Dairy Science &Technology

(Animal Husbandry and Dairying)

E –Content

Membrane processing for whey processing

by

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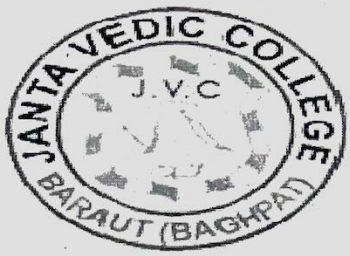

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E –Content(Pre Ph D Course work)

(Dairy Science &Technology (Milk and Milk product Technology)

Membrane processing for whey processing

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Introduction-Whey is the liquid remaining after the coagulation of milk during the manufacture of cheese, casein, and chhana. It constitutes approximately **85–90% of the original milk volume** and retains nearly **50–55% of milk nutrients**, making it a valuable source of nutritional and functional components.

Historically, whey was considered a waste product and its disposal created environmental problems due to its high **Biological Oxygen Demand (BOD: 30,000–50,000 mg/L)** and **Chemical Oxygen Demand (COD: 60,000–80,000 mg/L)**. With advancements in dairy processing technology, whey has become an important raw material for producing high-value products such as **Whey Protein Concentrate (WPC), Whey Protein Isolate (WPI), lactose, bioactive peptides, and mineral concentrates**.

Membrane processing has revolutionized whey utilization because it enables selective separation and concentration of valuable components without exposing them to severe heat treatment.

Types of Whey **A. Sweet Whey** Produced during rennet coagulation in cheese manufacture.,pH: **6.0–6.7**

Contains higher lactose and lower mineral content.

Widely used for WPC and lactose production.

B. Acid Whey -Produced during acid coagulation of milk (e.g., casein, yogurt, chhana).,pH: **4.3–4.6**

Contains higher levels of calcium and phosphate.

More challenging to process due to higher mineral content.

Composition of Whey

Component	Percentage (%)
Water	93–94
Lactose	4.5–5.0

Component	Percentage (%)
Whey proteins	0.6–0.8
Minerals	0.5–0.7
Fat	0.05–0.5
Lactic acid (acid whey)	0.05–0.5

Major Whey Proteins

- β-Lactoglobulin (~50%): Major whey protein, excellent source of essential amino acids.
- α-Lactalbumin (~20%): Rich in tryptophan; important in infant nutrition.
- Bovine Serum Albumin (~5–10%)
- Immunoglobulins (~10–15%)
- Lactoferrin and other minor proteins

Need for Membrane Processing of Whey-Conventional methods such as evaporation and drying require high thermal energy and may cause denaturation of proteins.

Membrane processing offers:

- Lower energy consumption.
- Processing at low temperatures.
- Better retention of functional properties of proteins.
- Selective separation of molecules based on size and molecular weight.
- Reduced environmental pollution by utilizing whey effectively.

Principle of Membrane Processing

Membrane processing is a **pressure-driven separation technology** in which a semi-permeable membrane acts as a selective barrier.

Depending on membrane pore size and molecular weight cut-off (MWCO), different components of whey are separated.

Important Terms-Feed: The original whey solution entering the membrane system.

Permeate: The fraction passing through the membrane (water, lactose, minerals depending on membrane type).

Retentate (Concentrate): The fraction retained by the membrane (mainly proteins or other large molecules).

Factors Affecting Membrane Performance

- Transmembrane pressure (TMP)

- Temperature
- pH
- Flow velocity
- Membrane material and pore size
- Concentration polarization and fouling

. Types of Membrane Processes Used in Whey Processing

A. Microfiltration (MF)

Pore size: 0.1–10 μm
Operating pressure: 1–2 bar

Principle

Separates suspended particles based on particle size.

Applications

- Removal of bacteria and spores.
- Reduction of fat globules.
- Clarification of whey.
- Production of microbiologically stable whey.

B. Ultrafiltration (UF)

MWCO: 1,000–100,000 Da
Operating pressure: 2–10 bar

Principle

Allows water, lactose, and minerals to pass through while retaining whey proteins.

Applications

- Production of Whey Protein Concentrate (WPC).
- Concentration of whey proteins.
- Improvement of protein recovery.

Products

- WPC 35 (≈35% protein)
- WPC 50 (≈50% protein)

- WPC 80 (≈80% protein)

C. Nanofiltration (NF)

Pore size: Approximately 1 nm
Pressure: 5–40 bar

Applications

- Partial removal of minerals.
- Lactose concentration.
- Reduction of water content.
- Preparation of demineralized whey.

D. Reverse Osmosis (RO)

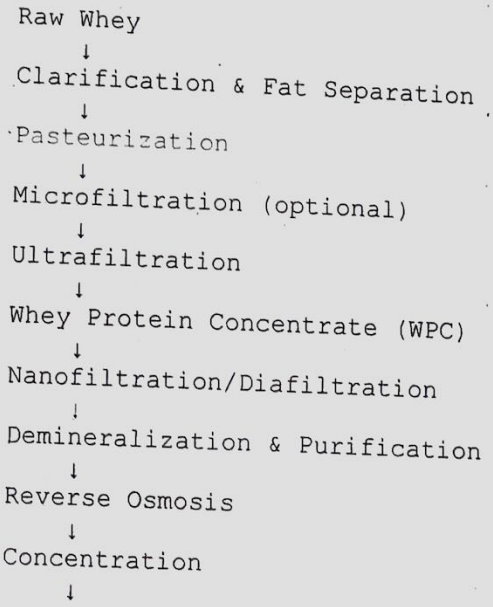
Pore size: <0.001 µm
Pressure: 20–100 bar

Principle

Only water molecules pass through the membrane while all dissolved solids are retained.

Applications

- Pre-concentration of whey before evaporation and spray drying.
- Reduction of transportation and drying costs.
- **Processing Flow Diagram**



Spray Drying
↓
WPC/WPI Powder

Diafiltration in Whey Processing

Diafiltration is a modification of ultrafiltration where water is added to the retentate to wash out lactose and minerals.

Advantages

- Increases protein purity.
- Produces high-protein WPC and WPI.
- Improves functional properties.

Membrane Fouling-Causes

- Protein deposition on membrane surface.
- Mineral scaling (calcium phosphate deposits).
- Fat deposition.
- Microbial growth.
- Concentration polarization.

Effects

- Reduced permeate flux.
- Increased energy consumption.
- Shorter membrane life.
- Reduced product quality.

Control Methods

- Proper pre-treatment of whey.
- Cross-flow filtration.
- Optimized pressure and temperature.
- Regular Cleaning-In-Place (CIP).
- Use of suitable cleaning agents.

. Cleaning-In-Place (CIP) of Membranes

Typical cleaning sequence:

1. Water rinse.
2. Alkaline cleaning (NaOH) to remove proteins and fats.

3. Acid cleaning (nitric or phosphoric acid) to remove mineral scales.
4. Final water rinse.
5. Sanitization if required.
6. **Whey Protein Products and Their Applications**

Whey Protein Concentrate (WPC)

Protein: **35–80%**

Uses:

- Sports nutrition.
- Bakery products.
- Dairy beverages.
- Infant formula.
- Protein fortification.

Whey Protein Isolate (WPI)

Protein: **≥90%**

Uses:

- Medical nutrition.
- High-protein supplements.
- Functional foods.

Demineralized Whey Powder

Uses:

- Infant formula.
- Confectionery.
- Special dietary products.

. Recent Advances in Membrane Processing

- Ceramic membranes with longer life and better cleaning resistance.
- High-performance spiral-wound membranes.
- Integration of membrane processes with evaporation and chromatography.
- Recovery of bioactive peptides and minor proteins (lactoferrin, immunoglobulins).
- Membrane bioreactors for advanced dairy applications.

. Advantages of Membrane Processing

- Low-temperature processing.
- Preservation of protein functionality.
- Lower energy requirement.
- High separation efficiency.
- Minimal use of chemicals.
- Environment-friendly technology.
- High recovery of valuable nutrients.

Limitations

- High initial investment.
- Membrane fouling.
- Regular cleaning requirement.
- Limited membrane lifespan.
- Performance affected by operating conditions.

. Conclusion-Membrane processing has transformed whey from an environmental waste into a valuable source of high-quality nutritional ingredients. Technologies such as **Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis, and Diafiltration** are widely used to recover whey proteins, concentrate lactose, remove minerals, and manufacture premium products such as **WPC and WPI**.

With ongoing developments in membrane materials and process optimization, membrane technology will continue to play a central role in the sustainable and economical utilization of whey in the modern dairy industry.

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