**Chapter 1 - Introduction**

The principles of food engineering are embedded in physics, chemistry, mathematics and biology. A review of important concepts inherent to these foundational sciences is essential in the study of food engineering. Knowledge of dimensions and units is necessary to solve mathematical problems related to design and analysis of food processing systems. In analyzing a given problem, the system under study must be carefully defined. Properties of systems, such as density, temperature, pressure and enthalpy are required to characterize a system. Conservation of mass and energy, and the fundamental laws of thermodynamics, are frequently used in analyzing processing operations. The design of [food processing equipment](https://www.sciencedirect.com/topics/food-science/food-processing-equipment) relies the concepts of mass and energy balance.

**Keywords**

Dimensions

units

system

density

temperature

pressure

enthalpy

conservation of mass

conservation of energy

Mass balance

energy balance

**Chapter 2 - Resource Sustainability**

Food processing operations are carried out by using energy in the form of steam, electricity and natural gas. Steam is usually generated at the processing plant sites using boilers. Conversion of water into steam involves phase change that is described by the application of thermodynamics. Upon generation, steam must be transported using pipes to processing operations where it condenses to release heat in a controlled manner. Similarly, combustion of natural gas involves the use of burners for heating air which is then used in processes such as baking. In using electrical energy to operate electrical motors, knowledge of electrical circuits is essential. Sustainable use of energy requires careful analysis of energy requirements and conservation. Life cycle assessment can also provide useful information on the impact of food processing on the environment.

**Keywords**

Steam

natural gas

burners

electric circuits

Water

sustainability

environment

life cycle assessment

**Chapter 3 - Preservation Processes**

Heating plays an important role in food preservation processes. Commercial thermal processing involves the use of retorts for [canned foods](https://www.sciencedirect.com/topics/food-science/canned-food). Heating influences the inactivation of enzymes, destruction of microorganisms, and degradation of nutrients and other quality attributes in foods. Rate kinetics of such reactions can be described using mathematical expressions. Thermal death time calculations are useful in determining required thermal processes for [pasteurization](https://www.sciencedirect.com/topics/food-science/pasteurization) and [food sterilization](https://www.sciencedirect.com/topics/food-science/food-sterilization).

**Keywords**

food preservation

blanching

pasteurization

retort processing

aseptic processing

high pressure processing

pulsed electric field

rate kinetics

first order kinetics

zero order kinetics

thermal death time

thermal process

spoilage probability

pouch processing

**Chapter 4 - Refrigeration**

Refrigeration is a key to preservation of many [perishable foods](https://www.sciencedirect.com/topics/food-science/perishable-food). The design of a refrigeration system for foods involves selection of an appropriate refrigerant, and an understanding of various components such as evaporator, compressor, condenser, and the expansion valve. Relationships between temperature, pressure and enthalpy for refrigerants are used in designing the size of each component and determining the rate of heat transfer. These relationships are useful in determining the coefficient of performance of a refrigeration system. Multistage systems including flash gas removal are used to improve performance of commercial systems.

**Keywords**

Refrigerants

evaporator

compressor

condenser

expansion valve

coefficient of performance

refrigerant flow rate

Ammonia

Refrigerant R-134a

flash gas

multistage refrigeration systems

**Chapter 5 - Evaporation**

Evaporators are commonly used to concentrate foods by using heat to evaporate water from the food. As the liquid is concentrated, its boiling point is elevated. Using low pressure, boiling of liquid foods (such as juices) is carried out at low temperatures and the heat labile food attributes are preserved. Different types of evaporators are used in the food industry including batch-type, natural circulation, rising-film, falling-film, rising/falling-film, and agitated thin-film evaporators. Heat and mass balances are used in calculations to design single- and multiple-effect evaporators. Steam economy gives an indication of the process efficiency. Vapor recompression systems such as thermal recompression and mechanical vapor recompression are useful in minimizing energy use.

**Keywords**

Evaporator

Boiling point elevation

batch-type evaporator

natural circulation evaporator

rising-film evaporator

falling-film evaporator

rising/falling-film evaporator

agitated thin-film evaporator

single-effect evaporator

multi-effect evaporator

mass balance

heat balance

thermal recompression

mechanical vapor recompression

**Chapter 6 - Dehydration**

Dehydration is one of the oldest methods of food preservation. The modern food industry uses drying operations to create a wide range of food products. Storage of dried products requires an understanding of the [water activity](https://www.sciencedirect.com/topics/food-science/water-activity) and their sorption properties. Moisture diffusion during drying is governed by the complex internal structure of the food, often requiring experimental determination of drying rate curves. The dryer design involves use of heat and mass balances. Some of the common dehydration systems used in the food industry include tray dryers, tunnel dryers, puff dryers, fluidized bed dryers, spray dryers and freeze dryers. Heat and mass transfer calculations are useful in estimating drying time.

**Keywords**

Dehydration

water activity

adsorption isotherm

desorption isotherm

cabinet dryers

tunnel dryers

puff dryers

fluidized bed dryers

spray dryers and freeze dryers

drying time

**Chapter 7 - Extrusion Processes for Foods**

Extrusion is a common process in converting raw materials into a variety of popular products such as [snack foods](https://www.sciencedirect.com/topics/food-science/snack-food) and [breakfast cereals](https://www.sciencedirect.com/topics/food-science/breakfast-cereal). The basic principles of extrusion rely on describing the flow of extrudates. Mathematical expressions are developed to determine volumetric flow rate, an important operational parameter that describes the operating capacity of an extruder. Different extrusion systems used in the food industry include cold extrusion and extrusion cooking with single-screw and twin-screw extruders. The power requirements of an extruder depend upon the properties of product and extrudate, and the design characteristics of the extruder.

**Keywords**

Extrusion

extrudate flow

volumetric flow rate

cold extrusion

extrusion cooking

single screw extruder

twin screw extruder

extrusion power requirement

**Chapter 8 - Packaging Concepts**

Packaging is necessary for protecting foods during shipment and storage. Packaging provides protection to the food from various environmental factors such as oxygen, carbon dioxide, water vapor, aroma, and light. Mass transfer through the packaging wall must be well understood to design an appropriate package. Since packaging also provides a means of communication about the food to the consumer, innovations occur at a rapid pace. Some of the recent innovations in the field of packaging include development of passive and [active packaging](https://www.sciencedirect.com/topics/food-science/active-packaging), intelligent packaging, and interactive packaging. Packaging has a major role in influencing the shelf life of a food. Mathematical methods to predict shelf life of packaged foods include the use of chemical kinetics involving zero and first order reactions.

**Keywords**

Packaging

mass transfer

active packaging

passive packaging

intelligent packaging

interactive packaging

shelf life

chemical kinetics

zero order reactions

first order reactions

**Chapter 9 - Industrial cooking**

**Abstract**

Industrial cooking is used to change the organoleptic qualities of foods to meet specific requirements for particular flavours, aromas, colours or textures and to ensure that the products are microbiologically safe. It is used for the preparation of meals in centralised kitchens that supply institutions, in food service outlets and large hotels, or it is used to produce chilled or frozen ready-to-eat meals for retail sale. This chapter describes methods and equipment used for industrial cooking using moist heat, dry heat and [sous vide](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/sous-vide) processing. It outlines changes caused to the sensory characteristics of foods and the effects on [microorganisms](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/microorganisms), especially in sous vide processing. Reference is made to other relevant chapters, including baking, [toasting](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/toasting), frying microwave heating and smoking, which are also methods used in industrial cooking.

**Keywords**

Industrial cooking

sous vide

moist heat

dry heat

**Chapter 10 - Pasteurisation**

**Abstract**

[Pasteurisation](https://www.sciencedirect.com/topics/food-science/pasteurization) is a mild heat treatment in which food is mostly heated to below 100°C. It is used to minimise health hazards from pathogenic [microorganisms](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/microorganisms) in [low-acid foods](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/low-acid-foods) and to extend the shelf-life of acidic foods by several days or weeks by destruction of [spoilage microorganisms](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/spoilage-microorganisms) and/or [enzyme inactivation](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/enzyme-inactivation). This chapter describes the pasteurisation of liquid foods either packaged in containers, or unpackaged using [heat exchangers](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/heat-exchangers), and reviews the changes caused by pasteurisation to the sensory characteristics and [nutritive value](https://www.sciencedirect.com/topics/food-science/nutritive-value) of foods.

**Keywords**

Pasteurisation

phosphatase

*D*-values

*z*-values

HTST processing

heat exchangers

**Chapter 11 - Heat sterilisation**

**Abstract**

Heat sterilisation describes both in-container processing (canning) and ultrahigh-temperature aseptic processes. Both heat foods at a high temperature to destroy microbial cells and [spores](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/spores) and inactivate enzymes, thus rendering foods safe and significantly extending their shelf-life at ambient temperatures. This chapter describes the theory of microbial and [enzyme inactivation](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/enzyme-inactivation) using different time–temperature combinations, the equipment used for in-container and [aseptic processing](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/aseptic-processing) and the effects of heat sterilisation on the safety, sensory characteristics and [nutritional value](https://www.sciencedirect.com/topics/food-science/nutritive-value) of foods.

**Keywords**

Heat sterilisation

canning

aseptic processing

heat exchangers

**Chapter 12 - Evaporation and distillation**

**Abstract**

Evaporation and distillation are processes that use heat to remove water and/or more volatile components from liquid foods by exploiting differences in their volatility. This chapter explains the theory of evaporation, and describes the equipment and methods used to reduce energy consumption. It then describes the theory of distillation, the equipment used commercially, and an outline of the effects of both operations on [microorganisms](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/microorganisms) and food quality.

**Keywords**

Evaporation

distillation

multiple effects

vapour recompression

azeotropic mixtures

**Chapter 13 - Dehydration**

**Abstract**

Dehydration using hot air or heated surfaces removes water from foods and reduces their [water activity](https://www.sciencedirect.com/topics/food-science/water-activity), which inhibits [microbial growth](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/microbial-growth) and [enzyme activity](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/enzyme-activity) to extend their shelf-life. Drying can cause [deterioration](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/deterioration) of both the organoleptic quality and the [nutritional value](https://www.sciencedirect.com/topics/food-science/nutritive-value) of foods, and the design and operation of dehydration equipment aim to minimise these changes. The chapter first describes psychrometrics, the theory of drying and calculation of drying rates. It then summarises the many different types of hot-air and contact [drying equipment](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/drying-equipment) and methods used to control their operation. The chapter concludes by describing [rehydration](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/rehydration) and the effects of dehydration on [microorganisms](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/microorganisms) and the quality of foods.

**Keywords**

Dehydration

psychrometrics

hot-air dryers

heated-surface dryers

rehydration