Chapter IV : Unit Operations in Food Processes

1. Unit Operation

Any single operation of a physical nature common to several processes. Each unit operation is based on defined physical properties.

In addition to "physical nature" unit operations, chemical and biochemical operations are also important in the processing of several foods... These include:

- Enzymatic reactions and fermentations
- Chemical additions (preservatives, flavors, colors, etc.).

2. Unit Operations Used in Industrial Processes

Six unit operations commonly used in industrial processes: Mixing, Separation, Heat Transfer, Mass Transfer, Size Adjustment, Flow.

2.1. Mixing

Production of a homogeneous mass from two or more components. Two main objectives of mixing are ingredient incorporation and heat transfer.

The efficiency of mixing depends, among other things, on the mixer design and speed.

Different mixer configurations are employed depending on the intended purpose...

2.2. Heat Transfer

Movement of energy in the form of heat to or from a product.

2.2.1. Factors Influencing Heat Transfer

- Heat exchanger design
- Thermal conductivity properties of the product
- Density
- Method of heat transfer (conduction, radiation, convection)
- Viscosity
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2.2.2. Heating is used for:

- Germ destruction to produce a healthy product
- Extending shelf life by destroying certain enzymes
- Improving the organoleptic acceptability of the product.

2.2.3. Cooling primarily serves a preservation function.

2.3. Mass Transfer

- Transfer of matter to or from a medium
- Transfer of a chemical compound from one phase to another

* Diffusion: high concentration to low concentration
* Evaporation: liquid to gas

- Mainly involved in separation or drying techniques...

Examples: Absorption, Crystallization, Distillation, Lyophilization...

2.4. Separation

Separation of components based on a physical property: Size, density, boiling point...

- Density

Examples: Separation of cream from milk, Solid settling in a suspension, Bacteria removal from fluids

- Size

Examples: Membrane filtration, Gel filtration, Sieving

- Boiling point

Example: Distillation

2.5. Size Adjustment

Changing the size of a product or one of its components:

- Size reduction of the product: Grinding, milling, chopping - Cutting, slicing - Emulsification
- Size increase through aggregation, agglomeration, or gelatinization - e.g., Milk -> Curd -> Cheese

2.6. Flow

Transfer of a fluid from one point to another.

3. Unit Operation

A simple, specific, and identifiable step in the manufacture of a product.

Every production system requires a combination of unit operations to transform raw material into a finished product.

Examples: Filtration, Cleaning, Peeling, Slicing, Grating, Concentration, Drying, Coating

Several unit operations involve a combination of more than one unit operation and/or chemical or biochemical operations...

3.1. Unit Operations Combining Multiple Unit Operations

- Filtration - Flow - Separation
- Evaporation - Heat Transfer - Mass Transfer

Pasteurization - Flow - Heat Transfer

• Cheese curdling - Mixing (enzyme or bacteria) - Heat Transfer - Enzymatic reactions or fermentation - Size increase - Mass Transfer – Separation

4. Processes in the agri-food industries

4.1. Changes induced by heating

4-1-1- Desirable

- Destruction of microorganisms
- Inactivation of enzymes
- Improvement of color, aroma, taste, texture
- Improvement of digestibility

4-1-2- Undesirable

- Nutrient degradation
- Degradation of sensory attributes

4-2- Thermal processes by heat addition

4-2-1- Blanching

Definition and effects

• Thermal treatment intended to inactivate enzymes that could cause deterioration during storage

• Mainly against browning and the development of undesirable flavors

• Treatments vary from one product to another

Advantages

• Drying of the plant material may not necessarily be enough to inactivate the enzymes which can be reactivated by simple rehydration.

• Freezing does not stop enzymatic reactions.

• In an unblanched product, enzymatic activity can occur even under refrigeration, freezing, or dehydration conditions. This activity can also occur during the heating of canned products.

Limitations

• Limited applications to fruits/vegetables and some seafood

• Only a simple reduction in the population of vegetative cells

• Requires a second barrier

• Safety depends on the second barrier

4-2-2- Pasteurization and Sterilization

Depending on their intensity and objectives, three main types of treatments:

Sterilization

• High-temperature thermal treatment, above 100°C, capable of destroying all microbial forms present, including bacterial endospores.

Pasteurization

• Moderate to low-temperature treatment allowing the maintenance of product quality.

• Pasteurization reduces the microbial population in milk and other heat-sensitive foods (juices, beer, sauces).

• Acts on vegetative forms.

• Bacterial endospores may, if pH permits, germinate and alter the product...

• If pH is acidic: stabilizing pasteurization.

4-2-3- Concentration and Drying

Drying: Total dehydration: almost complete water removal

- Examples: Powdered milk, instant coffee

Concentration: Partial dehydration

- Examples: Condensed milk, syrups

Objectives

Why dry agricultural and food products?

• Stabilize products and increase shelf life.

• Produce ingredients or additives for further processing.

• Reduce weight and volume.

Why concentrate agricultural and food products?

• Increase product shelf life (likely).

• Reduce weight and volume.

4-2-4- Distillation

Physical separation of various constituents of a liquid, liquefiable, or fusible mixture. The vapor phase is produced by evaporation by supplying heat to the system.

4-2-5- Cooking-Extrusion

Extrusion means: pushing out, a unit process of transformation involving forcing a product through a small-dimension orifice: the die.

4-3- Thermal Processes by Heat Removal

Functions of Cold in the Agri-food Industry

Cold Maintenance

• Stability of physical, biological, and chemical characteristics

• Maintenance-storage (associated with refrigerated storage)

• Maintenance-sales (associated with sales and distribution)

• Maintenance-transport (associated with transportation)

Cold Processing

• Product treatment

• E.g., cooling at the end of cooking, production of food ice cream, sugar crystallization, distillation, or lyophilization.

4-4-. Ambient Temperature Processes

4-4-1- Raw Material Preparation

a. Pre-process stages

Handling (examples): Manual/mechanical harvesting, Transportation, Conveying, Pumping, Storage

Considerations

• Maintain sanitary conditions

• Minimize losses
• Maintain the quality of the raw product
• Minimize bacterial growth

b. Cleaning: Washing, Brushing, Blowing, Filtration, Steam, Magnets, Screening

c. Separation

Examples
• Sorting, screening, sieving...
• Manual sorting of individual units
• Mechanical sorting by size
• Photoelectric sorting by color
• Peeling, boning, plucking...
• Separation of fruit skin
• Separation of damaged leaves

4-4-2- Size Adjustment Processes

4-4-2-1- Size Reduction: Raw materials are often too large to be used.

Two categories:

A- Solid foods

± Cutting, slicing (meat, vegetables, fruits)
± Chopping, grinding, grating (meat, cheese)
± Molding (cereals)
± Pulping (fruit)

B- Liquids

± Emulsification and homogenization

Emulsions are more or less stable suspensions of fine droplets of one liquid in another, with both liquids being immiscible. Generally milky or cloudy in appearance.

Examples of emulsification:
° Fat dispersed in water: Milk, cream, egg yolk...
° Water dispersed in fat: Butter, margarine, ice cream...

Examples of products affected by homogenization:
° Milks: Whole, semi-skimmed, UHT, concentrated...
° Creams: Ice cream, pastry cream, whipped cream, fresh cream <20%, >20% fat

° Other dairy products: Cottage cheese, spreads, drinkable yogurts,

° Purees: Tomato, banana, apple...

° Beverages: Chocolate drinks, tomato juice, thick juice and nectar, soy milk...

° Others: Sauces, soups, mayonnaise, ketchup, baby food

4-4-2-2- Size Increase (aggregation, agglomeration, gelatinization)

A gel: A fluid trapped in a rigid structure in both directions (fluid in gel, gel in fluid), polymers (chains) bound to each other, obtained by hydration or gelatinization and thickening.

4-4-3- Separative and Concentration Techniques

Why separate?

° Concentrate a useful fraction in a mixture

° Isolate a useful fraction from a mixture

° Eliminate an undesirable fraction from a mixture

Fraction: solutes, particles, or portions of the mixture

Nature of separations

Solid from solid: peeling, pitting...

Solid from liquid: centrifugation, filtration...

Liquid from solid: centrifugation, filtration...

Liquid from liquid: extraction, filtration...

4-4-4- Mixing Processes

Factors affecting mixing: the products, quantities, solubility, temperature, type of mixer, mixer speed, mixing time, order of component addition.

4-4-5- Biological Processes such as fermentation and enzymatic techniques