FOOD INDUSTRIES MANUAL

22nd edition

Edited by M D Ranken

Published with the authority of BFMIRA
(the Leatherhead Food Research Association)

Blackie

USA and Canada: avi, an imprint of
Van Nostrand Reinhold Company, New York

FOOD INDUSTRIES MANUAL

22nd edition

Edited by M D Ranken
BScTech, MChemA, MFC, CChem, FIFST, FRSC, MInstM

Published with the authority of BFMIRA
(the Leatherhead Food Research Association)

Blackie
Glasgow and London

Published in the USA and Canada by
avi, an imprint of
Van Nostrand Reinhold Company, New York

Blackie and Son Ltd
Bishopbriggs, Glasgow G64 2NZ

7 Leicester Place, London WC2H 7BP

Published in the USA and Canada by
AVI, an imprint of
Van Nostrand Reinhold Company Inc.
115 Fifth Avenue
New York, New York 10003

Distributed in Canada by
Macmillan of Canada
Division of Canada Publishing Corporation
164 Commander Boulevard
Agincourt, Ontario M1S 3C7

British Library Cataloguing in Publication Data

Food, industries manual.—22nd ed.
1. Food industry and trade
I. Ranken, M.D.
664 TP 370

ISBN 0-216-92472-3

For the USA and Canada

International Standard Book Number
0-442-20674-7

Library of Congress Catalog Card Number
88-77

Phototypesetting by Thomson Press (India) Limited, New Delhi
Printed in Great Britain by Bell & Bain (Glasgow) Ltd.

Preface

Since the appearance of the 21st edition of the *Food Industries Manual* there have been large apparent changes in the manner of operation of the food manufacturing industry.

The first and most obvious feature, much remarked upon in the industry, is the social phenomenon of the 'consumerist lobby'—the strident complaints from some consumers about the nature, substance or quality of, it seems, almost every food commonly available in the shops. The industry has responded in several ways. Some new foods, and some new versions of old foods, have come into fashion and are being produced—for instance, stone-ground flours, muesli mixtures, yoghurts. The use of added colouring materials is diminishing and the open declaration of quite complex lists of ingredients on labels, beyond the already increased demands of the law in that respect, is becoming common. In a few cases the technology has been modified to provide benefits similar to those previously conferred by functional additives—for instance, the development of chilled foods, where efficient chill storage and fast distribution can now be relied upon in many cases to provide, or to avoid the need for, the shelf life which was conferred before by added preservatives.

However, with a few exceptions, changes in technology and manufacturing practice in direct response to the consumer pressures alone have not been large. Most of the changes consist either of applications and extensions of techniques already available in principle, or simple reversions to earlier practices which some thought had been superseded. What is perhaps the most striking general advance in technology owes nothing to the 'consumer revolution'. This is the rapid spread of computerized control systems. Automated control of recipes and the quantities of raw materials used is increasingly common, often linked to the computer programs which marshal cost accounting, reordering and other production information. Automatic weighing of particulate materials, using computerized multi-weigh heads, has transformed product weighing operations in a very short time; not only can packs be very accurately filled to the required minimum or average net weights, with reliability well in excess of that required to pass the legal tests, but the safe tolerances above the minimum can be drastically reduced, with such economies of cost that the machines very soon pay for themselves.

Running parallel both with the public expressions of dissatisfaction with food manufacture in Britain and with the growth of computerized control systems in the factories, has come a new understanding that the responsible control of food manufacture goes well beyound the requirements only of the Food Law. The industry is active in self-regulation. In Britain, for example, the Bacon and Meat Manufacturers' Association has published a series of Codes of Practice for the manufacture of meat products and set up its own quality monitoring scheme; the Department of Health and Social Security has published Guidelines for the nutritional labelling of products *not* legally required to be so labelled; and—perhaps the most far-reaching—the Institute of Food Science and Technology has published its professional view of how things should be done, in the form of Guidelines entitled *Good Manufacturing Practice—a Guide to its Responsible Management*.

The effects and consequences of all these trends are described in the chapters which follow. All have been revised since the last edition, some extensively re-written. A new chapter has been added, entitled 'Quality Assurance and Control Operations', drawing together aspects of quality control systems which were to be found in various places in the previous editions and taking particular note of the developments in thinking and practice referred to above.

I wish to express my thanks to all the authors for their diligence and care in writing or revising the text, and to the editors and authors of the previous editions, on whose careful work we have been able to build.

MDR

Contributors

K.G. Anderson CBiol, MIBiol, MFC, FIFST, FRSH
Technical Services Manager
Brooke Bond Oxo Ltd, Croydon CRO 4XL

A.E. Bender BSc, PhD, DSc(Hon), FRSH FIFST
(Emeritus Professor of Nutrition
University of London)
2 Willow Vale Fetcham, Surrey KT22 9TE

J. Bettison BSc, AIFST, MIInfSci
Customer Technical Services
UK and Overseas
Metal Box plc, R & D Division
Denchworth Road, Wantage
Berks. OX12 9BP

R.G. Booth BSc, PhD, CChem, FRSC, FIFST, MIBiol, FRSM
Consultant Food Scientist
19 Homewood Road, St Albans AL1 4EG

R.W. Broomfield ANCFT, AIFST
Technical Services Manager
Ledbury Preserves (1928) Ltd
Ledbury, Herefordshire HR8 2JT

K.J. Burgess BScEng, MSc, PhD, AIFST
Development Manager
Dairy Crest Foods, Development Centre
Crudgington, Telford, Shropshire TF6 6HY

G. Campbell–Plant BSc, PhD, FIFST
National College Professor of
Food Technology
University of Reading
Whiteknights, Reading RG6 2AP

D.A. Cruickshank MIBiol
Chocolate Feedstocks Manager
Cadbury Ltd,
Bournville, Birmingham B30 2LU

J. McN. Dalgleish BSc, CEng, FIFST, FIMechE
Food Engineering Consultant
124 Myton Road Warwick CV34 6PR

W.E. Elstow BSc, PhD, MChemA, CChem, FRSC, FIFST
Director
Weston Research Laboratories Ltd
Vanwall Road, Maidenhead SL6 4UF

A.J. Francis LRSC, AIFST
Research and Development Technologist
Mandora (UK) Ltd
Bellamy Road, Mansfield NG18 4 EW

P.W. Harmer BSc, CChem, MRSC
Research and Development Manager
Mandora (UK) Ltd
Bellamy Road, Mansfield NG18 4EN

S.D. Holdsworth BSc, MSc, CEng, FIChemE, CChem, FRSC, FIFST
Head of Food Processing and Engineering
Camden Food Preservation Research Association
Chipping Camden, Glos. GL55 6LD

A.E.V. Lilly BSc, CChem, FRSC, FIFST
(formerly Senior Lecturer in
Food Engineering,
National College of Food Technology,
University of Reading)
2 Brooke Forest, Fairlands,
Guildford GU3 3JH

D.J. Millin MA, DPhil, CChem, FRSC
Consultant Food Scientist
APF Consultants Ltd
P O Box 11, Pangbourne, Berks RG8 7ED

D. Stansell BSc CChem MRSC
Development Manager
Callard & Bowser Ltd
Waterton Industrial Estate, Bridgend,
Mid-Glamorgan CF31 3JD

M.D. Ranken BScTech, MChemA, MFC, CChem, FRSC, FIFST, MInstM
Consultant Food Technologist
9 Alexandra Road, Epsom, Surrey KT17 4BH

J.A.G. Rees DipFoodTech, AIFST
Manager, LAMIPAC and Product Innovation
Metal Box plc, R & D Division
Denchworth Road, Wantage,
Berks, OX12 9BP

J.B. Rossell BSc, DPhil, ARCS
Manager, Oils and Fats Section
Leatherhead Food RA
Randalls Road, Leatherhead,
Surrey KT22 7RY

M.J. Urch DipFoodTech, AIFST
Consultant Food Technologist
5 Bridge Road, Epsom, Surrey KT17 4AN

D.J. Wallington BSc,
Chief Cereals Scientist
Weston Research Laboratories Ltd
Vanwall Road, Maidenhead SL6 4 UF

W.E. Whitman BSc, FIFST
Manager,
Energy and Productivity Advisory Service
Leatherhead Food Research Association
Randalls Road, Leatherhead KT22 7RY

Contents

1

Meat and Meat Products

· M D Ranken ·

ACTIN

One of the major constituent proteins of the contractile mechanism of muscles, actin may be extracted from lean meat by salt solutions of low ionic strength. In solution it exists as G-actin, a globular protein of molecular weight *c.*70000. In the presence of ATP and 0.1 M salt the globular form is polymerized into a filamentous form, F-actin. The globules are arranged in long chains, paired in double helix form. This is the form in which the protein occurs in meat in combination with myosin.

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 chemical mechanism by which this occurs is not yet clear: it is probably related to the rupture of cross-links between actin and myosin, between actin and actin or between myosin and myosin molecules. 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 d*
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. Futhermore, very few micro-organisms are found deep within the intact meat after ageing and it may be concluded that neither the observed tenderizing nor the proteolysis is caused by bacterial action.

Accelerated ageing

The tenderization brought about by hanging may be accelerated by hanging at elevated temperatures, though 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 (110°F) 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 (33°F), five days at 13°C (55°F), two days at 18°C (65°F) and a few hours at 29°C (36°F). After accelerated ageing at higher temperatures, the meat should be cooled and stored as necessary at 2°C (36°F).

Cold shortening

If beef (to some extent) or lamb (expecially) is chilled rapidly after slaughter, the muscles may undergo extreme contraction 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, which 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 temperature within the meat must not fall to 10°C (50°F) in less than 10h, or cold shortening will occur unless other precautions are taken—see below.

The 'Tenderstretch' Process

If the contraction of the muscles on the carcass can be prevented, then cold shortening cannot occur even if the meat is cooled rapidly after slaughter. In the 'Tenderstretch' process beef carcasses are suspended after slaughter, not in the usual manner by the hind legs, but by brackets which secure them by the aitchbone. This keeps the muscles of the loin and back 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 to change the suspension of the carcasses after evisceration to the special brackets, which may interfere with the flow of slaughterhouse operations.

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, considerable contraction of the muscles takes place. The energy needed for this contraction consumes the remaining reserves of glycogen and ATP so that further contraction is no longer possible when the carcass is cooled later. The process is effective both with cattle and lambs, and is coming into 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 of primal cuts.

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

ANTIBIOTICS

Antibiotics are chemical substances, usually prepared from micro-organisms, which interfere with the metabolic processes of other organisms and retarded their growth. The use of antibiotics in the preservation of uncanned meat and uncanned meat products infringes the UK Preservatives Regulations: the Food Standards Committee Preservative Sub-Committee (1959) considered that antibiotics, by checking spoilage, might reduce a major incentive towards good hygiene, and supported the continuance of this prohibition.

The 1959 Swann Committee (Joint Committee on the Use of Antibiotics in Animal Husbandry and Veterinary Medicine) 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 suppressing bacteria in the animal gut 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 is effective: 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, the property of drug resistance is transferable among micro-organisms, so that the resistance of an animal pathogen being treated with antibiotic might be transferred to other organisms such as, for instance, salmonellae, not pathogenic to the animal but able to cause human food poisoning which would be resistant to treatment with the same antibiotic. The Swann Committee therefore recommended that the antibiotics used in human medicine might be used also in veterinary medicine, with care and under proper veterinary supervision, but 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 IU ml^{-1}; a similar standard could be applied to meat.

ANALYSIS OF MEAT PRODUCTS

Chemical analysis

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 determinations 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 nitrogen content have been tested, but modifications of the Kjeldahl process are still the most favoured. In the Kjel–Foss™ apparatus, a batch of 12 samples is automatically digested with sulphuric acid, and subsequent treatment with alkali followed by steam distillation and titration of the distillate is done semi-automatically. The first result is available in 18 minutes from commencement and later ones at 3 minute intervals. For the calculation of meat content from the nitrogen content, see below.

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. Eight times the hydroxyproline content is reckoned as collagen or dry connective tissue.

The estimation of nitrogen-containing substances other than meat protein presents difficulties (see under Meat content, below).

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.

Nitrate 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.

Rapid methods

To meet increasing pressure from regulatory authorities for precise control of composition at the point of manufacture, and in the manufacturer's own interest also, a number of good and rapid 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 depending on:

(a) Infrared spectroscopy of a prepared sample surface (e.g. the Infra-lyser). 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 is convenient only for long production runs of the same product.

(b) Rapid non-destructive analysis by physical 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 it 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. Other instruments measure the sample density and calculate its fat content using a pre-programmed conversion factor, different for each meat species.

Meat content

The protein and moisture contents of pure muscle are relatively constant (see under COMPOSITION OF MEAT) and this fact is 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. These natural components are included in the 'commonsense' definitions of meat accepted in English law. 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, as agreed with the Society for Analytical Chemistry, which take some of this variability into account. The factors (per cent nitrogen on the fat-free basis) include:

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 meats 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 Analytical Methods Committee of the Royal Society of Chemistry (1986) has recently recommended the following factors for use when the individual cut of pork is known (per cent nitrogen on the fat-free basis):

	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

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 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.

Lean meat content may be estimated directly by measurement of the content of 3-methylhistidine, an amino acid which is characteristic of meat protein (Poulter and Lawrie, 1980), but the estimate is not always precise enough. (See under CORNED BEEF for the meat content of corned beef.)

In other countries, 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.

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 or the fat (Patterson, 1985).

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 must, of course, follow these.

The most common practical test is the Total Viable Count. There is no common agreement on the temperature of incubation for this count, which may be between 5°C and 37°C. The temperature used should be chosen with regard to the likely temperature of handling of the meat and, of course, any customer requirements.

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

Total viable 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

Other tests commonly done include tests for:

Presumptive coliforms, followed if necessary with a faecal coliform count
Staphylococcae
Salmonellae
Clostridium welchii.

The 'agar sausage', where the exposed cut end of a sausage of nutrient agar is pressed on to the surface to be sampled and a slice cut off and incubated, was used as a simple means of checking the level of microbial contamination of equipment, but is now largely superseded by newer methods.

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.

ASCORBIC ACID AND ASCORBATES

Ascorbic acid, or Vitamin C, occurs 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 EEC. 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 rather than the free acid. If the acid is used in nitrite-containing solutions such as curing brines, 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 one 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 $mg\,kg^{-1}$ or more of ascorbate is used and the product is exposed to the air, hydrogen peroxide may be formed by reaction with oxygen, forming green choleglobin or colourless further breakdown products and 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 concentraion 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, as long as some residual nitrite is also present.

American workers in the early 1970s demonstrated the effectiveness of ascorbates in reducing the formation of nitrosamines (see NITRITES AND NITROSAMINES) in heated cured meats. The use of ascorbate was then required by the US authorities, at concentrations of 470 $mg\,kg^{-1}$ (ascorbic or erythorbic acid) or 550 $mg\,kg^{-1}$ (sodium ascorbate or sodium erythorbate).

Ascorbyl palmitate finds some use in proprietary mixtures as a fat antioxidant. 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 and can then 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 most essentials.

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 of 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 reservior of pickle. The sites of injection are carefully controlled to ensure uniform distribution, so far as possible, throughout the meat. Some bones, such as the shoulder blade, are usually removed in the preparation of the side. In this case, the 'pocket' which remains in the meat and 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 recently it has been shortened to only two or three days.

A typical Wiltshire brine as used nowadays in the curing tanks contains salt, 24–25% by weight (a saturated salt solution contains 25%), 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 previous curers, 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. Firstly, 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 content, so that the routine measurement of salt, nitrate and nitrite content forms the basis of all bacon-factory quality-control testing. This in turn has led on to new and simpler curing processes in which nitrite is added to the brine directly without any need to rely on microbiological processes to produce it from nitrate. These newer processes will be discussed presently.

The third stage, the process of maturation, was previously considered to be the most important for the production of good bacon, but was not well understood. During maturation the salt, nitrate, nitrite and any sugar and other ingredients present were believed to continue to diffuse through the meat, so that the composition became more uniform. It never becomes completely uniform, however, and all samples of bacon show differences in composition from point to point. During the maturation stage the characteristic bacon flavour does become more fully developed.

The BMMA Code of Practice provides fuller details (BMMA, 1985).

Dry curing

Instead of the tanking stage described above, the product may be made, after preliminary injection, by adding the requisite curing salts not in the form of brine but in the dry state. Originally in this process the sides were sprinkled liberally with salt and saltpetre, built up in stacks of about eight sides, skin side downwards, and stored for about ten days. If this operation was carried out in or near to a celler in which 'live' brines from a traditional Wiltshire process were in use, similar microbial flora would become established in the dry-cured bacon, with consequent production of nitrite in it. Since no brine was added at this stage in the production, the moisture content of the product was lower and this was also helpful in ensuring good conservation. Furthermore, since the process is rather difficult to control, there is a tendency to use plenty of salt so as to ensure a good margin of safety. The product therefore tends to be rather salty, but for that reason it also has a good shelf life.

Machines are now available to provide a more controllable, more uniform distribution of the dry curing salts over the meat, but they are not in very widespread use.

Block curing and other rapid curing methods

Two further developments in the last 10–20 years have greatly speeded up the process of making bacon. The practice has grown of cutting the pork

into blocks smaller than a whole side, for instance into backs or loins, bellies, fores or shoulders, etc. These cuts may also be more or less completely boned out before curing, in contrast to the Wiltshire method in which very few of the bones are removed until after the bacon is made. By these means the quantity of material to be handled is reduced, by the elimination of bones and often by the diversion of some of the cuts of the pork to products other than bacon, and there are good possibilities of curing similar cuts together, adjusting the curing conditions to suit them particularly, and working with smaller and more manageable batch sizes.

The second development is that of the continuous automatic multi-needle injection machine. Applied to boneless pieces of meat, this has not only greatly speeded up the preliminary injection stage of Wiltshire-type curing processes, but, because the injections can be made easily in very many places, close together in the meat, it has become possible to achieve reasonable uniformity of composition in the product without need for the long tanking and maturing stages previously required. The brines used in these cures are almost all 'fresh' brines made up as required, containing the necessary proportions of nitrite and not relying on microbial action to produce nitrite from nitrate. Indeed, nitrate is often omitted completely and there are good grounds to consider that unless one is working in premises where 'live' brines were previously in use and the appropriate nitrite-producing micro-organisms are present in the environment, it is better that nitrate should not be used (Ranken, 1978).

Brines used in rapid curing processes typically contain 24–25% salt by weight, as in a Wiltshire brine. With, say, 10% weight uptake in the injection process, this will give about 2.5% salt in the bacon. Similarly, 0.2% sodium nitrite in the brine will give bacon theoretically containing 200 $mg\,kg^{-1}$ (in practice about 100–150 $mg\,kg^{-1}$) salt.

These developments probably reached their peak in the slice curing process which was operated commercially for some years in the UK. This gave bacon of good uniform composition by dipping individual pork slices in a brine of appropriate composition. Satisfactory product was obtained in a few hours, less time than was required to distribute and sell it in pre-packed form. Unfortunately the handling of individual slices detracted from the neatly shingled appearance that customers expected in pre-packed bacon and the process is not now operated commercially.

Sweet cures

Any of the cures described above may be modified by the addition of sugar, honey or other sweet substances. The sweetness modifies the sharp taste of the salt and is liked by consumers for that reason. If significant amounts of reducing sugars are present, as in honey or liquid glucose, brown colours and strong flavours will be produced by Maillard reactions during cooking and are favoured by some consumers. Reducing sugars also favour the formation of the red cured meat colours in the uncooked bacon and are of minor value for that reason. 0.25% sugar in the final product is typical.

BEEF

Beef intended as butchers' meat, to be served as grills, roasts and the like, comes on the whole from male animals. The most plentiful hindquarter meat actually comes from the so-called 'heavy' breeds of cattle developed specially for that purpose—traditionally Aberdeen Angus and Hereford for example, but more recently the 'modern' breeds such as Charolais or Belgian Blue—and in these breeds the females as well as the males are used for beef meat. Otherwise the male beef animals are produced alongside the requirements for milk production from the females. 'Dual purpose' breeds such as Shorthorn and Red Poll, or the beef/dairy cross-breeds widely farmed in Britain, provide the most economical means of meeting both kinds of requirement. The meat, like the animal, where male, is referred to as 'bull' or 'bullock' according to age, 'steer' if castrated.

Beef for manufacturing purposes consists partly of the forequarter meat from the beef animals noted above, but the major part comes from the carcasses of milk cattle at the end of their economic lives as milk producers, at five to eight years of age. The meat is known as 'cow beef'.

Milk production is a sequel to calving. The male calves and many of the females are surplus to requirements for replacement of the milk cattle and provide veal calves at three to four months, or 'bobby veal' at under three months.

BRITISH FRESH SAUSAGE

See SAUSAGE.

BURGERS

In Britain this has become the generic name for raw meat patties with high content of lean meat.

Originally the name derives from the German Hamburger sausage, made of beef and commonly cut into thick slices before consumption, but in English usage any other meat may be substituted for the 'Ham' part of the German city. So we have beefburgers, porkburgers and even baconburgers.

In North America a hamburger is made with 100% beef, with about 20% fat content. In Britain this product is also common, especially in American-style fast food outlets. Other burgers are made containing 90%, 80% or less of beef, the balance being made up with rusk and water.

The meat is prepared by mincing or flaking. A little salt may be added, with the other ingredients if required, and the whole mixed under carefully controlled conditions: the degree of comminution and mixing very largely control the cohesive properties and the eating qualiy of the finished burger. The mixture is then fed to a patty-former or burger press, and either pressed or extruded into the required shape. In some of these machines there is a tendency to orient the fibres of the meat in one direction, which may lead to differential shrinkage on cooking and consequent distortion of the patties. This may be overcome, in the case of patties intended to be circular, by forming them slightly elliptical in the first place.

Maintenance of the desirable bright red colour of beefburgers sometimes causes problems, especially with frozen burgers. The cause of the trouble is frequently traceable either to defective microbiological quality of the meat or other ingredients or to oxidative rancidity in the fat which promotes browning of the meat pigments.

CASINGS

Natural casings

Natural casings are processed from various parts of the alimentary tract of cattle, hogs or sheep. The types and amounts available are approximately as follows:

	Small intestine 'Rounds' or 'runners'		Large intestine 'Middles' and 'bungs'	
	Length per animal (m)	Diameter (mm)	Length per animal (m)	Diameter (mm)
Cattle	36–40	36–46	9–12	45–60
Sheep	22–47	18–26	5–6	*
Pig	17–19	32–42	4–5	40–45

* Not usually used for casings, but sheep stomachs are used as casings for haggis.

These may be used as casings for sausages of various kinds, from chipolatas to large bologna types, according to diameter. About 1% of the sausage weight consists of casing.

Casings are normally packed in salt. Before use they should be thoroughly soaked and washed in lukewarm water, about 29–32°C (85–90°F). Too high a temperature is liable to ruin the texture of the casings, which may burst on subsequent filling. After washing the casings should be kept wet at all times until they are filled.

The production and use of natural casings has diminished greatly in Western countries, as they have tended to be replaced with the more hygienic and more easily controllable artificial varieties. Some smaller manufacturers still prefer to use them.

Artificial casings

The advantages of artificial casings over natural casings lie in their uniformity of size, the absence of risk of contamination from improper preparation and the ability in most cases to be used without preliminary washing, soaking etc. They are of several types.

Cellulose casings. These are made from cotton fibre or wood pulp, chemically dissolved, regenerated and extruded in the form of continuous tubing. The smaller diameters are widely used in the manufacture of skinless sausages. The raw sausage mix is filled into the cellulose casing in the usual way, then the surface of the sausage is cooked by scalding to a temperature of about 80°C (175°F) which produces a firm coagulated layer below the casing. The casing is cut lengthwise and peeled off mechanically, leaving the sausage skinless. For 'scalded' sausages of which the Frankfurter is typical, the scalding time is made long enough to cook the sausage right through, or the cooking is completed in a later stage, for instance if the product is canned.

Large-diameter casings usually require to be soaked in water before use. They are used for a variety of bologna and large sausage types, which are sold with the casing intact, though it is removed before consumption.

Fibrous cellulose casings. These are cellulose casings containing cellulose fibre for additional strength and are used for slicing sausage. They require to be soaked before use.

Collagen casings. These are made by a solution and chemical regeneration process similar in principle to the cellulose process, but the starting material is animal collagen, usually in the form of

cattle hides. They may be coloured for special purposes.

Reconstituted collagen casings have now very largely replaced natural casings for most ordinary sausage manufacture in medium- to large-sized establishments, because of their convenience in use and consistency of performance. Their behaviour in other respects is similar to that of the natural casing.

CHILLING AND COOLING

It is always important that warm food which is not intended for immediate consumption should be cooled as rapidly as possible.

When an animal has been slaughtered and dressed, the remaining body heat of the carcass should next be removed in an efficient chiller. Some of the complications which may arise if this chilling is carried out excessively rapidly have already been discussed (see AGEING), but too-rapid chilling only occurs in rather exceptional circumstances. The more usual problem is that the chilling is not done sufficiently, rapidly or thoroughly, and that the microbiological condition of the meat suffers accordingly. The proceedings of a conference organized by the Meat Research Institute, Langford, Bristol, in 1972, published as *Meat Chilling—Why and How?* (Cutting, 1972), despite subsequent advances in detail, remains an excellent general summary of the subject.

Meat products which have been cooked or otherwise processed in a warm state also require to be cooled as rapidly as possible. Sausages which may emerge warm from the chopping operation, and which tend to remain warm during filling and packing, may be passed through a continuous chilling unit to bring them to a centre temperature in the region of 0–4°C (32–39°F). With freshly-baked pies, efficient chilling is even more important, partly because the temperature after baking is higher and it may therefore take longer for the available heat to be removed, partly because of the high probability of mould growth inside the pie or within the wrapping of the pie if conditions in those confined spaces remain warm and moist. Pies may be allowed to cool initially in the atmosphere, to bring their temperature down to near the ambient temperature, but the cooling should where possible be completed in a chiller using cold, filtered air. Alternatively, vacuum cooling units may be used. These are batch chambers into which racks of warm pies may be put, the door closed and a vacuum drawn. The vacuum causes the evaporation of some of the moisture in the pies, and the loss of latent heat by evaporation reduces the temperature very rapidly. The process is efficient, but the capital cost is high. The loss in weight resulting from evaporation can be allowed for in the original formulation of the pies.

It should be noted that the specifications for the performance and design of chilled stores and frozen stores usually make the assumption that the goods going into stores have been properly chilled beforehand. If this is not done, an extra burden will be placed on the refrigeration equipment, for which it was not designed, and the overall performance of the store will be adversely affected.

COLOUR

Colour of fresh meat

(1) Colour of lean. The colour of lean meat varies with the species, the age of the animal and with the cut of meat. These differences are related to differences in the concentration of the pigment myoglobin which is present in the muscles. Myoglobin is a large molecule consisting of a protein part (the globin) linked to a porphyrin ring structure containing an iron atom (the haem part). Its concentration is higher in beef than in pork, and higher in old cow beef than in veal. There are also differences in the form in which the myoglobin is present. The bright red outer surface colour of fresh meat is due to oxymyoglobin, the oxygenated form which exists in the presence of plentiful oxygen, in this case in the air around the meat. Where oxygen is absent, as in the centre of the meat or in a vacuum pack, the pigment is in the reduced form, often called just 'myoglobin', which is a deep purple-red in colour. Between these two colours there is found a brown layer, due to the oxidized form of the pigment, called metmyoglobin. This colour is more stable than the others and is formed where the oxygen concentration is positive but small. It therefore tends to accumulate as the oxygen concentration gradient in the meat alters due to consumption of oxygen by metabolic processes and by any microbial growth within the meat mass. So as the meat becomes older, its colours becomes duller because of the increasing brown layer below the surface.

The colour is further influenced by the post-mortem history of the meat. A high ultimate pH is associated with muscles with a closed structure, holding large quantities of water, appearing swollen and tightly packed. This muscle scatters relatively little of the incident light and appears dark red. At the other extreme is muscle with low pH,

or ultimate pH reached quickly, where some of the protein is denatured, the structure is more open and the meat appears pale and wet.

It is not possible to do much about pale or dark colours resulting from the post-mortem conditions (see under POST-MORTEM CHANGES), but the chemical changes of the pigments can be influenced to some extent. In pre-packaging of fresh meat it is essential to select packaging materials with as high a permeability to oxygen as possible, to ensure maximum retention of the surface oxymyoglobin. On the other hand, reducing agents can slow down the rate of formation of the oxidized met-myoglobin and so delay the onset of the unacceptable brown colour. Ascorbic acid or ascorbates applied to the meat surface can give an extra day of apparent shelf life under normal storage conditions, but this is usually held to be to the detriment of the consumer, since the microbiological deterioration of the meat continues during the period when the colour appears to be satisfactory. The addition of ascorbates to fresh meat is prohibited in the UK under the Meat Treatment Regulations, 1964. Sulphur dioxide has a similar effect on the meat pigments, but also has a preservative action against any microbial infection. It is not permitted in fresh meat but is permitted in sausages and burgers in the UK, as also are ascorbates.

The addition of oxidizing agents to the meat promotes the formation of met-myoglobin. One very common case is the accidental contamination of fresh meat or a fresh meat product with traces of sodium nitrite. This can turn sausages brown or grey almost instantaneously. Chlorine-based cleaning agents may have a similar effect.

(2) Colour of fat. Beef, mutton and poultry fats may be of various shades from white to deep yellow. The yellow colour is due to carotenoids in the diet. In beef and mutton, and in poultry in some countries, it is considered objectionable, although it has no effect on palatability. Yellow fat in beef usually indicates old age or a dairy herd. When cows undergo a period of lower nutrition the fat depots are depleted, but the carotenoids remain behind. They consist of a mixture of the grass pigments carotene and xanthophylls, the carotene predominating. The majority of sheep have colourless fat, but in some countries including Iceland and New Zealand, a small number of sheep have yellow fat due to exclusive deposition of grass xanthophylls, predominantly lutein, lutein-5:6-epoxide and flavoxanthin. Chickens respond markedly to the carotene content of their diet and in countries such as the UK where white-skinned birds, with white body fat and leg scales, are preferred, care must be taken to control the use of grass meal or 'yellow' varieties of cereals in the feed.

Cured meat colour

The colour of cured meats is due to the pigment nitrosyl myoglobin or nitroso-myoglobin, formed from nitrite salts added or formed during the curing process. Nitric oxide is formed from the nitrite and combines with myoglobin in the meat. In the undenatured form, as in uncooked, unpasteurized bacon or raw dry sausage, the pigment is a deep red colour. On heating, this is converted into a pink colour in which the protein is denatured. This is the colour of ham, canned luncheon meats or frankfurters. The red, undenatured, pigment is relatively unstable to air, becoming oxidized to brown met-myoglobin. It is not stabilized by the presence of ascorbate; on the contrary, at moderate ascorbate concentrations in the presence of air it may be completely destroyed. It is best preserved by vacuum packing or, in the case of unpacked bacon, by leaving the meat intact and unexposed to the air for as long as possible. The pink, denatured, pigment on the other hand is less unstable to air but is very sensitive to light: it is, however, significantly stabilized by the presence of moderate concentrations of ascorbate. Ascorbate is commonly added to the curing mixtures for this class of product. Vacuum packaging is helpful for reasons other than colour stability, but care should be taken to minimize exposure of the packed product to light, especially to intense display illumination.

In all cured meats the stability of the cured colour is assisted by the presence of residual nitrite in the product. The movement in recent years to keep nitrite levels as low as possible, because of their implication in nitrosamine formation, has made it more difficult to manufacture cured meat products with reliable long-term colour stability, but with careful control of both manufacturing and storage conditions it can be achieved satisfactorily.

Colour of cooked meat

The brown colour of cooked uncured meat is due to a heat-denatured myoglobin or haemichrome, in which the links between the haem part of the molecule and the protein part become rearranged and even randomized during the denaturation. The colour is relatively stable, but fades on long exposure to air and light. The heat denaturation of the globin usually takes place at temperatures close to 68°C (at which the meat can be considered microbiologically safe to eat), but the exact temperature may vary somewhat. One problem,