Anticipating and Solving Equipment and Process Constraints

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Why Good Ideas Fail

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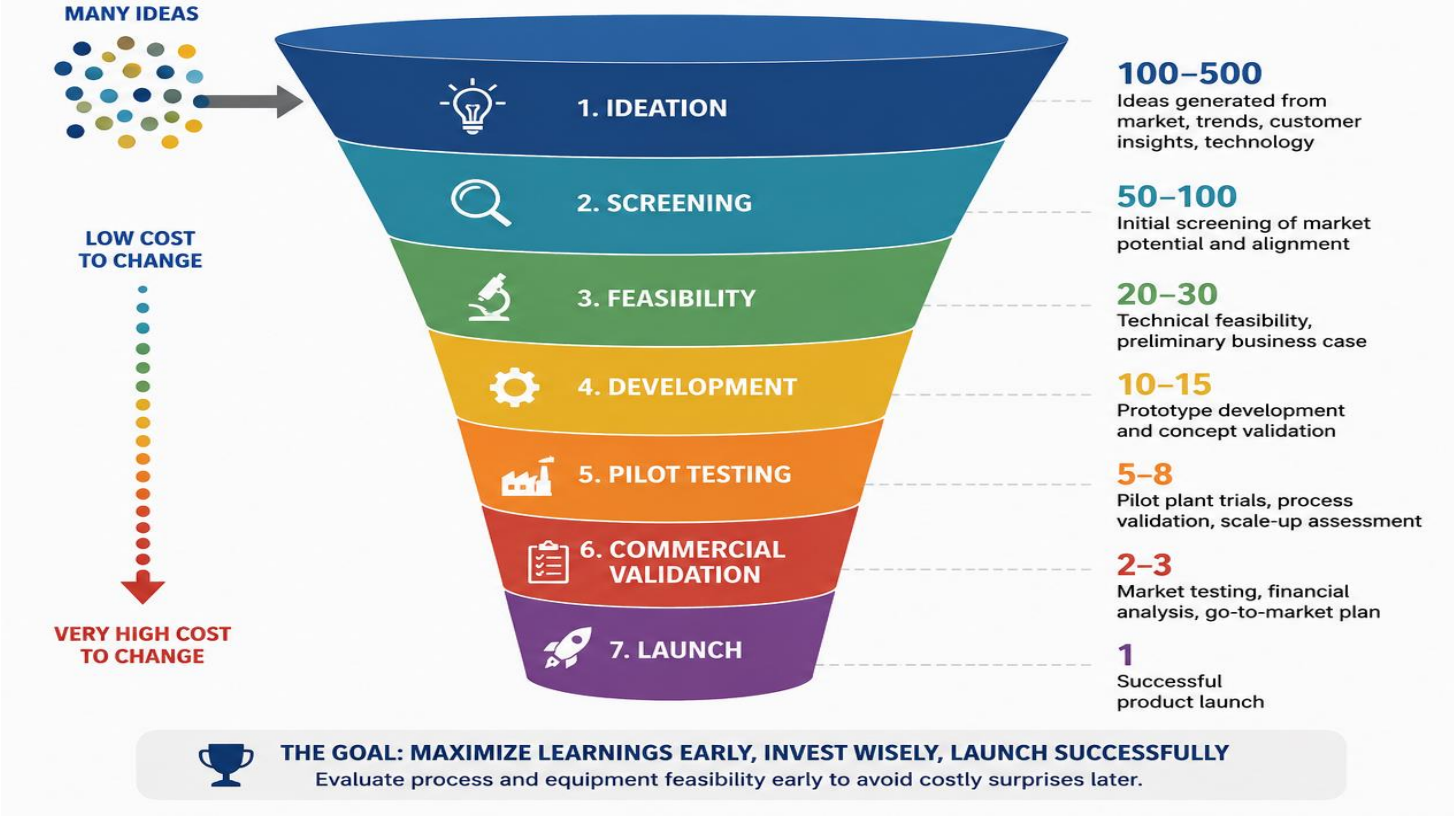
- Equipment limitations
- Manufacturing capacity
- Ingredient handling issues
- Process incompatibility
- Cleaning difficulties
- High production cost
- Scale-up failures



Product Development Timeline

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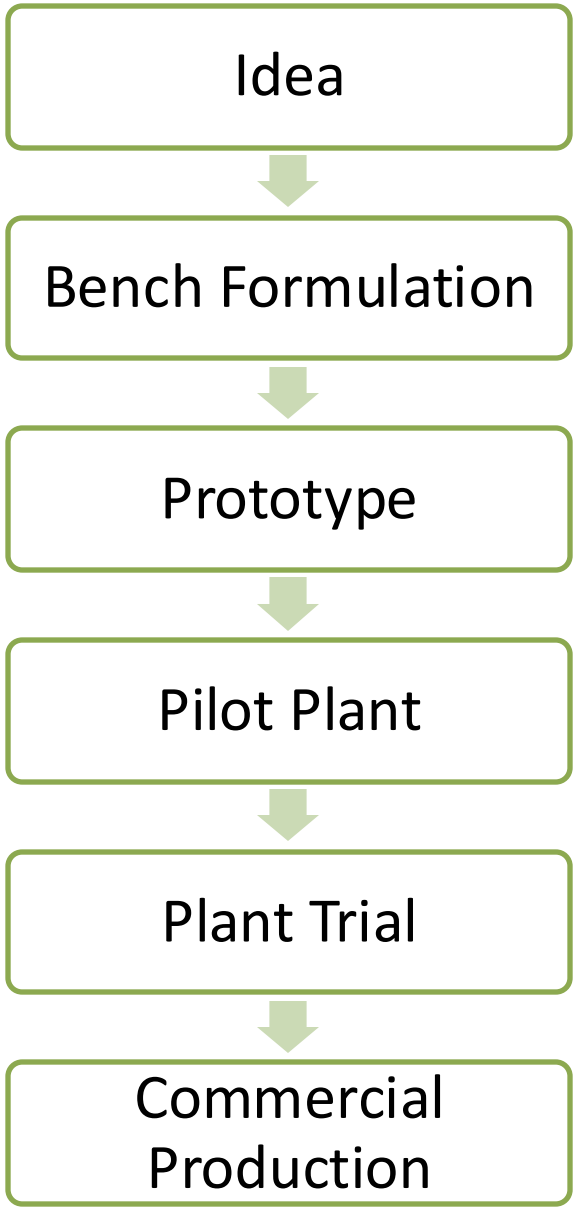
- As we go down, cost increases!!
  - Changing a stabilizer in the lab costs almost nothing.
  - Changing equipment after commercialization can cost millions.



The Product Determines the Process

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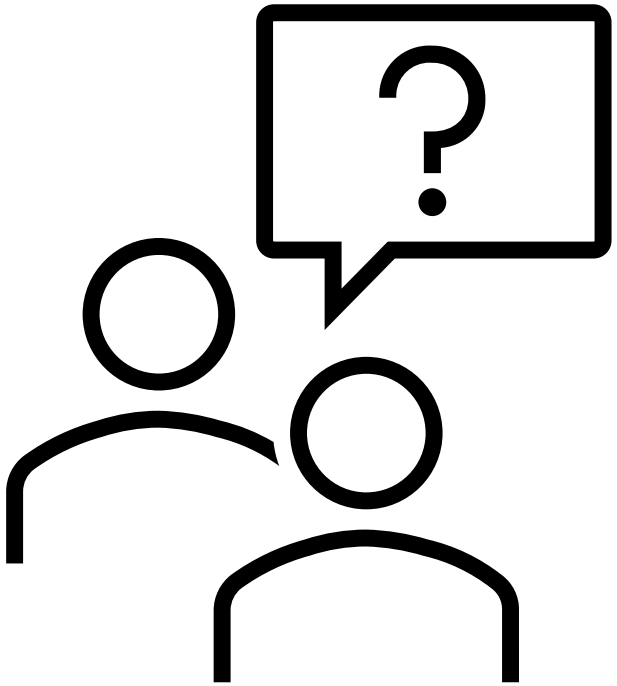
- Instead of asking “What equipment do we have?”
- **Ask**
  - **"What product are we trying to make?”**
  - **“What are the product’s attributes”**
    - Protein level
    - Fat level
    - Moisture
    - Texture
    - Viscosity
    - Shelf life
    - Particle size
    - Microbial stability



The Product Determines the Process

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Five questions every R&D scientist should ask **before** locking a formulation.

Can it be mixed?

Ingredient dispersion at scale

Can it be heated?

Thermal processing without degradation

Can it be pumped?

Viscosity and shear compatibility

Can it be packaged?

Filling, foam control, shelf stability

Can the equipment be cleaned?

CIP compatibility and fouling risk

Typical Dairy Manufacturing Overview

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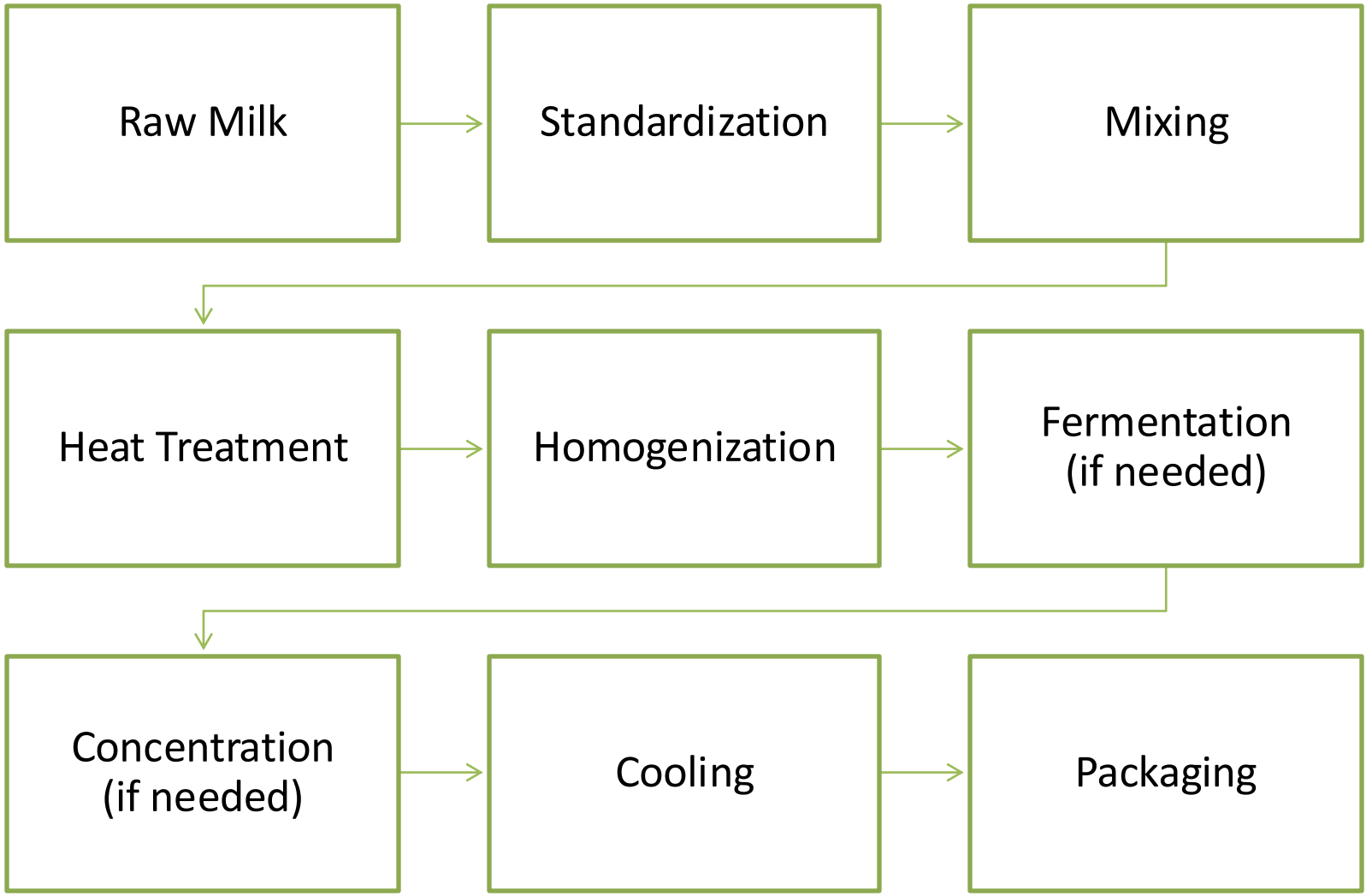
- Almost every dairy product uses many of these same unit operations
- The difference is:
  - Sequence
  - Intensity
  - Equipment size



The Product Determines the Process

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- Requires concentration
- Large fermentation tanks
- Different filling equipment
- Pumpable
  (High viscosity vs. Lower viscosity)
- Ingredients
  (Fluid vs. dry)
- Processing
  (UHT vs. Pasteurization)

Greek yogurt vs. drinking yogurt

↓

High-protein drink vs. regular drink

Typical Equipment Throughout the Plant

Typical Equipment Throughout the Plant

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- Typical dairy pumps are the centrifugal, liquid-ring, and positive displacement pumps
- Centrifugal Pump
  - This is the most common type of pump used in the dairy industry
  - Low viscosity products but not heavily aerated
  - The most adaptable pump for different operating conditions
  - Easy to maintain

Typical Equipment Throughout the Plant

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- Tanks
  - Tanks in a dairy factory are used for a number of purposes
  - Tanks can generally be divided into two main categories according to function:
    - Storage tanks
    - Process tanks

Typical Equipment Throughout the Plant

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- Pasteurization

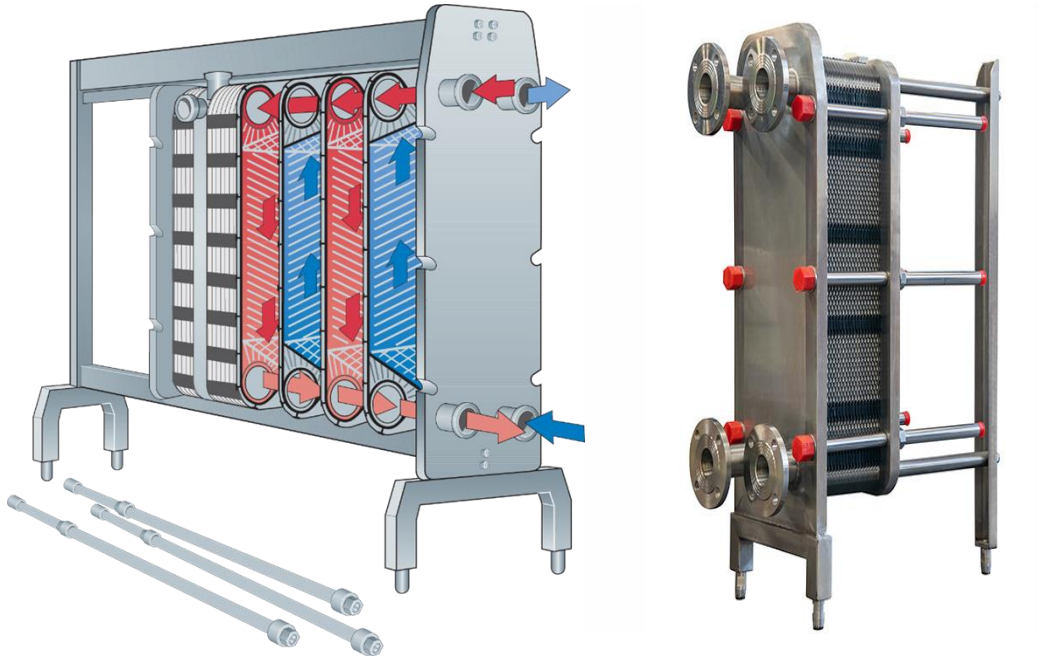
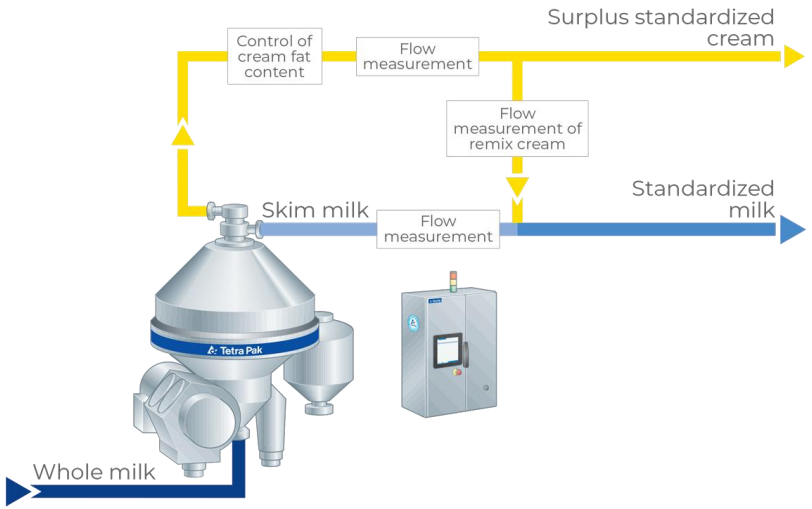


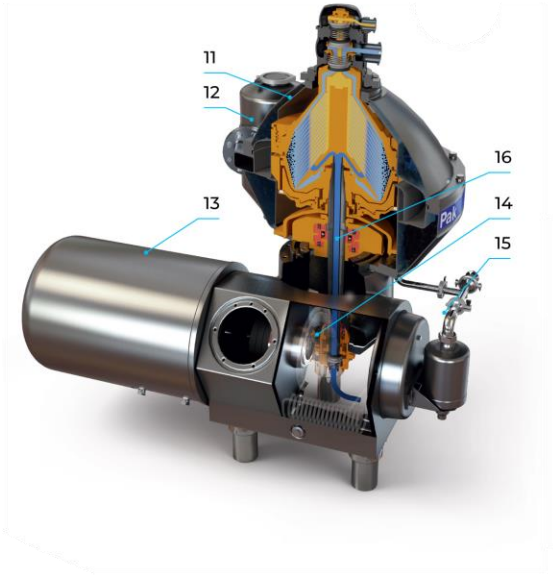
Plate-and-frame HEX:
High Temperature Short Time HTST

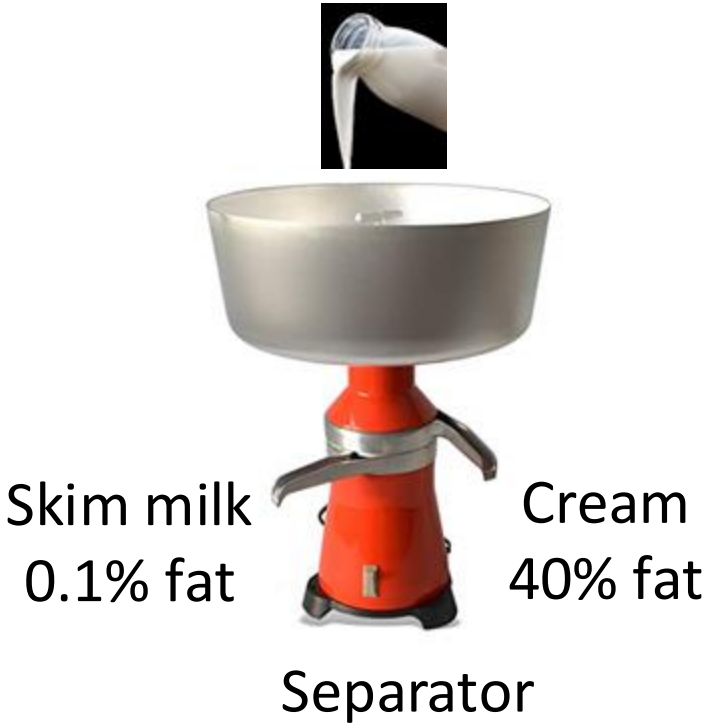
Vat or Batch Pasteurization:
Long temperature long time LTLT

Typical Equipment Throughout the Plant

- Centrifugal Separator
  - Process of adjusting the milk fat by the addition or removal of cream or non-fat (skim) milk







Typical Equipment Throughout the Plant

- Mixers: high-shear mixing
  - High-shear mixing involves subjecting substances to intense mechanical forces, breaking down particles and promoting dispersion

Typical Equipment Throughout the Plant

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- Double-jacket Vat
  - For cheese and yogurt (or pasteurization if vat pasteurizer)

Typical Equipment Throughout the Plant

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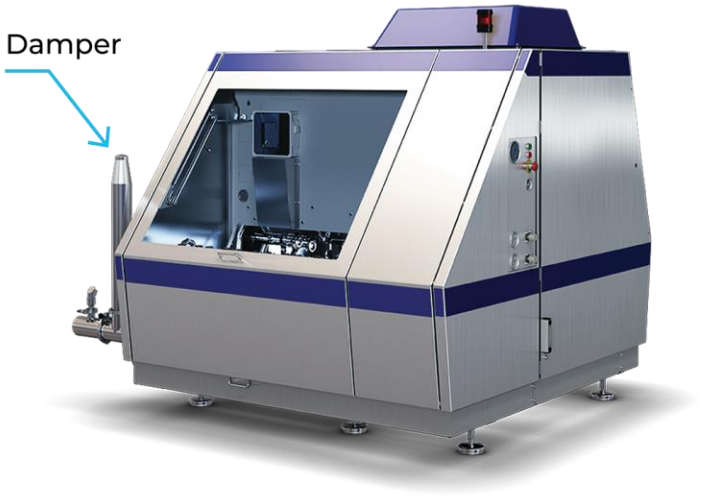
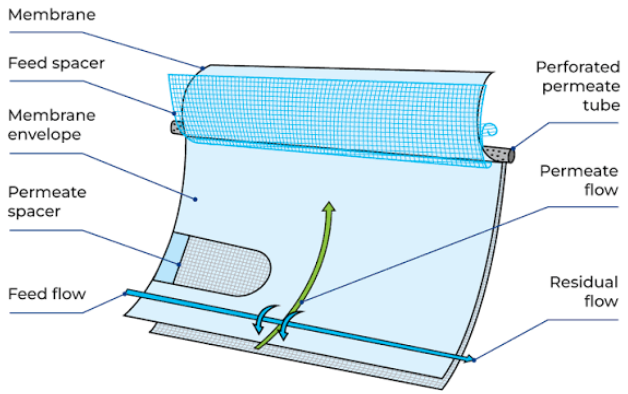
Homogenizer



Fluid products and Ice cream

Membrane separation



Fractions: UF milk, MPCs, WPCs

Evaporator

Condensed products

Typical Equipment Throughout the Plant

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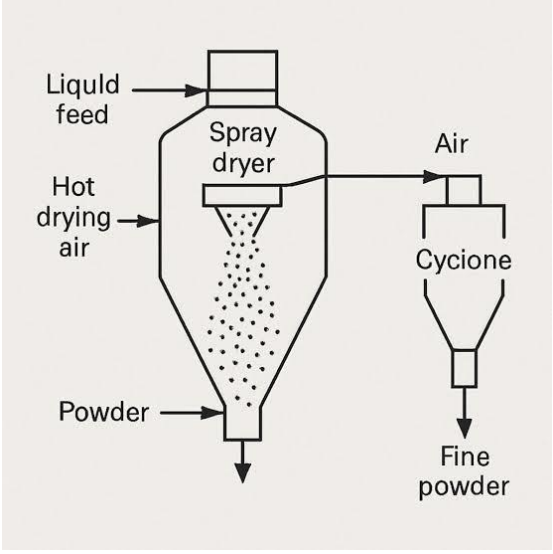
Spray dryer

UHT

Filler

Powders



Extended-Shelf Life (ESL)
or Shelf-stable (UHT)

Fluid products, ice cream, yogurt

Typical Equipment Throughout the Plant

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Ice cream churn/freezer

Frozen desserts and ice cream

Butter churn

Butter

Cheese vat

Cheese

Typical Equipment Throughout the Plant

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Every piece of equipment creates boundaries for product design

Equipment	Limitation
Pasteurizer	Limits production rate, viscosity limitations, and heat exchanger fouling
Homogenizer	Limits pressure, viscosity limits, heat generation
Mixing tank	Limits batch size
Spray dryer	High energy use, nozzle clogging, viscosity limits, wall deposition
Filler	Limits package format, viscosity restriction

Formulation-related challenges and constraints

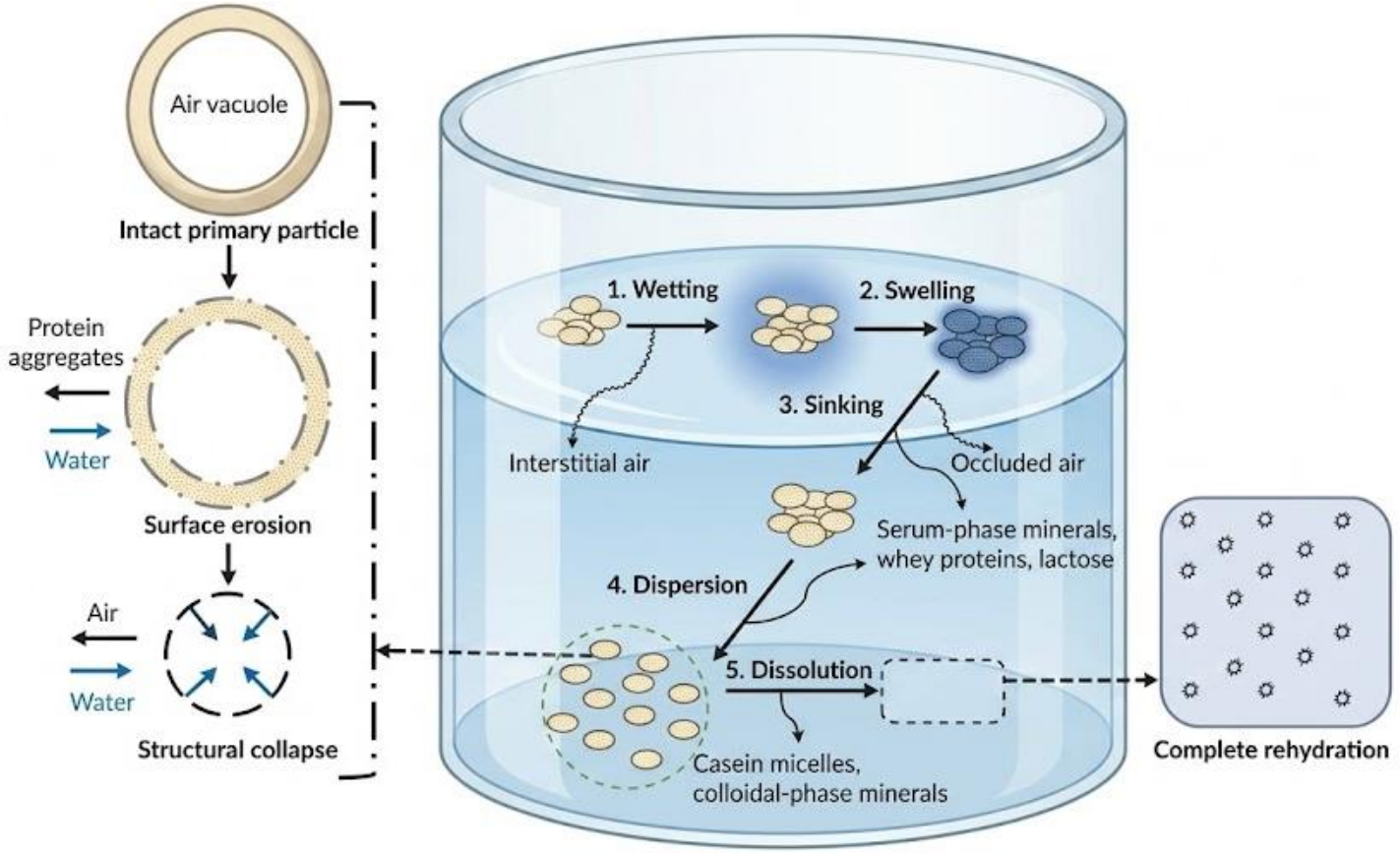
Formulation Fluid Ingredients

- Milk
- Cream
- Condensed milk
- Syrup
- Liquid whey

Advantages	Disadvantages
Easy pumping	Cold storage
Uniform mixing	Transportation cost
Lower dust	Limited shelf life
Less labor	Bulk tanks required

Formulation Dry Ingredients

- Such as:
  - Milk protein concentrate
  - Whey protein
  - Skim milk powder
  - Starches
  - Stabilizers
  - Emulsifiers
- Challenges:
  - Poor wetting
  - Dust
  - Hydration time
  - Storage space
  - Separation



Choosing Between Fluid and Dry Ingredients

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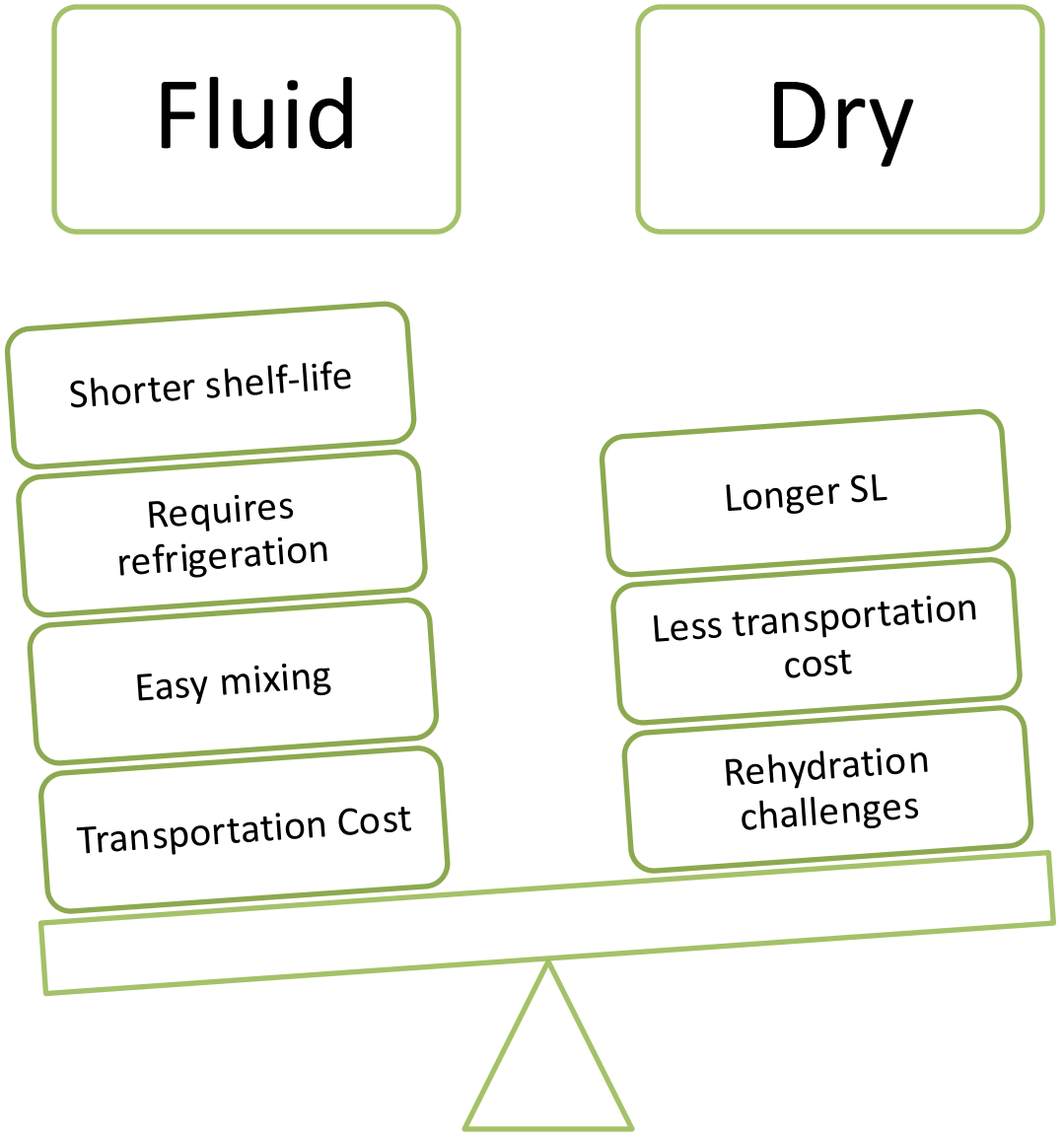

Mixing Considerations

- Shear speed
  - Foaming?
- Addition sequence
  - What to add first: protein powder or fiber?
- Hydration temperature
  - Cold vs heated hydration
- Hydration time
  - MPC needs longer than WPC
- Mix viscosity
  - pumping

Membrane Filtration Systems

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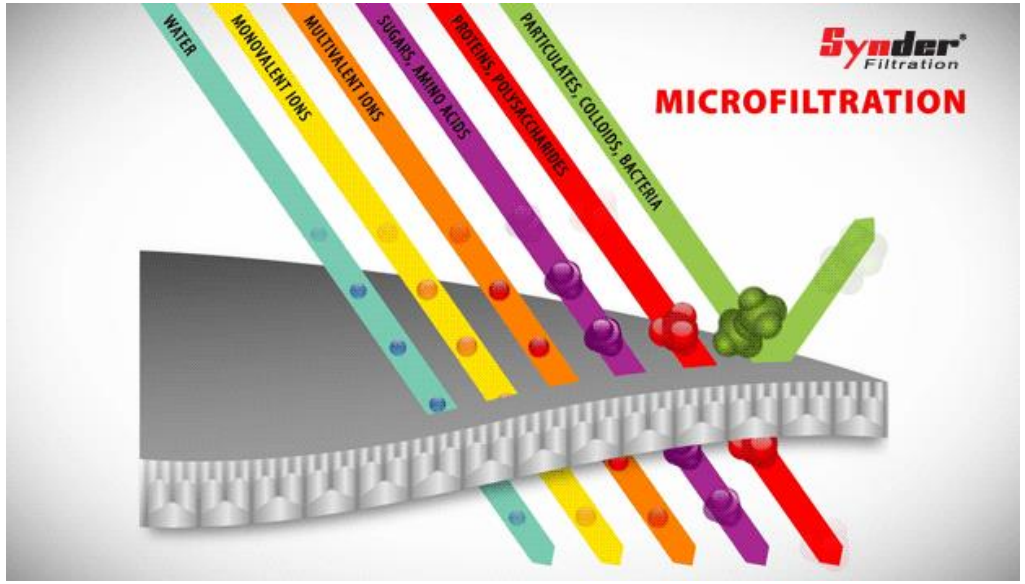

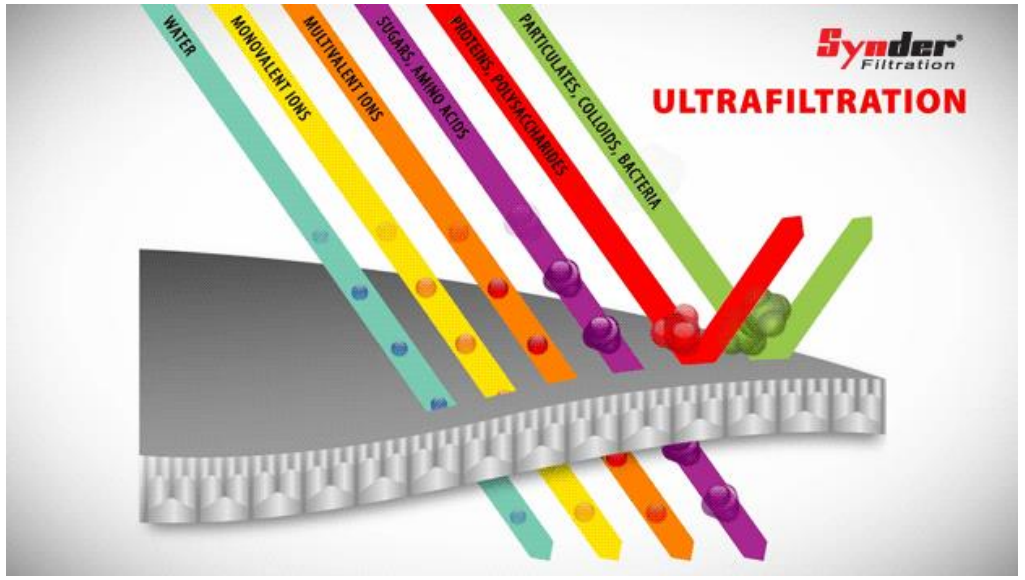

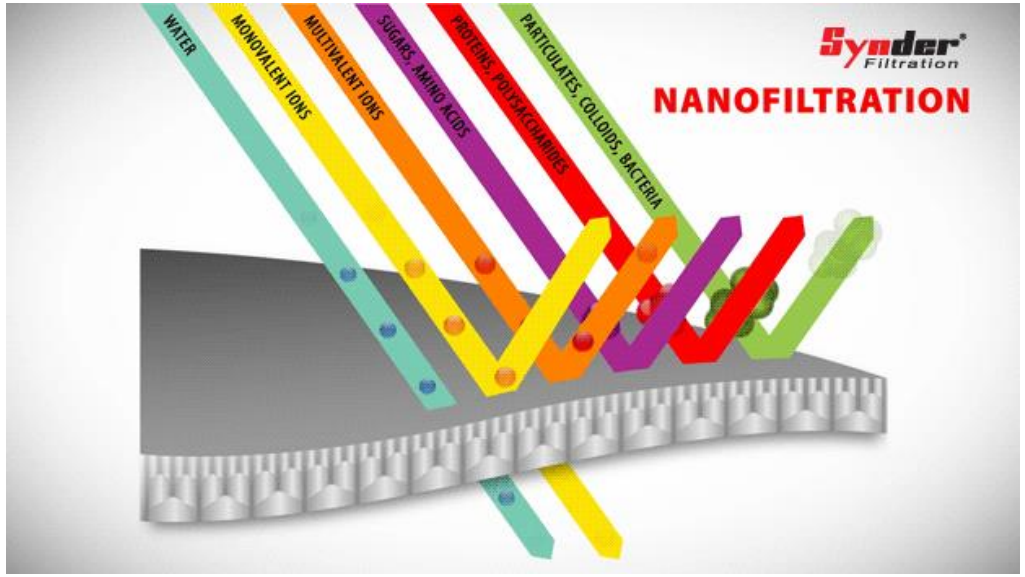

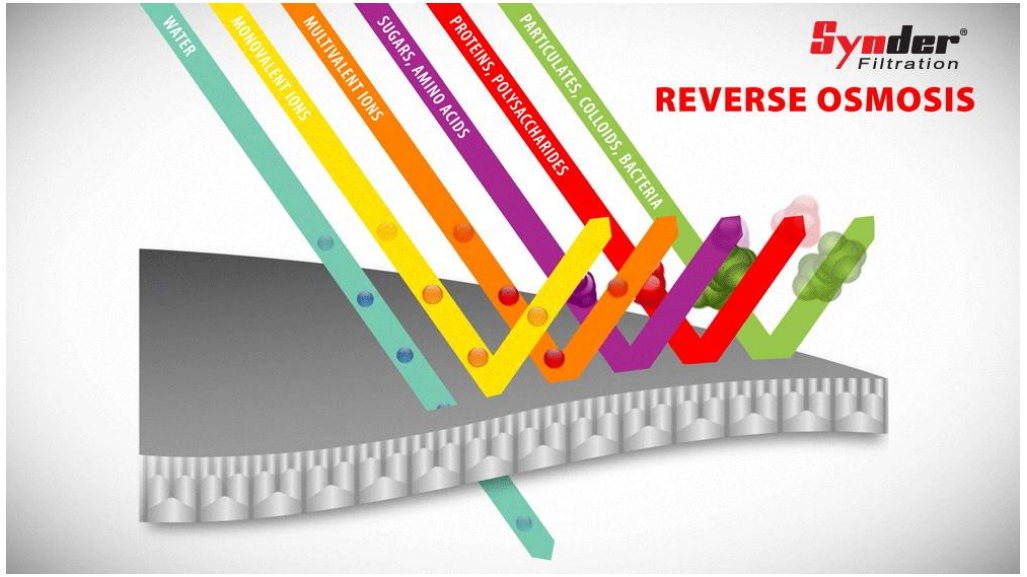

Why Membranes Matter to R&D

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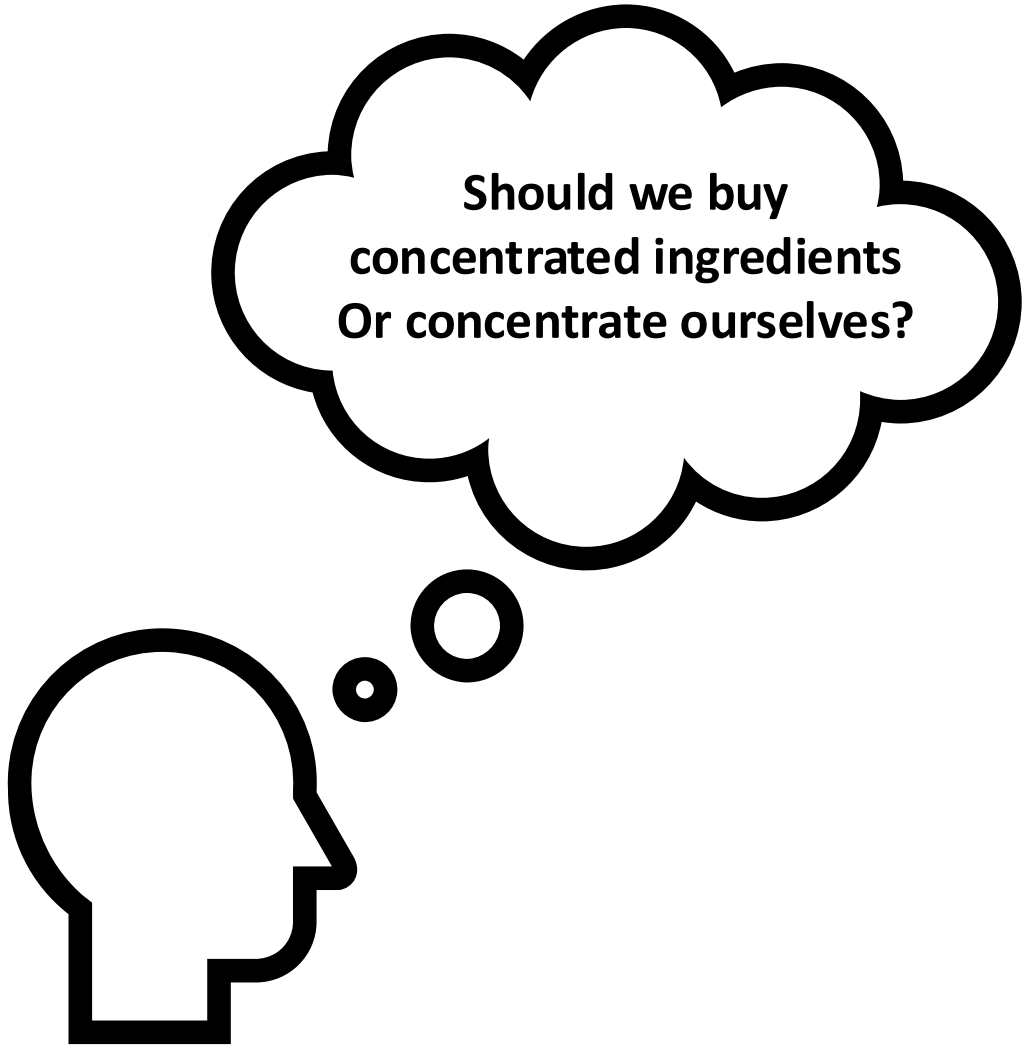
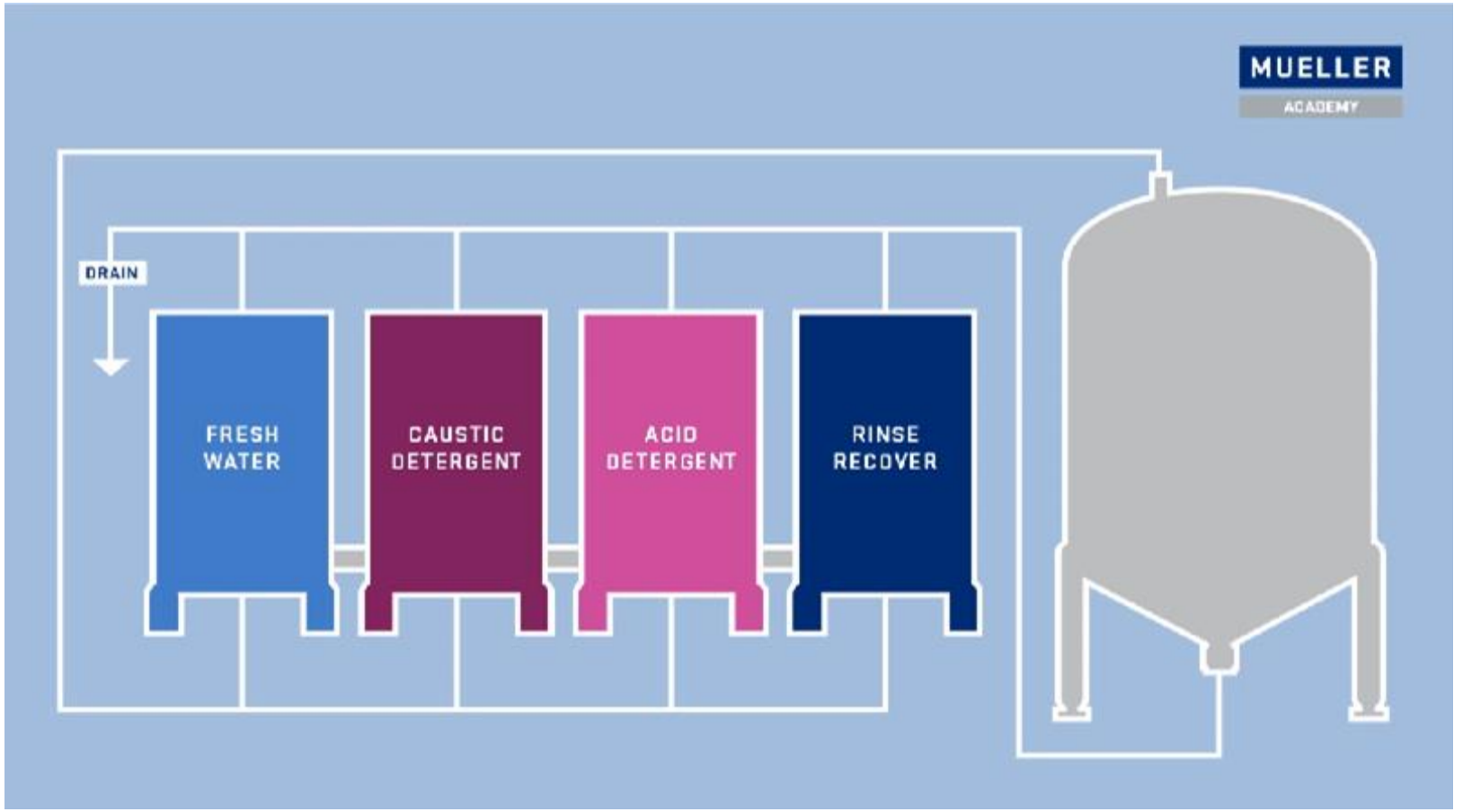
- Uses:
  - Higher protein
  - Reduced lactose
  - Higher viscosity
  - Improved yield
  - Lower transportation cost
- Challenges
  - Fouling
  - Higher pumping energy
  - Different heat stability
  - Protein aggregation





Formulation and CIP Consideration

CIP (Cleaning in Place)

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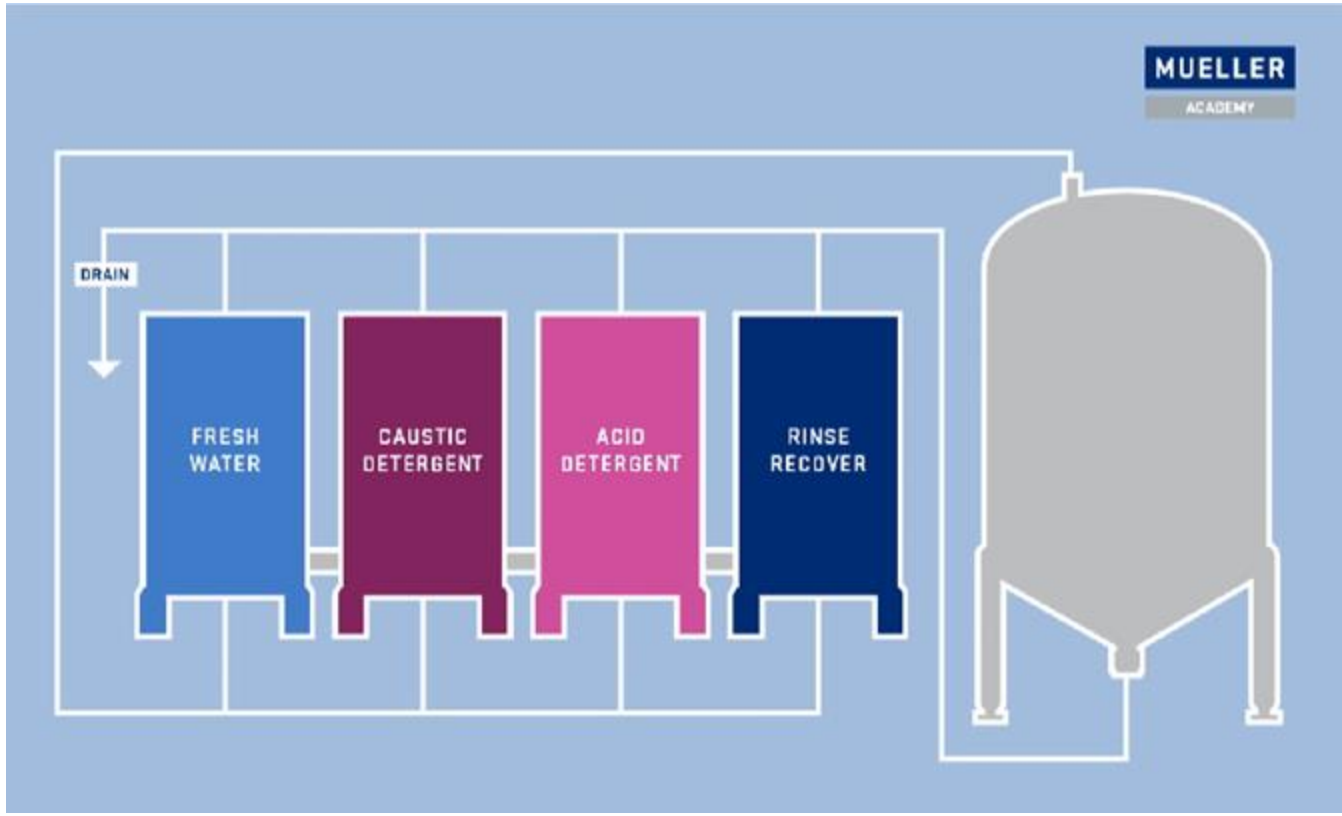
- **Pre-Rinse**: Water
- **Caustic Wash**: Caustic soda (sodium hydroxide)
- **Rinse**: Water
- **Acid Wash**: Phosphoric acid
- **Rinse**: Water
- **Sanitization**: hypochlorite solutions (potassium, sodium, or calcium), peracetic acid (PAA)- a combination of hydrogen peroxide and acetic acid.



Cleaning influences formulation

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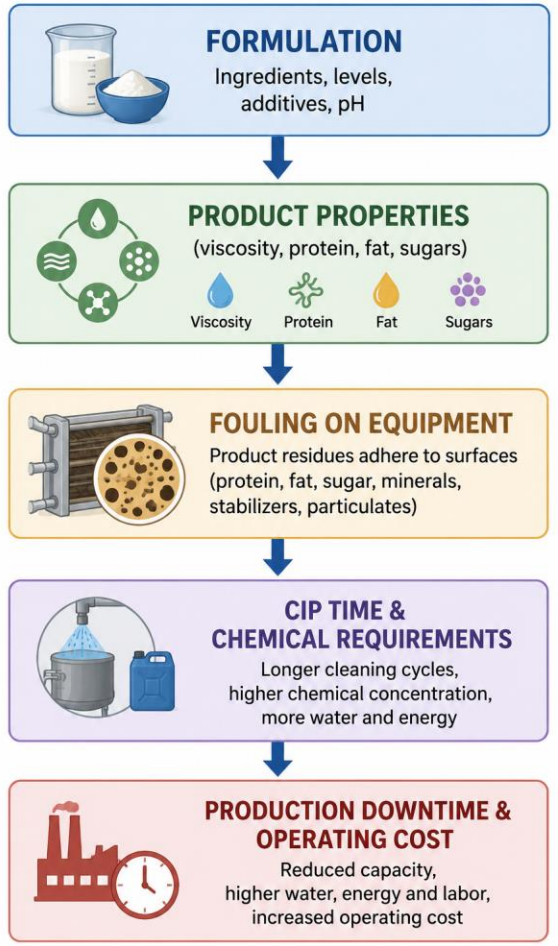
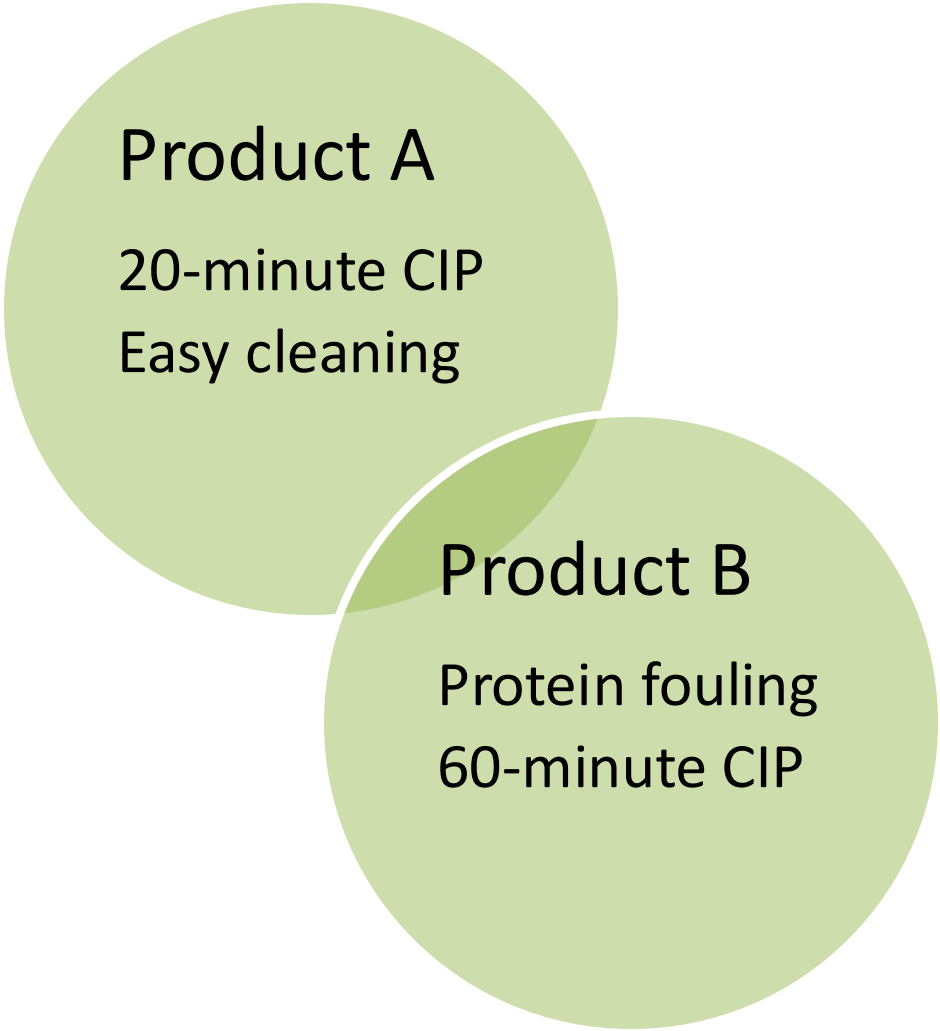
- High-protein formulations → High-protein fouling →requiring longer or more aggressive CIP
- High-fat products → Fat greasy deposits → require effective alkaline cleaning
- High sugar formulations → Sugar residues (caramelize or crystallize)
- Burn-on
- Mineral deposits



Formulation influences cleaning (CIP), and therefore, cleaning requirements should influence formulation decisions

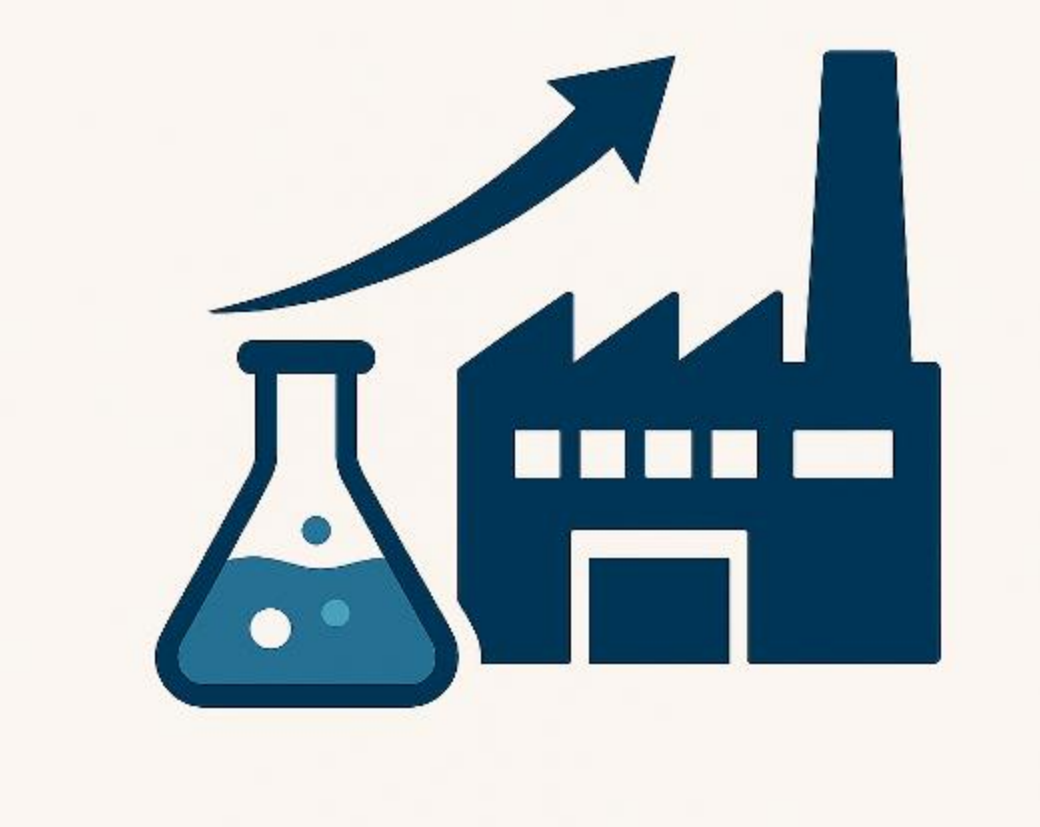
Cleaning influences formulation

- Production impact:
  - One extra CIP everyday equals
    - Less production
    - Higher labor
    - More chemicals
    - Higher water usage



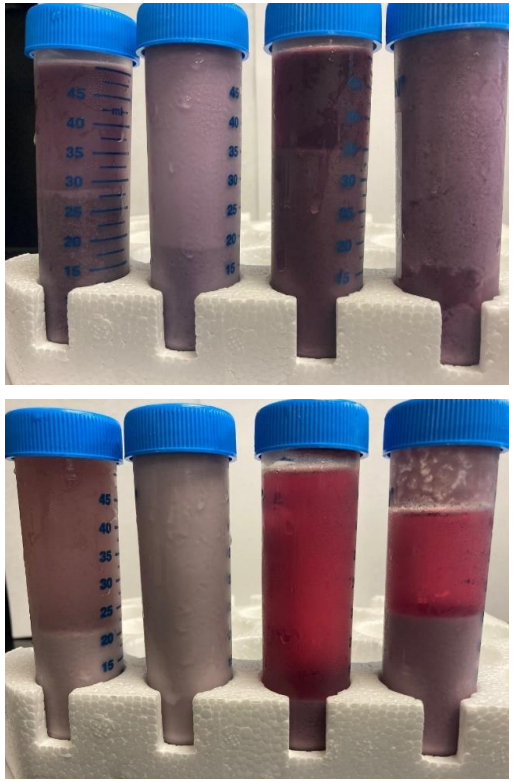
Scale-Up Challenges

- Lab is NOT the plant
- 5 L vs 5,000 L
- Hand mixing vs Mechanical agitation
- Rapid vs Slow cooling
- Batch pasteurization vs HTST
- Long pipelines, different shear



Scale-Up Challenges

- Protein beverage
  - Stable in the laboratory vs. Coagulates after UHT due to different heating profile
  - Stabilizer: Hydrates perfectly in blender vs. Forms fisheyes in production tank due to Different mixing energy
- Chocolate milk
  - No settling in lab vs. Settles after transport



Best Practices

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- Five recommendations:
  - Involve Operations early ☑
  - Understand equipment capability ☑
  - Design formulations for manufacturing ☑
  - Consider cleaning during formulation ☑
  - Validate assumptions during pilot trials ☑

Key Takeaways

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CONSUMER-PREFERRED

Loved for taste, texture, nutrition and overall experience.

MANUFACTURABLE

Can be produced reliably and safely with existing or planned capabilities.

ECONOMICAL

Delivers value through attractive margins and efficient use of resources.

CONSISTENT

Same quality, taste and performance in every batch, every time.

SCALABLE

Can grow to meet market demand across geographies and channels.

Questions?

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