before the chemical and microbiological principles were understood this could be achieved in practice only by strictly following the procedures laid down by generations of curers before, but now it is possible to control the process more rationally. The essential features are those which control the microbial flora which converts nitrates into nitrites and which suppresses the growth of other micro-organisms detrimental to the product. These factors are firstly that the brine concentration must be maintained at or close to saturation. This enables a population of micrococci and lactobacilli to become established. These organisms reduce nitrate to nitrite in the course of their ordinary metabolism. The high salt concentration also assists in the suppression of other micro-organisms which could produce off-flavours or accelerate the later spoilage of the bacon. The maintenance of low temperatures is also important here. Secondly, it is obviously essential that there should be a continuous supply of nitrate for reduction and as part of the food supply of the bacteria. This dependence of the whole process on the establishment and maintenance of the right microbial population throws light upon the old assertions that a curing brine should never be destroyed if it could possibly be salvaged, and that a new brine would always perform much better if it was 'seeded' by the addition of a portion of a good quality old brine.

With the recognition of the nature of the microbiological activity of Wiltshire brines has come also the appreciation of the need to monitor and control nitrite contents, so that the routine measurement of salt, nitrate and nitrite contents forms the basis of all bacon factory quality control testing. This in turn has led on to new and simpler curing