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FOOD PROCESSING TECHNOLOGY

Principles and Practice

Second Edition

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For Wen

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PART III PROCESSING BY APPLICATION OF HEAT

A. Heat processing using steam or water

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Glossary

Absorption	Uptake of moisture by dry foods.
Acid food	A food with a pH of less than 4.6 and a water activity (a_w) equal to or greater than 0.85.
Additives	Chemicals added to food to improve their eating quality or shelf life.
Adiabatic	Changes to the humidity and temperature of air without loss or gain of heat (in drying).
Adiabatic process	Processing in which no heat is added or removed from a system.
Adulterants	Chemicals that are intentionally added to food which are forbidden by law.
Agglomeration	The production of granules from powder particles.
Algorithms	Software building blocks used to construct control sequences in computerised process control.
Alkaline phosphatase	An enzyme in raw milk having a similar *D*-value to heat-resistant pathogens, used to test for effectiveness of pasteurisation.
Annealing	Heating to control the ductility of a material.
Aseptic processing	Heat sterilisation of foods before filling into pre-sterilised (aseptic) containers.
Atomiser	A device to form fine droplets of food (e.g. in a spray drier).
Bacteriocins	Naturally produced peptides that inhibit other micro-organisms, similar in effect to antibiotics.
Baroresistance	Resistance to high pressure.
Barosensitivity	Sensitivity to high pressure.
Biological oxidation demand (BOD)	A measure of the oxygen requirement by micro-organisms when breaking down organic matter, used as a measure of the polluting potential of materials in water.
Black body	A theoretical concept for a material that can either absorb all the heat that lands on it or radiate all of the heat that it contains.
Blancher	Equipment used to blanch foods.
Blanching	Heating foods, especially vegetables, to below 100ºC for a short time, to both inactivate enzymes which would cause a loss of quality during storage and to remove air and soften the food.
Blinding	Blocking of a sieve by food particles.

Bloom	A thin layer of unstable forms of cocoa fat that crystallise at the surface of a coating to produce dullness or white specks.
Botulin	An exotoxin produced by *Cl. Botulinum*, able to cause fatal food poisoning.
Bound moisture	Liquid physically or chemically bound to a solid food matrix which exerts a lower vapour pressure than pure liquid at the same temperature.
Boundary film (or surface film)	Film of fluid next to the surface over which a fluid flows that causes a resistance to heat transfer.
Breading	The application of pre-prepared breadcrumbs to the surface of a food.
Calandria	Heat exchanger used in an evaporator.
Carborundum	An abrasive material made from silicon and carbon.
Case hardening	Formation of a hard impermeable skin on some foods during drying, which reduces the rate of drying and produces a food with a dry surface and a moist interior.
Cashflow	The balance of money at a given time entering and leaving a business.
Cavitation	Production of bubbles in foods by ultrasound and their rapid expansion/contraction.
Centrifugation	The separation of immiscible liquids or solids from liquids by the application of centrifugal force.
Chelating agents	Chemicals which sequester trace metals.
Chemical oxidation demand (COD)	A chemical method used to measure the polluting potential of materials in water.
Chilling	Reduction in the temperature of a food to between −1ºC and 8ºC.
Chilling injury	Physiological changes to some types of fruits and vegetables caused by low temperatures which result in loss of eating quality.
Choke	Restriction of the outlet to a mill to retain particles until sufficiently small (or restriction of the outlet in an extruder).
Climacteric	Abrupt increase in respiration rate in some fruits during ripening.
Clinching	Partial sealing of can lids.
Coating	A generic term to describe the application of a viscous covering (such as batter, chocolate, starch/sugar mixtures) to the surface of a food.
Co-extrusion	The simultaneous extrusion of two or more films to make a co-extruded film or the extrusion of two foods in which a filling is continuously injected into an outer casing in an extruder.
Cold shortening	Undesirable changes to meat caused by cooling before rigor mortis has occurred.
Collapse temperature	The maximum temperature of a frozen food before solute movement causes a collapse of the food structure and prevents movement of water vapour during freeze drying.
Commercial sterility	A term used in heat sterilisation to indicate that processing inactivates substantially all micro-organisms and spores which, if present, would be capable of growing in the food under defined storage conditions.
Common Object Resource Based Architecture (CORBA)	Computer software that acts as an information broker to link process control systems with other computerised company information.
Compound coating	A coating material in which cocoa solids and hardened vegetable oils are used to replace cocoa butter.
Conduction	The movement of heat by direct transfer of molecular energy within solids.
Constant-rate drying	The drying period in which the rate of moisture loss is constant when surface moisture is removed.
Continuous phase	The medium that contains the dispersed phase in an emulsion.

Convection	The transfer of heat in fluids by groups of molecules that move as a result of differences in density or as a result of agitation.
Critical control point (CCP)	A processing factor of which a loss of control would result in an unacceptable food safety or quality risk.
Critical moisture content	The amount of moisture in a food at the end of the constant-rate period of drying.
Crumb	Pre-prepared breadcrumbs used to cover food pieces, or the porous inner part of baked foods.
Crust	Hard surface layer on baked foods.
Cryogen	A refrigerant that absorbs latent heat and changes phase from solid or liquid to a gas, e.g. subliming or evaporating carbon dioxide or liquid nitrogen.
Cryogenic freezers	Equipment that uses subliming or evaporating carbon dioxide or liquid nitrogen directly in contact with food to freeze it.
Cryogenic grinding	Mixing liquid nitrogen or solid carbon dioxide with food to cool it during grinding.
Dead-folding	A crease or fold made in a material that will stay in place.
Decimal reduction time	The time needed to destroy 90% of micro-organisms (to reduce their numbers by a factor of 10).
Depositor	Machine for placing an accurate amount of food onto a conveyor or into a mould.
Desorption	Removal of moisture from a food.
Detergents	Chemicals that reduce the surface tension of water and hence assist in the release of soils from equipment or foods.
Dew point	Temperature at which an air–water vapour mixture becomes saturated with moisture, marking the onset of condensation.
Diafiltration	A process to improve the recovery of solutes by diluting the concentrate during reverse osmosis or ultrafiltration.
Die	A restricted opening at the discharge end of an extruder barrel.
Dielectric constant	The ratio of the capacitance of a food to the capacitance of air or vacuum under the same conditions.
Dielectric heating	A generic term that includes heating by both microwave and radio frequency energy.
Dilatant material	Food in which the consistency increases with shear rate.
Direct heating ovens	Ovens in which products of combustion are in contact with the food.
Dispersed phase	Droplets in an emulsion.
Dosimeter	A device that qualitatively or quantitatively measures the dose of irradiation received by a food.
Dry bulb temperature	Temperature measured by a dry thermometer in an air–water vapour mixture.
Effective freezing time	The time required to lower the temperature of a food from an initial value to a pre-determined final temperature at the thermal centre.
Electrical conductivity	The capacity of a material to conduct electricity.
Electrodialysis	The separation of electrolytes into anions and cations by the application of a direct electrical current and the use of ion-selective membranes.
Emulsification	Creation of an emulsion by the dispersion of one immiscible liquid (dispersed phase) in the form of small droplets in a second immiscible liquid (continuous phase).
Emulsifying agent	Chemical that forms micelles around each droplet in the dispersed phase of an emulsion to reduce interfacial tension and prevent droplets from coalescing.
Enrobing	The unit operation in which food pieces are coated with chocolate or other materials.

Entrainment	Oil droplets that are carried over in steam produced by vigorously frying foods, leading to loss of oil, or loss of concentrated droplets of product with vapour during evaporation by boiling.
Equilibrium moisture content	The moisture content of a food at which it neither gains nor loses moisture to its surroundings (at a given temperature and pressure, the food is in equilibrium with the air vapour mixture surrounding it).
Equilibrium relative humidity	Relative humidity of the storage atmosphere in equilibrium with the moisture content of food.
Eutectic temperature (in freezing)	The temperature at which a crystal of an individual solute exists in equilibrium with the unfrozen liquor and ice.
Exhausting	Removal of air from a container before heat processing.
Expeller	A horizontal barrel, containing a helical screw, used to extract oil from seeds or nuts.
Expression	The separation of liquids from solids by applied pressure.
Extractors	Equipment used to extract food components using solvents.
Extruder	One or more screws rotating in a barrel with restricted apertures at the discharge end, used for producing extruded foods.
Extrusion	A process that involves the combination of several unit operations including mixing, cooking, kneading, shearing, shaping and forming to produce extruded foods.
F-value	The time required to destroy a given percentage of micro-organisms at a specified reference temperature and *z* value.
Falling-rate drying	The drying period in which the rate of moisture loss declines.
Feedback control	Automatic control of a process using information from sensors to adjust processing conditions.
Feed-forward control	Comparison of processing conditions with a model system, used in automatic process control.
Field heat	Heat within crops when they are harvested.
Filter cake	Solids removed by filtration.
Filter medium	Porous material through which food is filtered.
Filtrate	The liquor remaining after solids are removed by filtration.
Filtration	The separation of solids from liquids by passing the mixture through a bed of porous material.
Final eutectic temperature (in freezing)	The lowest eutectic temperature of solutes in equilibrium with unfrozen liquor and ice.
Flash pasteurisation	Heat treatment involving temperature greater than 72ºC for 15 s for milk. (Also known as higher-heat shorter-time processing.)
Flash-over	Arcing of electricity between electrodes without heating taking place.
Fluence	Energy imparted by light to the surface of a material.
Flux	Flow of liquid through reverse osmosis or ultrafiltration membranes.
Foam	A colloidal system with a liquid or solid continuous phase and a gaseous dispersed phase.
Forming	Moulding of doughs and other materials into different shapes.
Fouling	Deposits of food or limescale on surfaces of heat exchangers.
Free moisture	Moisture in excess of the equilibrium moisture content at a particular temperature and humidity, and so free to be removed.
Freeze concentration	Concentration of liquid foods by freezing water to ice and removal of ice crystals.
Freeze drying	Dehydration of food by freezing water to form ice, followed by removal of ice by sublimation.
Freezing plateau	The period during freezing when the temperature of a food remains almost constant as latent heat of crystallisation is removed and ice is formed.

Friability	The hardness of a food and its tendency to crack.
Grading	The assessment of a number of attributes to obtain an indication of overall quality of a food.
Grey body	A concept used to take account of the fact that materials are not perfect absorbers or radiators of heat.
Half-life	The time taken for an isotope to lose half of its radioactivity.
Hazard analysis	The identification of potentially hazardous ingredients, storage conditions, packaging, critical process points and relevant human factors which may affect product safety or quality.
Headspace	The space in a container between the surface of a food and the underside of the lid.
Heat sterilisation	Destruction of the majority of micro-organisms in a food by heating.
Hermetically-sealed container	A package that is designed to be secure against entry of micro-organisms and maintain the commercial sterility of its contents after processing.
Heterofermentative micro-organisms	Micro-organisms that produce more than one main metabolic product.
Homofermentative micro-organisms	Micro-organisms that produce a single main byproduct.
Homogenisation	The reduction in size and increase in number of solid or liquid particles in the dispersed phase.
Humectants	Chemicals (e.g. salt, sugar, glycerol) that are able to lower the water activity in a food by depressing the vapour pressure.
Hydrocooling	Immersion of fruits and vegetables in chilled water.
Hydrophile-lipophile balance (HLB value)	The ratio of hydrophilic to hydrophobic groups on the molecules of an emulsifier.
Hygroscopic foods	Foods in which the partial pressure of water vapour varies with the moisture content.
Hydrostatic head	The pressure resulting from the weight of a column of liquid.
Hyperfiltration	Reverse osmosis.
Impact strength	The force required to penetrate a material.
Indirect heating ovens	Ovens in which heat from combustion is passed through a heat exchanger to heat air which is then in contact with the food.
Inventory	The stored accumulation of materials in an operation.
Ion exchange	The selective removal of charged molecules from a liquid by electrostatic adsorption, followed by their transfer to a second liquid using an ion-exchange material.
Ionisation	Breakage of chemical bonds (e.g. during irradiation).
Irradiation	The use of γ-rays to preserve foods by destruction of micro-organisms or inhibition of biochemical changes.
Isostatic	Uniform pressure throughout a food.
Isotope	A source of γ-rays from a radioactive material such as cobalt-60 or caesium-137.
Just-in-time	Management system in which goods are ordered as they are required and stocks are not held in warehouses.
Kinetic energy	Energy due to motion.
Lamination	Bonding together of two or more packaging films, papers or foods.
Latent heat	Heat taken up or released when a material undergoes a change of state.
Leaching	Washing out of soluble components from the food.
Lethality	Integrated effect of heating temperature and time on micro-organisms.
Loss factor	A measure of the amount of energy that a material will dissipate when subjected to an alternating electric field (in microwave and dielectric heating). (Also termed the ‘dielectric loss’ or ‘loss tangent’.)

Low acid food	A food with a pH greater than 4.6 and a water activity (a_w) equal to or greater than 0.85.
Manufacturing resource planning	Computer-based systems used to control distribution networks by using forecasted demand for and actual orders to assist management decisions.
Material requirement planning	A single integrated computer system, containing a database that can be accessed by all parts of the company for management planning.
Mechanical refrigerators	Equipment which evaporates and compresses a refrigerant in a continuous cycle, using cooled air, cooled liquid or cooled surfaces to freeze foods.
Metallisation	A thin coating of aluminium on plastic packaging.
Microfiltration	A pressure-driven membrane process using membranes with a pore size of 0.2–2 μm at lower pressures than ultrafiltration.
Microwaves	Energy produced commercially at frequencies of 2450 MHz for domestic ovens, 896 MHz for industrial heating in Europe and 915 MHz for industrial heating in the USA.
Mimetics	Low calorie fat substitutes.
Mimic panel	A graphical display of a process.
Moulders	Machines that form dough or confectionery into different shapes.
Multiple effect	The re-use of vapour from boiling liquor in one evaporator as the heating medium in another evaporator operating at a lower pressure.
Nanofiltration	A membrane process to separate particles with molecular weights from 300–1000 Da, using lower pressures than reverse osmosis.
Neural networks	Computer systems that are able to analyse complex relationships in a process and 'learn' from experience.
Nip	The gap between rollers in a mill or a moulding/forming machine.
Nominal freezing time	The time between the surface of the food reaching 0ºC and the thermal centre reaching 10ºC below the temperature of the first ice formation.
Non-hygroscopic foods	Foods that have a constant water vapour pressure at different moisture contents.
Non-Newtonian liquid	Food in which the viscosity changes with rate of shear.
Nucleation	The formation of a nucleus of water molecules that is required for ice crystal formation.
Ohmic heating	Direct electrical heating of foods.
Overall heat transfer coefficient (OHTC)	The sum of the resistances to heat flow due to conduction and convection.
Panning	The process of building up thin layers of sugar, sweetener or other coatings in a controlled way onto solid cores of nuts, fruit, etc.
Pasteurisation	A relatively mild heat treatment in which food is heated to below 100ºC to preserve it without substantial changes to sensory characteristics or nutritional value. In low acid foods, the main reason for pasteurisation is destruction of pathogens.
Pinholes	Small holes in can seams or flexible packaging.
Plasticiser	Chemicals added to plastic films to make them more flexible.
Polymorphic fat	A fat that can crystallise into more than one form.
Potential energy	Energy due to position of an object.
Preforms	Small dense pellets made in an extruder from pre-gelatinised cereal dough, which are suitable for extended storage until they are converted to snackfoods by frying, toasting or puffing. (Also known as 'half-products'.)
Press cake	Solid residue remaining after extraction of liquid component from foods.
Process inter-locking	Linking different parts of a process so that one cannot operate until a

	second is correctly set up.
Programmable logic controllers (PLCs)	A microcomputer that is used in process control to replace electrical relays and to collect and store process data.
Pseudoplastic material	Food in which the viscosity decreases with increasing shear rate.
Psychrometrics	The study of inter-related properties of air–water vapour systems.
Radiation	The transfer of heat by electromagnetic waves.
Radio frequency energy	Energy produced commercially at frequencies of 13.56 MHz, 27.12 MHz or 40.68 MHz for industrial heating.
Radiolysis	Changes to a food material caused by ionising radiation to produce chemicals that destroy micro-organisms, etc.
Recrystallisation	Physical changes to ice crystals (changes in shape, size or orientation) which are an important cause of quality loss in some frozen foods.
Redox potential	Oxidation/reduction potential of a food or microbial substrate.
Refrigerant	A liquid that has a low boiling point and high latent heat of vaporisation so that it can change phase and absorb or lose heat in a refrigerator.
Refrigerators	Equipment that evaporates and compresses a refrigerant in a continuous cycle, using cooled air, cooled liquid or cooled surfaces to freeze foods.
Relative humidity	The ratio of the partial pressure of water vapour in air to the pressure of saturated water vapour at the same temperature, multiplied by 100.
Respiration	Metabolic activity of living animal or plant tissues.
Retort	A pressurised vessel used to heat foods above 100ºC during canning.
Reverse osmosis	Unit operation in which small molecular weight solutes (with molecular weights of approx. 100 DA) are selectively removed by a semi-permeable membrane under high pressure.
Screen	A sieve.
Sensible heat	Heat used to raise the temperature of a food or removed during cooling, without a change in phase.
Sequence control	A type of process control in which the completion of one operation signals the start of the next.
Soils	A generic term used for all types of contaminating materials on foods or equipment.
Sorption isotherm	A curve produced from different values of relative humidity plotted against equilibrium moisture content.
Sorting	The separation of foods into categories on the basis of a measurable physical property.
Specific electrical resistance	Electrical resistance of a food between two 1 cm^2 electrodes that are located 1 cm apart (i.e. the resistance of 1 cm^3 of product), having units of ohms cm^{-2} cm^{-1}.
Specific growth rate	The slope of the curve when the natural logarithm of microbial cell concentration is plotted against time.
Specific heat	The amount of heat that accompanies a unit change in temperature by a unit mass of material.
Stabilisers	Hydrocolloids that dissolve in water to form viscous solutions or gels.
Steady-state heat transfer	Heating or cooling when there is no change in temperature at any specific location.
Sterilants	Chemicals that inactivate micro-organisms.
Streamline (or laminar) flow	Flow of liquids in layers without significant mixing between layers.
Sublimation	A change in state of water directly from ice to water vapour without melting.
Substrate	A growth medium for micro-organisms.

Supercooling	A phenomenon in which water remains liquid although the temperature is below its freezing point.
Supercritical carbon dioxide	Liquid CO_2 used to extract food components.
Supervisory Control and Data Acquisition (SCADA)	A type of computer software that collects data from programmable logic controllers and displays it as graphics to operators in real-time.
Surface heat transfer coefficient	A measure of the resistance to heat flow caused by a boundary film of liquid.
Susceptor	A packaging material that is used to create a localised high temperature in microwave ovens; usually made from lightly metallised polyethylene terephthalate.
Tempering	Cooling food to close to its freezing point, or a process of re-heating, stirring and cooling chocolate to remove unstable forms of polymorphic fats.
Tensile elongation	A measure of the ability to stretch.
Tensile strength	The force needed to stretch a material.
Thermal centre	The point in a food that heats or cools most slowly.
Thermal conductivity	A measure of the heat transfer properties of solid materials.
Thermal death time (TDT) or *F*-value	The time required to achieve a specified reduction in microbial numbers at a given temperature.
Thermal diffusivity	The ratio of thermal conductivity of a product to specific heat, multiplied by the density.
Thermal shock	Heating: fracture to a glass container caused by rapid changes in temperature; freezing: a rapid reduction in temperature that causes foods to fracture.
Ultra high temperature (UHT)	Processing heat sterilisation at above 135ºC for a few seconds.
Ultrafiltration	Unit operation in which solutes having molecular weights in the range of 1–200 kDA are selectively removed using a semi-permeable membrane operating at lower pressure than reverse osmosis.
Ultrasonication	Treatment of foods using ultrasound.
Unitised loads	Grouping of packages into larger loads.
Usage value	The rate of usage of individual materials in an inventory multiplied by their individual value.
Unsteady-state heat transfer	Heating or cooling where the temperature of the food and/or the heating or cooling medium are constantly changing.
Venting	Removal of air from a retort before heat processing.
Viscoelastic material	Food materials which exhibit viscous and elastic properties including stress relaxation, creep and recoil.
Voidage	The fraction of the total volume occupied by air (the degree of openness) of a bed of material in fluidised-bed drying.
Water activity	The ratio of vapour pressure of water in a solid to that of pure water at the same temperature.
Web	A packaging film.
Wet bulb temperature	Temperature measured by a wet thermometer in an air–water vapour mixture.
Yield	Weight of food after processing compared to weight before processing.
Young's modulus	(also modulus of elasticity) = stress/strain and is a measure of the hardness of a material.

Symbols

A	Area
a	Thermal diffusivity
a	Throttling factor (extrusion)
a_w	Water activity
B	Time of heating (canning)
Bi	Biot number
b	Permeability
b	Slope of sorption isotherm
C_d	Drag coefficient (fluid dynamics)
c	Concentration
c	Internal seam length (canning)
c	Specific heat capacity
c_p	Specific heat at constant pressure
D	Diameter (pipe, vessel)
D	Dilution rate (fermentation)
D	Decimal reduction time
D	Diffusion coefficient
d	Diameter (sphere, size of sieve aperture)
d	Differential operator
E	Electrical field strength
E	Energy (size reduction, radio frequency heating)
F	Feed flow rate (sorting, fermentation)
F	F-value (canning)
F	Shape factors (extruders)
Fr	Froude number
f	Slope of heat penetration curve (canning)
f	Frequency (microwaves)
G	Geometric constants (extruders)
G	Air mass flowrate (dehydration)
g	Acceleration due to gravity (9.81 m s^{-2})
g	Retort temperature minus product temperature (canning)
H	Humidity

h	Heat transfer coefficient
h_c	Convective heat transfer coefficient
h_s	Surface heat transfer coefficient
I	Light intensity
I	Electrical current
I_h	Retort temperature minus product temperature (canning)
J	Flux (membrane concentration)
j	Heating/cooling factor (canning)
K	Mass transfer coefficient (dehydration, membrane concentration)
K	Constant
K_k	Kick's constant (size reduction)
K_R	Rittinger's constant (size reduction)
K_s	Substrate utilisation constant (fermentation)
k	Thermal conductivity
L	Length
L	Equivalent thickness of filter cake
l	Come-up time (canning)
M	Moisture content, dry-weight basis
M	Molar concentration
m	Mass
m	Mass flow rate
m	Moisture content (wet-weight basis)
N	Speed
N	Rate of diffusion
Nu	Nusselt number
n	Number
P	Pressure
P	Product Row rate (sorting)
P	Power
P	Productivity (fermentation)
Po	Power number (mixing)
Po	Vapour pressure of pure water
Q	Rate of heat transfer
Q	Volumetric flowrate
q_p	Specific rate of product formation (fermentation)
R	Universal gas constant
R	Reject flowrate (sorting)
R	Resistance to flow through a filter
R	Fraction of reflected light (packaging)
R	Electrical resistance
Re	Reynolds number
r	Radius
r	Specific resistance to flow through a filter
S	Substrate concentration (fermentation)
s	Compressibility of filter cake
T	Absolute temperature
T	Fractional transmission of light (packaging)
t	Time
t	Metal thickness (canning)
U	Overall heat transfer coefficient
U	Thermal death time at retort temperature (canning)
V	Volume
V	Voltage

V_c	Fractional volume of filter cake
v	Velocity
v_e	Air velocity needed to convey particles
v_f	Air velocity needed for fluidisation
W	Work index (size reduction)
x	Thickness, depth
x	Direction of heat flow
$\underline{x}$	Mass fraction
$\bar{x}$	Average
y	Cover hook length (canning)
Y	Yield or yield factor (fermentation)
z	Height
z	z-value (canning)
α	Absorbance, absorptivity
β	Coefficient of thermal expansion
Δ	Difference, change
δ	Half dimension
$\tan\delta$	Loss tangent (microwaves)
ϵ	Porosity
ϵ	Voidage of fluidised bed
ϵ	Emmisivity (infrared radiation)
ϵ'	Dielecric constant (microwaves)
ϵ''	Loss factor (microwaves)
θ	Temperature
λ	Latent heat
λ	Wavelegth
μ	Viscosity
μ	Specific growth rate (fermentation)
Π	Osmatic pressure
π	Constant $= 3.142$
ρ	Density
Σ	Sum
σ	Standard deviation
σ	Electrical conductivity
σ	Stefan-Boltzmann constant (infrared radiation)
ω	Angular velocity

Acronyms

AGV	Automatically guided vehicle
AQL	Acceptable quality limit
CAP	Controlled atmosphere packaging
CAS	Controlled atmosphere storage
CBE	Cocoa butter equivalent
CIP	Cleaning in place
CCP	Critical control point
CFC	Chlorofluorocarbon
CORBA	Common Object Resource Based Architecture
DCS	Distributed control systems
DDE	Dynamic data exchange
EDI	Electronic data interchange
EMA	Equilibrium modified atmosphere
EPSL	Edible protective superficial coating
ESR	Electron spin resonance
GEP	Gas exchange preservation
GMP	Good manufacturing practice
HACCP	Hazard analysis critical control point
HLB	Hydrophile-lipophile balance
HTST	High-temperature short-time
IBC	Intermediate bulk container
IQF	Individual quick frozen/freezing
JIT	Just in time
MAP	Modified atmosphere packaging
MAS	Modified atmosphere storage
MRP	Material resource planning
NMR	Nuclear magnetic resonance
NVDP	Non-volatile decomposition products
OLE	Object linking and embedding
ODBC	Open data base connectivity
OPC	Object linking and embedding for process control
PAM	Passive atmosphere modification

PCS	Process control system
PLC	Programmable logic controller
PPP	Product processing packaging
PSL	Photostimulated luminescence
PSL	Practical storage life
PVdC	Poly vinylidene chloride
RDA	Recommended daily allowance
REPFED	Ready-to-eat-products-for-extended-durability (also refrigerated-pasteurised-foods-for-extended-durability)
SCADA	Supervisory control and data acquisition
TDT	Thermal death time
TQM	Total quality management
TTT	Time temperature tolerance
UHT	Ultra high temperature
VDP	Volatile decomposition products
VOC	Volatile organic compounds
VP	Vacuum packaging
VSP	Vaccum skin packaging
WHO	World Health Organisation
WOF	Warmed over flavour
WTO	World Trade Organisation

Introduction

The food industry today

The aims of the food industry today, as in the past, are fourfold:

1. To extend the period during which a food remains wholesome (the shelf life) by preservation techniques which inhibit microbiological or biochemical changes and thus allow time for distribution, sales and home storage.
2. To increase variety in the diet by providing a range of attractive flavours, colours, aromas and textures in food (collectively known as *eating quality*, *sensory characteristics* or *organoleptic quality*); a related aim is to change the form of the food to allow further processing (for example the milling of grains to flour).
3. To provide the nutrients required for health (termed *nutritional quality* of a food).
4. To generate income for the manufacturing company.

Each of these aims exists to a greater or lesser extent in all food production, but the processing of a given product may emphasise some more than others. For example, frozen vegetables are intended to have sensory and nutritional qualities that are as close as possible to the fresh product, but with a shelf life of several months instead of a few days or weeks. The main purpose of freezing is therefore to preserve the food. In contrast, sugar confectionery and snackfoods are intended to provide variety in the diet, and a large number of shapes, flavours, colours and textures are produced from basic raw materials.

All food processing involves a combination of procedures to achieve the intended changes to the raw materials. These are conveniently categorised as *unit operations*, each of which has a specific, identifiable and predictable effect on a food. Unit operations are grouped together to form a process. The combination and sequence of operations determines the nature of the final product.

In industrialised countries the market for processed foods is changing, and in contrast to earlier years, consumers no longer require a shelf life of several months at ambient temperature for the majority of their foods. Changes in family lifestyle, and increased ownership of freezers and microwave ovens, are reflected in demands for foods that are convenient to prepare, are suitable for frozen or chilled storage, or have a moderate shelf

life at ambient temperatures. There is now an increasing demand by consumers for foods that have fewer synthetic additives, or have undergone fewer changes during processing. These foods more closely resemble the original raw materials and have a 'healthy' or 'natural' image. Correspondingly, growth in demand for organic foods has significantly increased in Europe during the 1990s. These pressures are an important influence on changes that are taking place in the food processing industry, and manufacturers have responded by reducing or eliminating synthetic additives from products (particularly colourants and flavours) and substituting them with natural or 'nature-equivalent' alternatives. They have also introduced new ranges of low-fat, sugar-free or low-salt products in nearly all sub-sectors (Anon., 1999). New products that are supplemented with vitamins, minerals and probiotic cultures (or 'functional' foods) have appeared in recent years, and products containing organic ingredients are now widely available. At the time of writing (2000), a debate over the safety of genetically modified (GM) food ingredients is unresolved. Consumer pressure for more 'natural' products has also stimulated development of novel 'minimal' processes that reduce the changes to sensory characteristics or nutritional value of foods.

Improvements to food quality during the last 10–15 years have also been achieved through changes in legislation, including legal requirements on manufacturers and retailers to display 'due diligence' in protecting consumers from potentially hazardous foods. This has in part arisen from a series of highly publicised cases of food poisoning and food adulteration in Europe during the 1980s and 1990s, and the outbreak of Bovine Spongiform Encephalitis (BSE) in British cattle, which led to public pressure for improved food safety and quality. Legislation is now increasingly international in its focus and application, and international standards for both specific products and also for methods of achieving quality assurance are in force.

Trends that started during the 1960s and 1970s, and accelerated during the last 10–15 years, have caused food processors to change their operations in four key respects. First, there is increasing investment in capital intensive, automated processes to reduce labour and energy costs. Second, there has been a change in philosophy from quality control, achieved by testing final products, to a more sophisticated approach to quality assurance, which involves all aspects of management. Third, high levels of competition and slowing of the growth in the food market in Europe and USA during the 1970s, has caused manufacturers to adopt a more proactive approach to creating demand, using sophisticated marketing techniques and large advertising budgets. Mergers or take-overs of competitors have resulted from the increased competition. Fourth, there has been a shift in power and control of food markets from manufacturers to large retail companies.

The changes in technology have been influenced by a variety of factors: substantial increases in the costs of both energy and labour, by public pressure and legislation to reduce negative environmental effects of processing, particularly air or water pollution and energy consumption. Food processing equipment now has increasingly sophisticated levels of control to reduce processing costs, enable rapid change-overs between shorter production runs, to improve product quality and to provide improved records for management decisions. Microprocessors are now almost universally used to control food processing equipment. The automation of entire processes, from reception of materials, through processing and packaging to warehousing, has become a reality. This requires a higher capital investment by manufacturers but, together with improved quality assurance, reduces production costs and wastage. It increases production efficiency, uses less energy and often fewer operators, and generates increased revenue and market share from products that have higher quality.

The food industry has now become a global industry, dominated by a relatively few multinational conglomerates. Many of the mergers and take-overs that created these companies took place in the 1980s and early 1990s when large companies bought their competitors in order to acquire brand names and increase their market share. In 1988 for example, a total of $42.5 billion was spent on the purchase of just three companies (Rowntree, Kraft and Nabisco) (Giles, 1993). Multinational companies are now focusing on development of new markets and are either buying up or forming alliances with local competitors in South East Asia, India, Eastern Europe and Latin America.

Global sourcing of raw materials and ingredients has been a feature of some industries from their inception (spices, coffee, cocoa are a few examples), but this has now expanded to many more sectors, to reduce costs and ensure continuity of supply. These developments have in turn prompted increased consumer awareness of both ethical purchasing issues, such as employment and working conditions in suppliers' factories, and also environmental issues, such as safeguards in countries which have less developed legislative controls, and the environmental impact of international transportation of foods by air. There has also been a resurgence of consumer interest in locally distinctive foods and 'Fair-Traded' foods in some European countries, but at the time of writing this is confined to higher value niche products.

During the last decade or so, there has been a substantial increase in the power and influence of large retailing companies, especially in the USA and Europe. Much of the change in food quality and choice that has been witnessed during this time has arisen from competition between these retail companies and the pressures that they have exerted on manufacturers. Manufacturers are now responding to the shift in power to supermarkets by forming international strategic alliances with other large manufacturers. This enables them to develop pan-regional economies of scale and to focus on their own core products while sharing the benefits of joint marketing or research and development. They are also promoting 'tele-shopping', especially using the Internet, and developing other types of sales outlets (e.g. at sports or cultural venues) that by-pass existing retailers.

About this book

Heat has important influences on food processing in a number of respects: it is the most convenient way of extending the shelf life of foods by destroying enzymic and microbiological activity, or by removing water to inhibit deterioration; it changes the nutritional and sensory qualities of foods; and generation of heat is a major processing cost. The unit operations described in this book are therefore grouped according to the nature of heat transfer that takes place.

After Part I, which describes some important basic concepts, Part II describes unit operations that take place at ambient temperature and involve minimum heating of foods; Part III includes those operations that heat foods to extend the shelf life or to alter the eating quality; Part IV describes operations that remove heat from foods to extend the shelf life with minimal changes in nutritional qualities and sensory characteristics; the final part, Part V, is concerned with operations that are integral to a food process but are supplementary to the main method of processing.

In each chapter, the theoretical basis of the unit operation is first described. Formulae required for calculation of processing parameters and sample problems are

given where appropriate, and sources of more detailed information are indicated. Details of the equipment used for practical implementation of theoretical concepts are then described, and developments in technology that relate to savings in energy or labour, or to improvement in product quality are noted. Finally the effect of the unit operation on sensory characteristics and nutritional properties of selected foods is described.

This book therefore aims to show how a knowledge of the properties of foods is used to design processing equipment and to control processing conditions on an industrial scale, to achieve the desired aims of altering the eating quality or extending the shelf life, with minimal changes to sensory characteristics and nutritional qualities. The book aims to introduce students of food science and technology, or biotechnology to the wide range of processing techniques that are used in food processing. It attempts to describe each topic at a level that is accessible without an advanced mathematical background, while providing reference to more detailed or more advanced texts. The book is therefore also suitable for students studying nutrition, catering or agriculture as an additional perspective on their subject areas.

Note on the second edition

There have been major developments in technology during the last decade which have justified new chapters on:

- computer control of processing (Chapter 2)
- novel food processes that have a minimal effect on food quality (Chapter 9 and ohmic heating in Chapter 18)
- modified atmosphere packaging (Chapter 20).

Nearly all of the unit operations described in the first edition have undergone significant developments and these are reflected in additional material in each chapter. This is especially so for:

- sorting foods (Chapter 3)
- membrane separation technologies (Chapter 6)
- bacteriocins (Chapter 7)
- detection of irradiated foods (Chapter 8)
- UHT/Aseptic processing (Chapter 12)
- chilling (Chapter 19)
- packaging (Chapters 24 and 25)
- materials handling (Chapter 26).

Additional material has also been included in Chapter 1 to both make the text more comprehensive and to include an outline of quality assurance and Hurdle Technology, and in Chapter 13 to include an outline of distillation.

Where appropriate, the original text has been clarified and edited, and new photographs, illustrations and tables have been included to provide additional information and updated descriptions of technologies. All new developments have been fully referenced in each chapter, and a new glossary of technical terms and list of acronyms has been included.

References

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