

Introduction to Food Engineering

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Key concepts, processes, and applications

1. What Is Food Engineering?

Aspect	Description
Definition	Application of engineering principles (chemical, mechanical, thermal, and biological) to the design, development, production, preservation, and distribution of food products.
Goal	Deliver safe, nutritious, tasty, and cost-effective foods while optimizing resource use and minimizing waste.
Core Disciplines	• Chemical Engineering – reactions, mass transfer, and formulation. • Mechanical Engineering – equipment design, fluid flow, and processing mechanics. • Thermal Engineering – heating, cooling, and energy balance. • Biological Engineering – microbiology, enzymology, and biotechnology.

2. Major Stages in Food Processing

Stage	Typical Operations	Engineering Focus
Raw Material Handling	Receiving, cleaning, sorting, size reduction	Conveyors, sieves, equipment durability
Preparation & Pretreatment	Washing, peeling, blanching, marination	Heat transfer, water usage, sanitation
Unit Operations	Mixing, grinding, emulsifying, extrusion, drying, freezing	Mass & energy balances, rheology, equipment design
Preservation	Pasteurization, sterilization, canning, fermentation, high-pressure processing (HPP)	Kinetic modeling of microbial inactivation, thermal design, pressure vessel safety
Packaging	Filling, sealing, labeling, modified atmosphere packaging (MAP)	Material selection, barrier properties, mechanical integrity

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Stage	Typical Operations	Engineering Focus
Distribution & Storage	Cold chain logistics, shelf-life monitoring	Temperature control, transport optimization, spoilage modeling

3. Fundamental Engineering Principles

3.1 Mass Transfer

- **Diffusion & Convection:** Governs ingredient mixing, drying, and flavor migration.
- **Key Equations:** Fick's law, Reynolds number, Sherwood number.

3.2 Heat Transfer

- **Conduction, Convection, Radiation:** Central to cooking, cooling, and pasteurization.
- **Design Tools:** Nusselt number correlations, heat exchanger sizing, transient heating models.

3.3 Fluid Mechanics

- **Laminar vs. Turbulent Flow:** Affects mixing efficiency and pump selection.
- **Important Parameters:** Reynolds number, pressure drop, pump curves.

3.4 Rheology

- **Viscosity & Yield Stress:** Critical for sauces, dough, and suspensions.
- **Models:** Newtonian, Bingham plastic, Herschel-Bulkley, Power-law.

3.5 Thermodynamics & Energy Balance

- **First Law:** Energy input vs. product temperature change.
 - **Second Law:** Entropy generation—used to assess process efficiency.
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4. Common Food Processing Technologies

Technology	Principle	Typical Applications
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Pasteurization	Time-temperature lethality curve (D -value)	Milk, juices, liquid eggs
Sterilization (UHT)	High temperature, short time (HTST)	Shelf-stable milk, soups
Extrusion	High shear & temperature in a barrel	Breakfast cereals, pet food, textured proteins
Freeze-Drying (Lyophilization)	Sublimation under vacuum	Instant coffee, probiotics, high-value pharmaceuticals
High-Pressure Processing (HPP)	Isostatic pressure (300–600 MPa)	Fresh-cut fruits, deli meats