# Dairy 101
# Dairy Powders
# World Food Aid Conference

May 10, 2017

UNITED DAIRYMEN of IDAHO

# Milk: Composition and Characteristics

- What, exactly, is milk?
- All mammals secrete milk, it is the defining characteristic of the class which includes 5000 species.
- We will focus only on Bos taurus.
- There is a legal definition:  the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows (see Code of Federal Regulations Title 21 Part 131.110).

UNITED DAIRYMEN of IDAHO

# Milk: Composition and Characteristics

- Milk is synthesized in the mammary gland of the cow
- Mammary epithelial cell is a miracle
- 1 gram secretory tissue synthesizes 2 g milk/day
- Conversion of one body fluid, blood, to another fluid, milk
- Blood being the precursor, all base components must come from blood
- 500 volumes of blood must flow through the mammary gland resulting in 1 volume of milk.

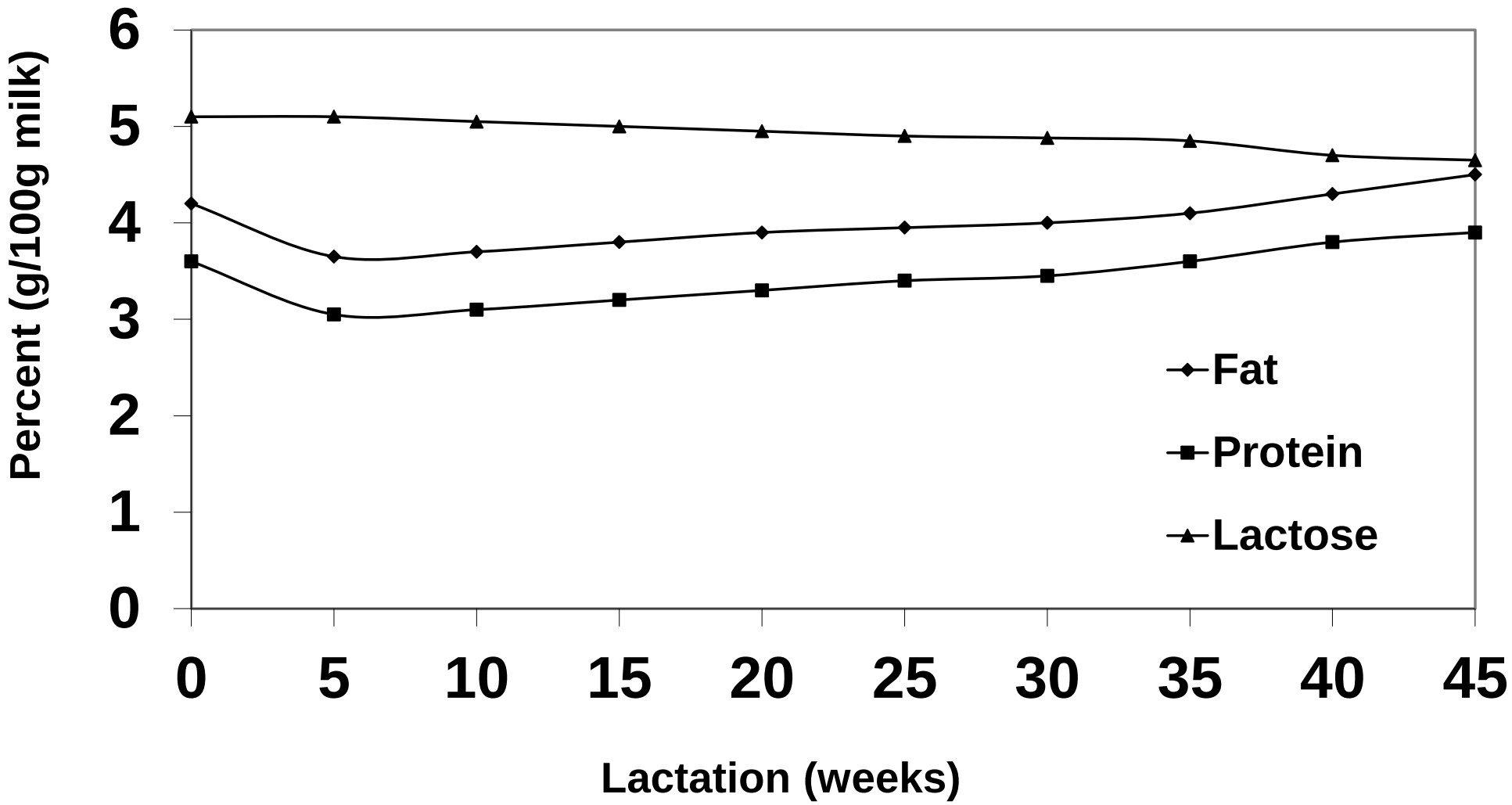
UNITED DAIRYMEN of IDAHO

# Milk: Composition and Characteristics

| Component | Average Percentage |
|---|---|
| Water | 86.6 |
| Fat | 4.1 |
| Protein | 3.6 |
| Lactose | 5.0 |
| Ash | 0.7 |

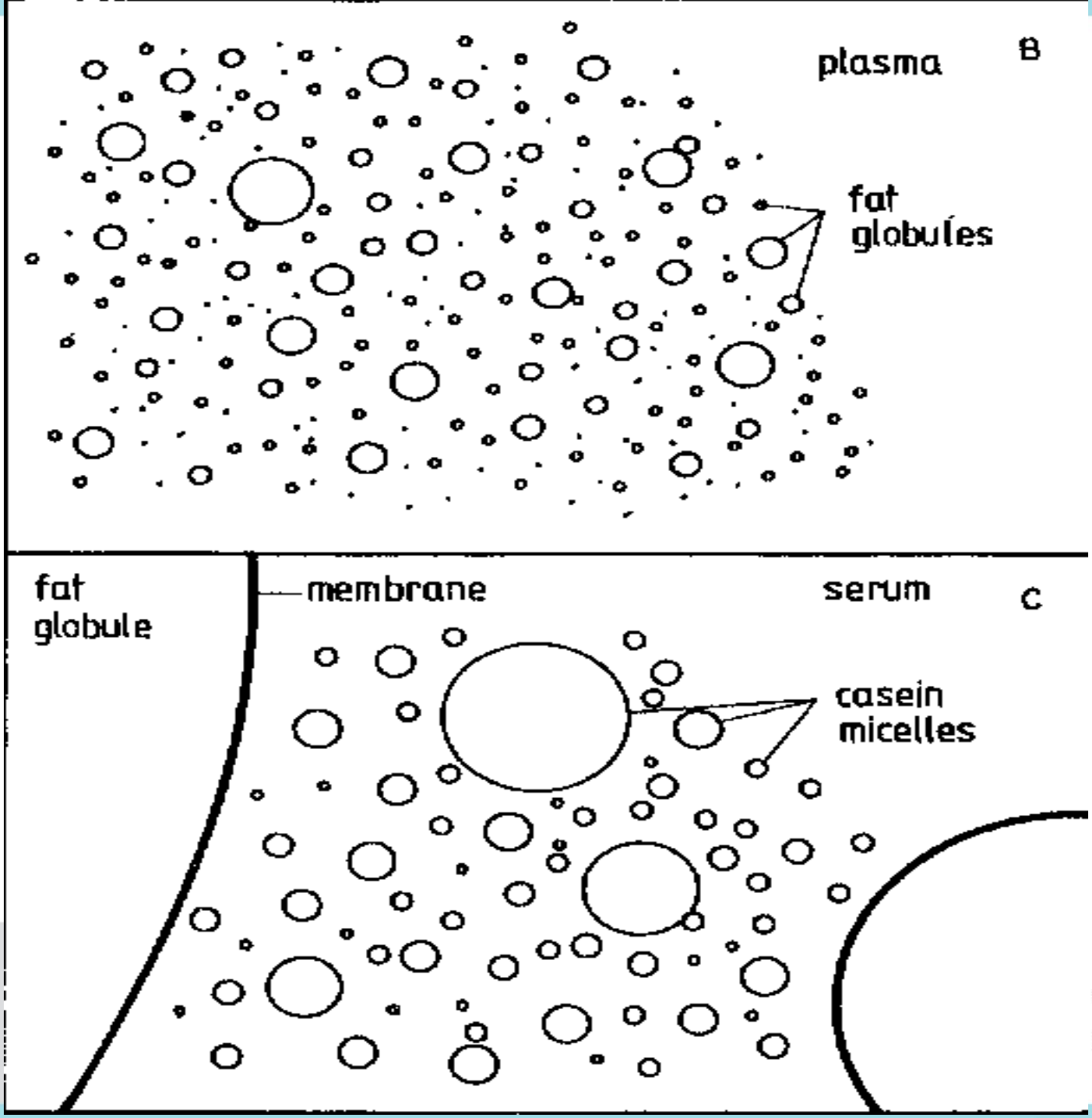
UNITED DAIRYMEN of IDAHO

# Lactational variations in milk composition



# Particles that Exist in Milk

- Fat globules
- Casein micelles
- Milk plasma is the term used to designate the fat-free portion of milk.
- Milk serum is the term used to designate the fat-free and casein micelle-free portion of milk.

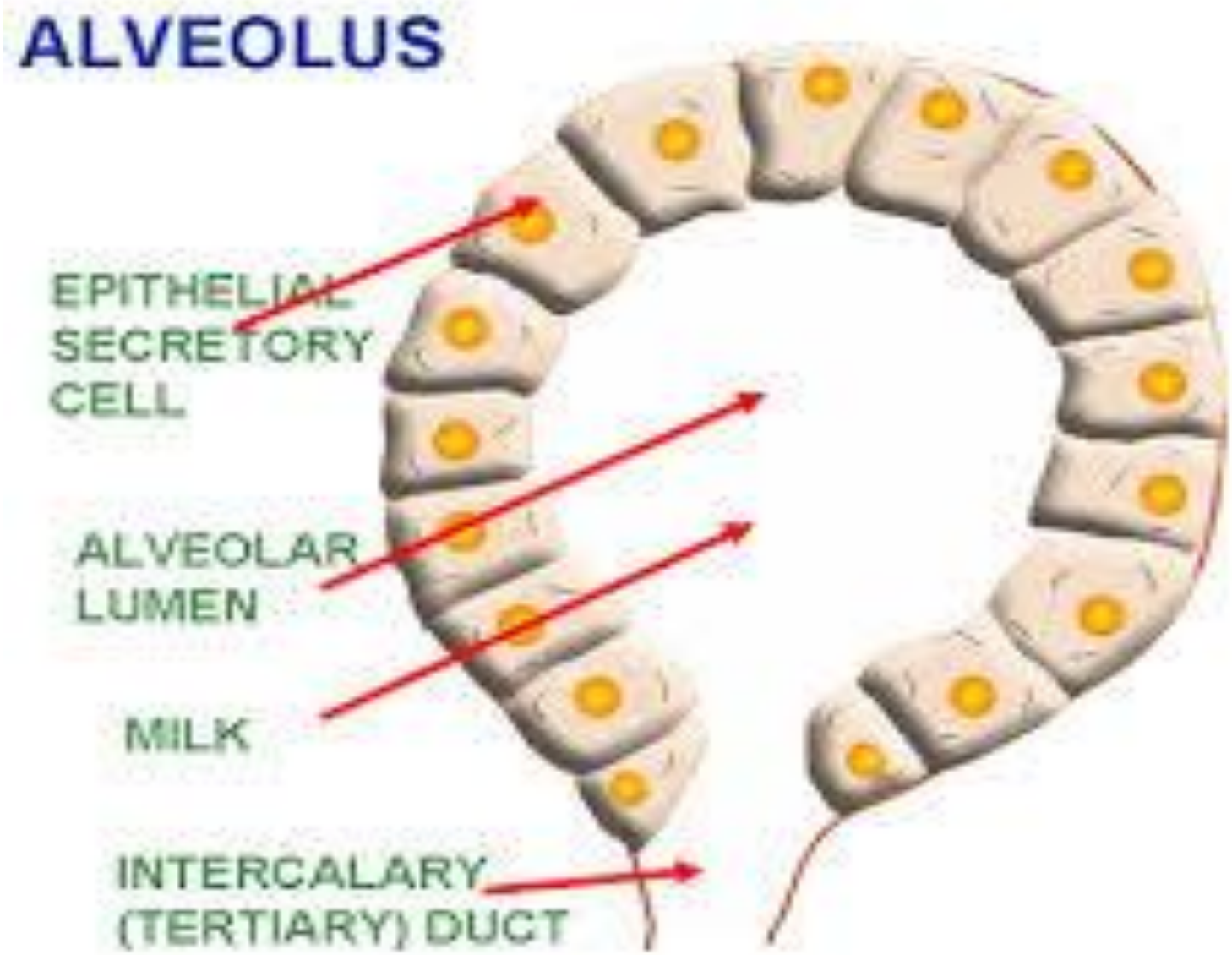

plasma
B
fat
globules
fat
globule
membrane
serum
C
casein
micelles

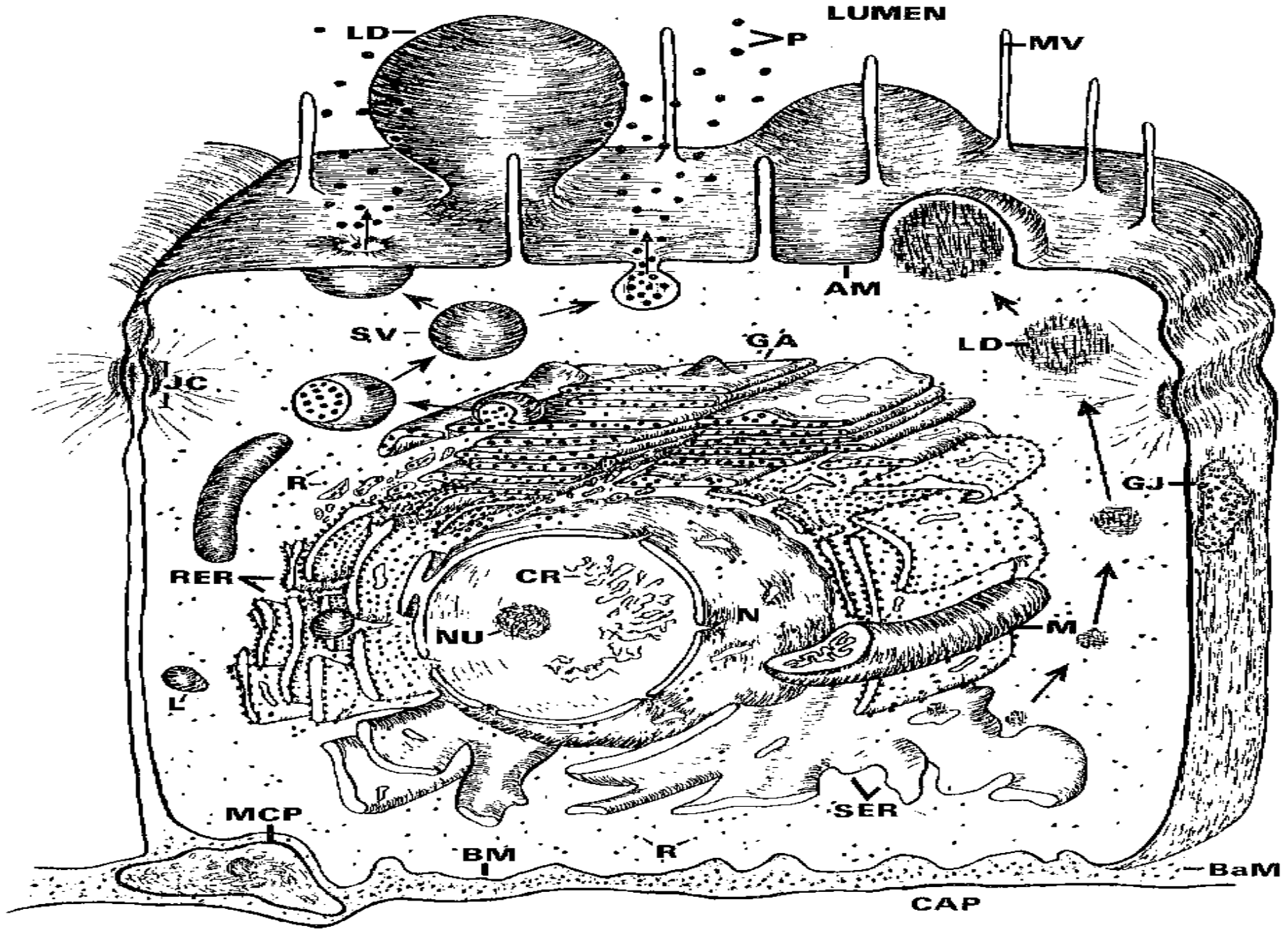
# Milk Fat Globules

- Large – 1-10 microns in size
- Milk Fat Globule Membrane – Cell membrane wrapped around the triglyceride core

UNITED DAIRYMEN of IDAHO

# Milk Secretion




LUMEN
LD
P
MV
AM
SV
GA
LD
JC
R
GJ
RER
CR
N
NU
M
L
MCP
SER
BM
R
BaM
CAP

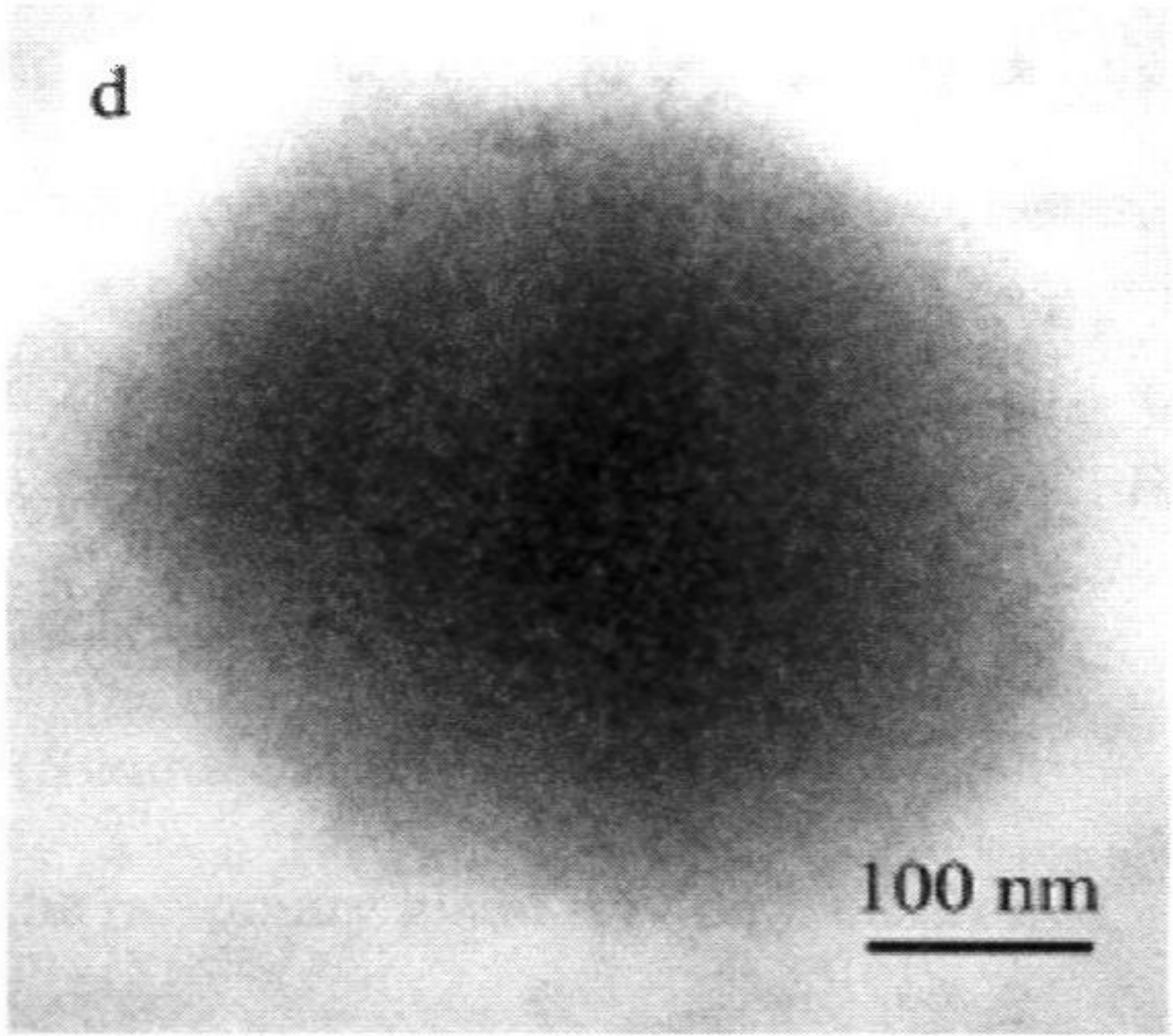
# Milk Proteins

| Protein | Concentration g/L | Approximate % |
|---|---|---|
| **Caseins** | **24-28** | **80** |
| Alpha-casein | 15-19 | |
| Beta-casein | 9-11 | |
| Kappa-casein | 3-4 | |
| Gamma-casein | 1-2 | |
| **Whey Proteins** | **5-7** | **20** |
| Beta-lactoglobulin | 2-4 | |
| Alpha-lactalbumin | 1-1.5 | |
| Serum albumin | 0.1-0.4 | |
| Immunoglobulins | 0.6-1.0 | |

# Casein Micelles

- Casein molecules tend to interact, forming large clusters of protein
- We call these clusters casein micelles.
- Calcium phosphate is highly involved in holding casein micelles together
- 2/3 of calcium in milk is tied into casein micelles and the other 1/3 exists in aqueous phase.
- Casein micelles range between 0.02-0.3 microns in size. Much smaller that fat globules.
- Casein micelles are “stabilized” by kappa-casein that is mostly located on the exterior areas of the micelle

UNITED DAIRYMEN of IDAHO

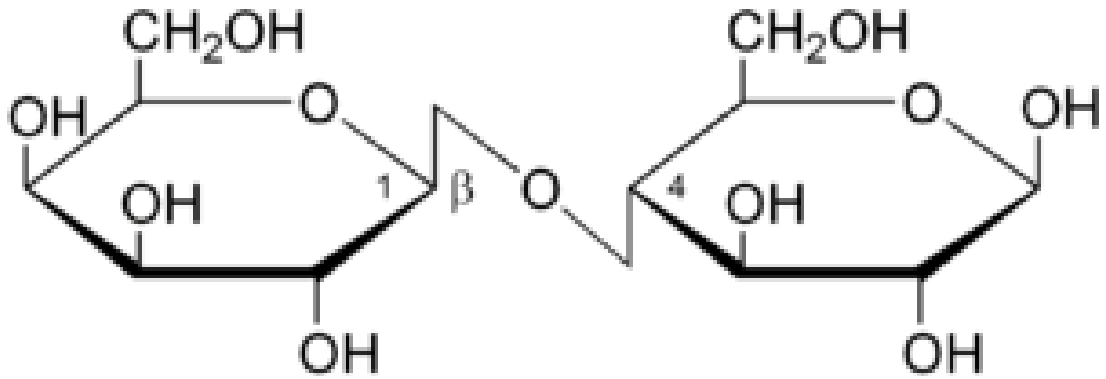

d
100 nm

# Lactose – Milk Sugar

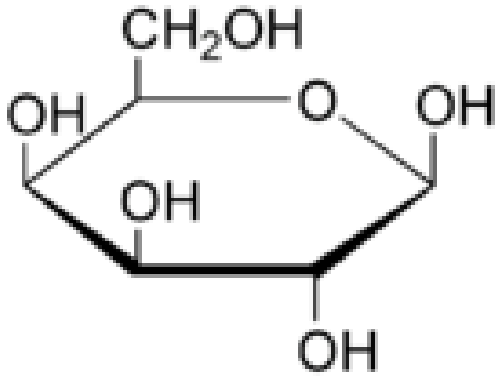
- Besides water, lactose is the component at highest concentration in milk.
- Lactose is a disaccharide, meaning there are two sugar units connected to form the compound. They are galactose and glucose.
- During cheese manufacture, most of the lactose goes into the whey.
- Some bacteria can grow on lactose, using it as an energy source. Most of these convert lactose to lactic acid.

UNITED DAIRYMEN of IDAHO

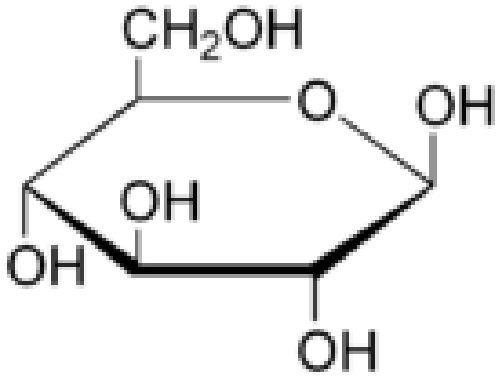
# Lactose and its two subunits



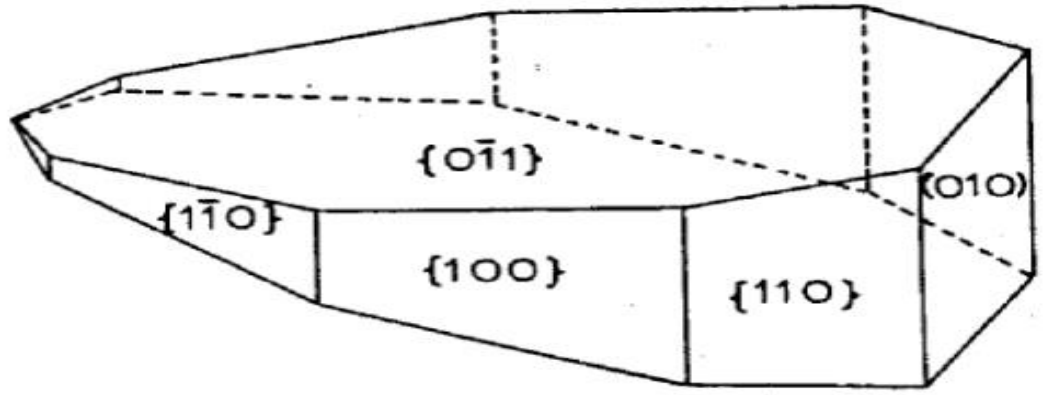

Lactose

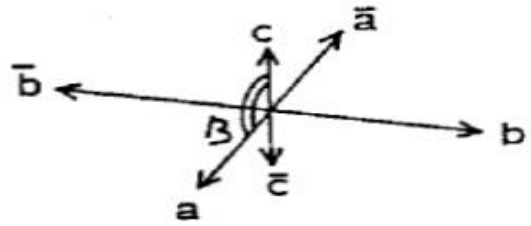


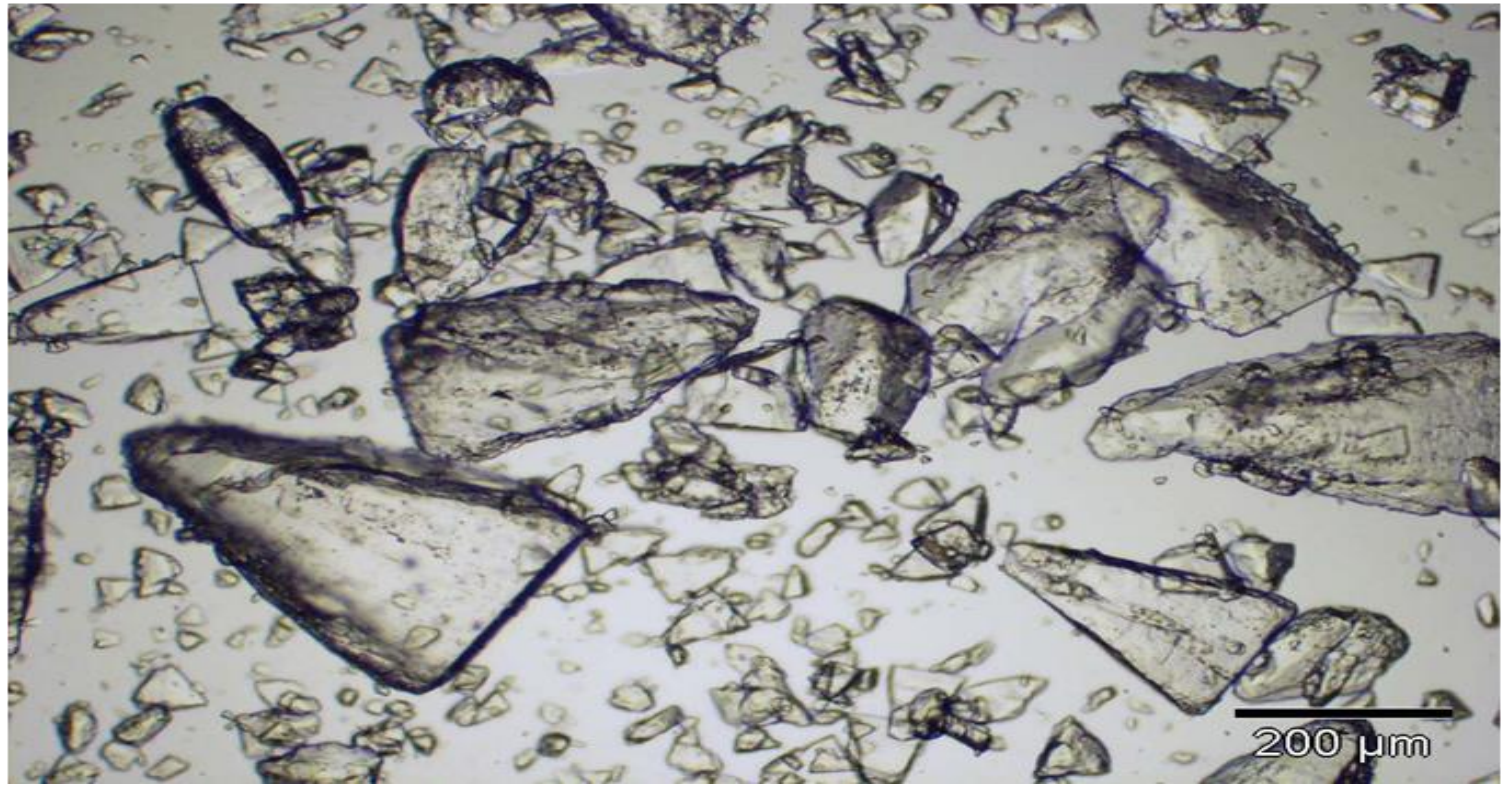

D-galactose




D-glucose


{0$\bar{1}$1}
{1$\bar{1}$0}
{100}
{110}
{010}


c
$\bar{a}$
$\bar{b}$
β
b
$\bar{c}$
a


200 µm

# Minerals in Milk

| Constituent | Mean (mg/100g) | Range (mg/100g) | Standard Deviation |
|---|---|---|---|
| Sodium | 58 | 47-77 | 10 |
| Potassium | 140 | 113-171 | 14 |
| Calcium | 118 | 111-120 | 2.5 |
| Magnesium | 12 | 11-13 | 0.6 |
| Phosphorus | 74 | 61-79 | - |
| Inorganic P | 63 | 52-70 | - |
| Ester P | 11 | 8-13 | 1.7 |
| Chloride | 104 | 90-127 | 11.4 |
| Citrate | 176 | 166-192 | 9 |

Taken from Fundamentals of Dairy Chemistry, 1988, Wong, Jennes, Keeney and Marth.

UNITED DAIRYMEN of IDAHO

# Milk Processing

- Milk hauling
- Pasteurization
- Homogenization
- Separation
- Filtration
- Evaporation
- Spray Drying

UNITED DAIRYMEN of IDAHO

# Milk Tanker

# Pasteurization

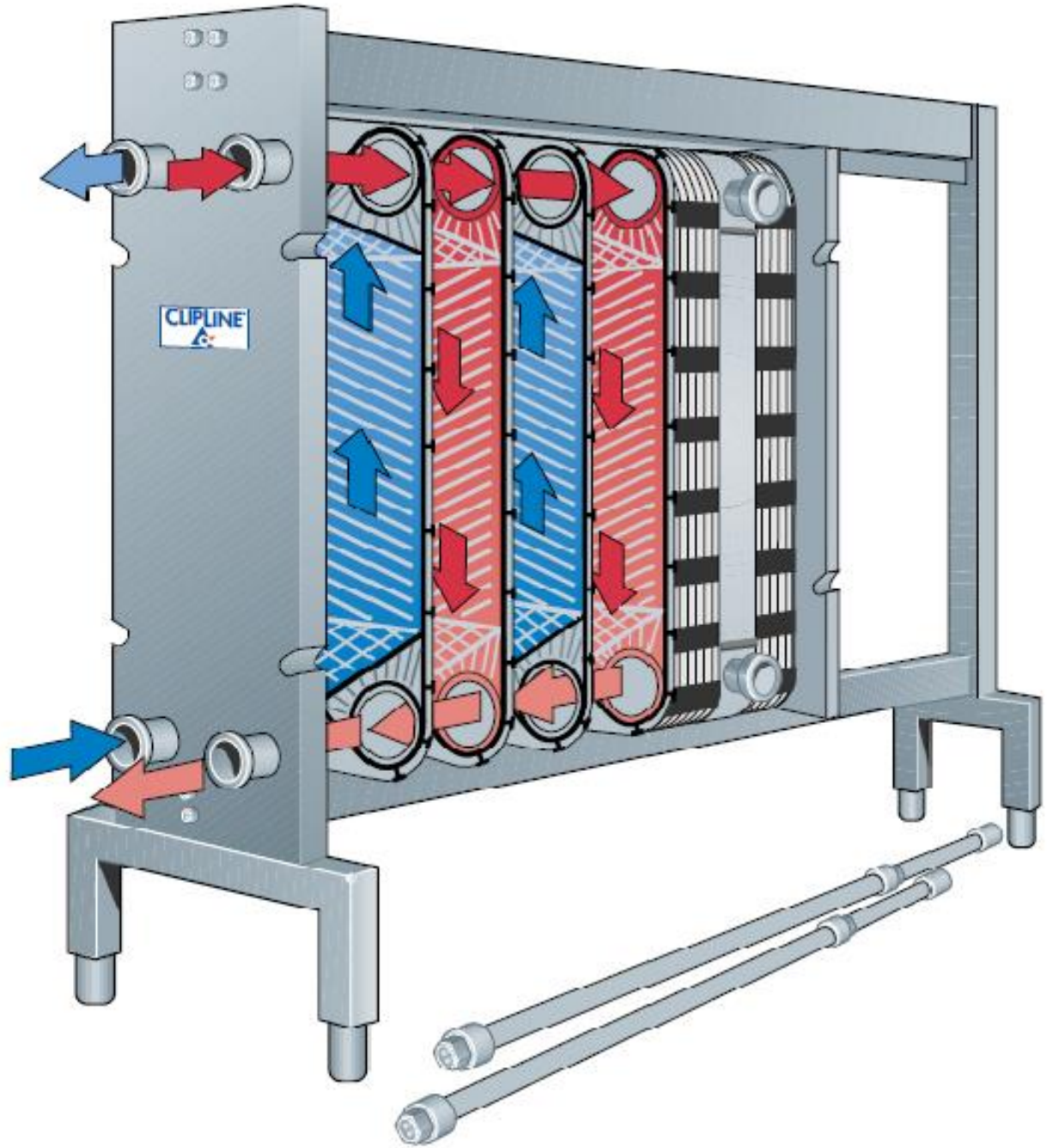
| Temperature | Time |
| --- | --- |
| 63°C (145°F) | 30 minutes |
| 72°C (161°F) | 15 seconds |
| 89°C (191°F) | 1 second |

UNITED DAIRYMEN of IDAHO

# Where do these numbers originate?

- Looking for destruction of the most heat-resistant pathogen that can be transmitted in milk.
- *Coxiella burnetti* – Q-fever
- *Mycobacterium tuberculosis*
- Pasteurization is not an aseptic process
  - Psychrophiles

UNITED DAIRYMEN of IDAHO


CLIPLINE

# Creaming

- Cream layer forms in normal pasteurized or raw milk.
- What if consumers don’t want to see the cream layer or have it formed?

- Homogenization!

# Homogenization

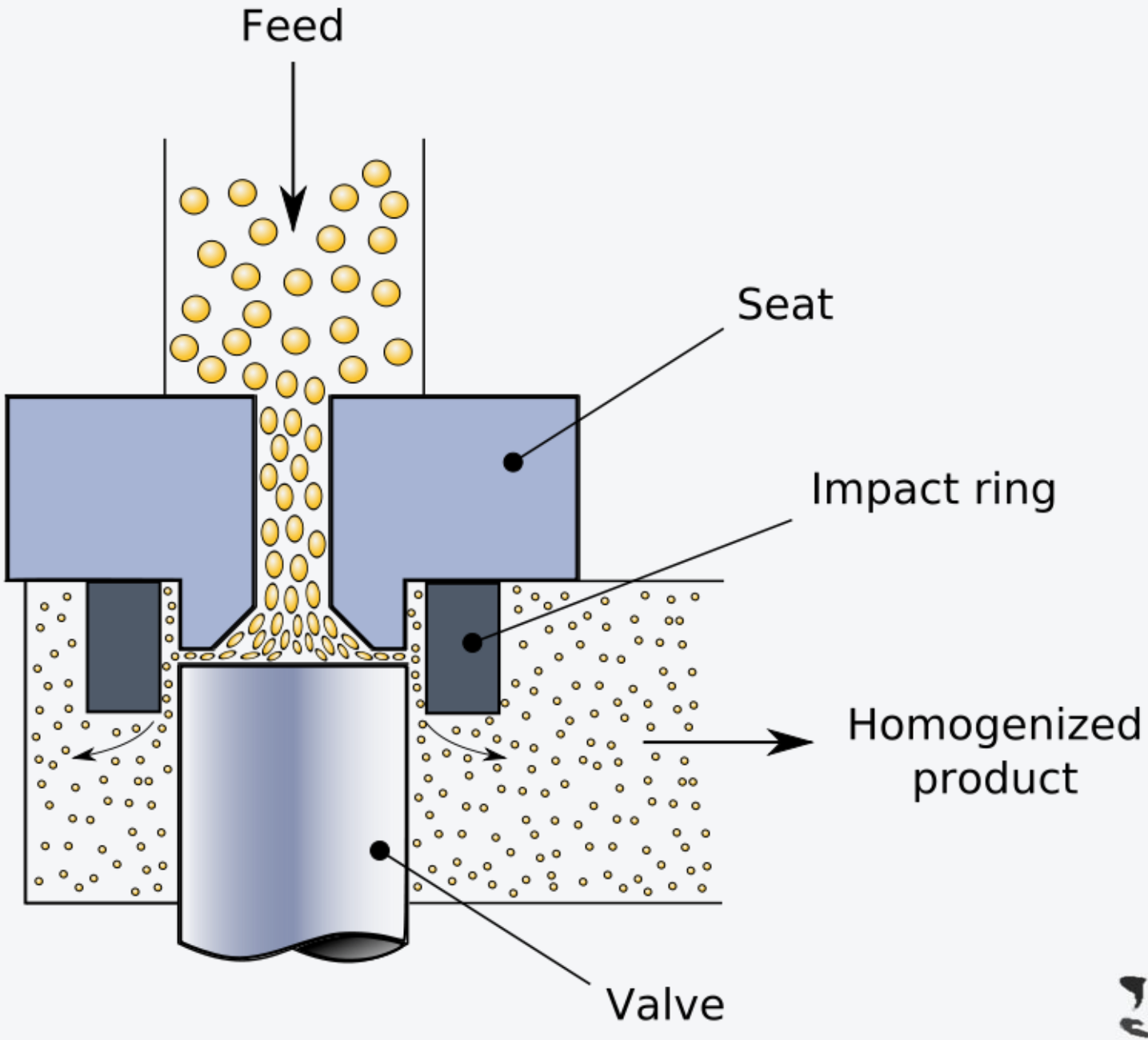
Milk treated such that after 48 h at 7°C (45°F)

1. there is no visible separation of cream.
2. the top 100 ml of milk in a quart does not differ by more than 10% from the remaining milk after mixing.

UNITED DAIRYMEN of IDAHO

# Homogenization

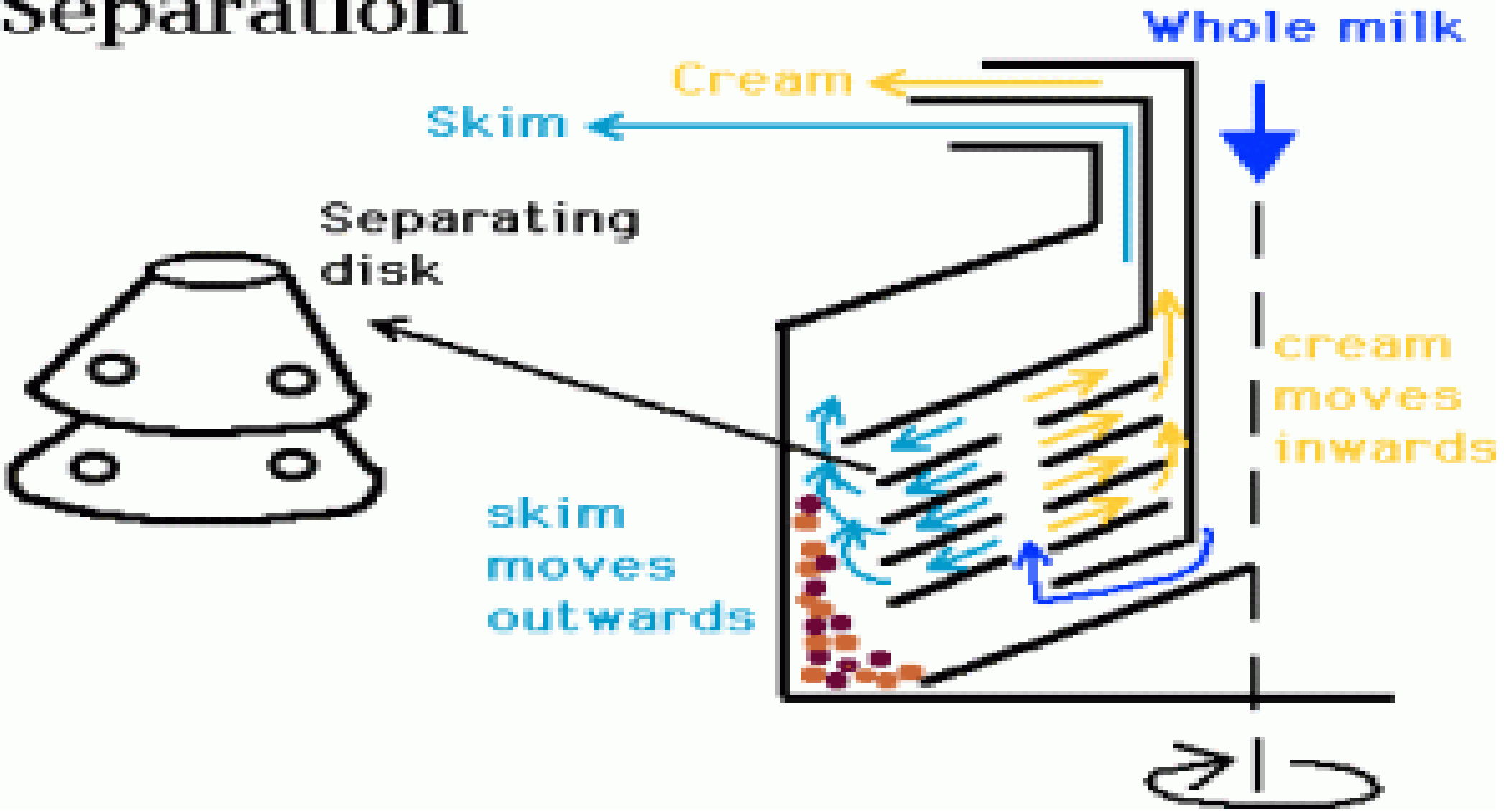

UNITED DAIRYMEN of IDAHO


Feed
Seat
Impact ring
Homogenized
product
Valve

# Separation

- Creaming can be significantly enhanced
  - Increase gravitational force
  - Centrifugal principle
  - Separation based on density difference
    - Density of milk serum – 1.036
    - Density of milk fat – 0.93

# Separation


Whole milk
Cream
Skim
Separating disk
cream moves inwards
skim moves outwards

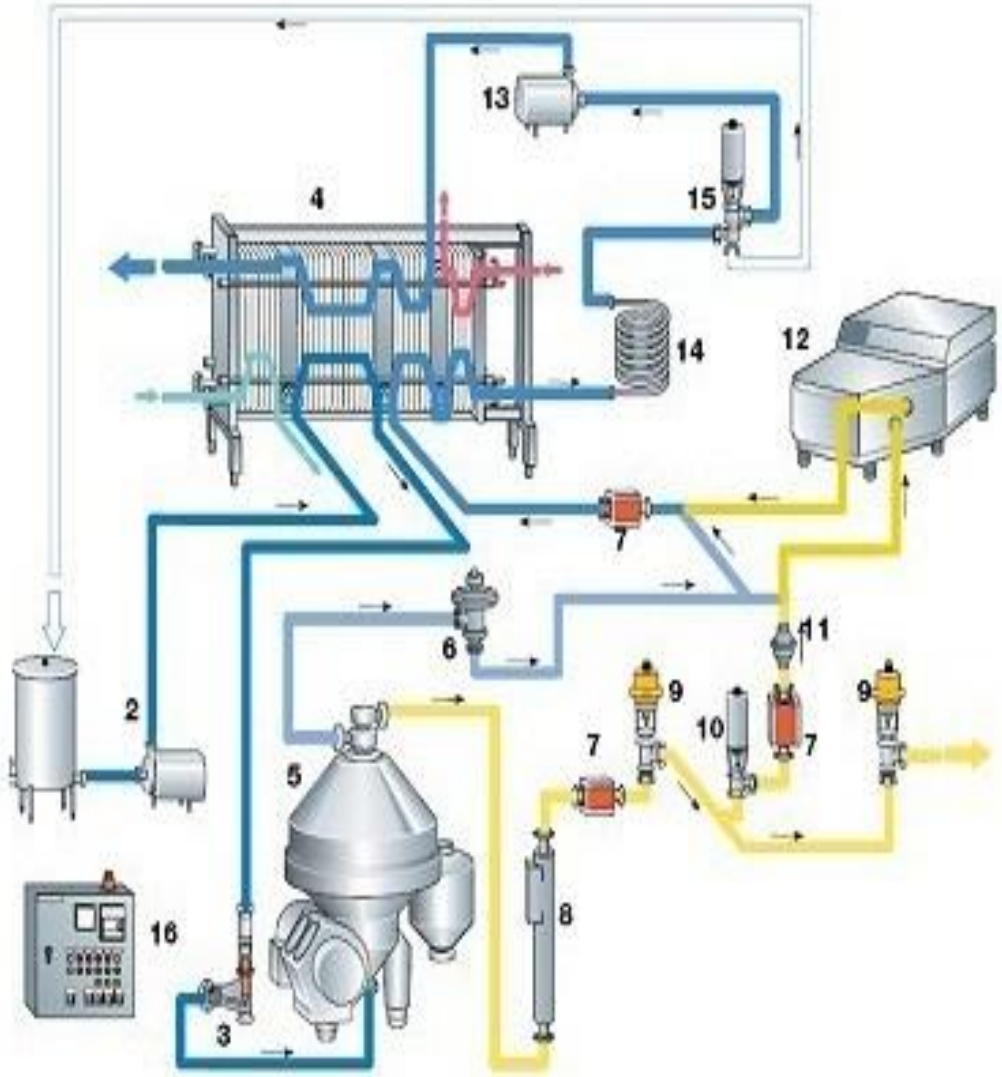


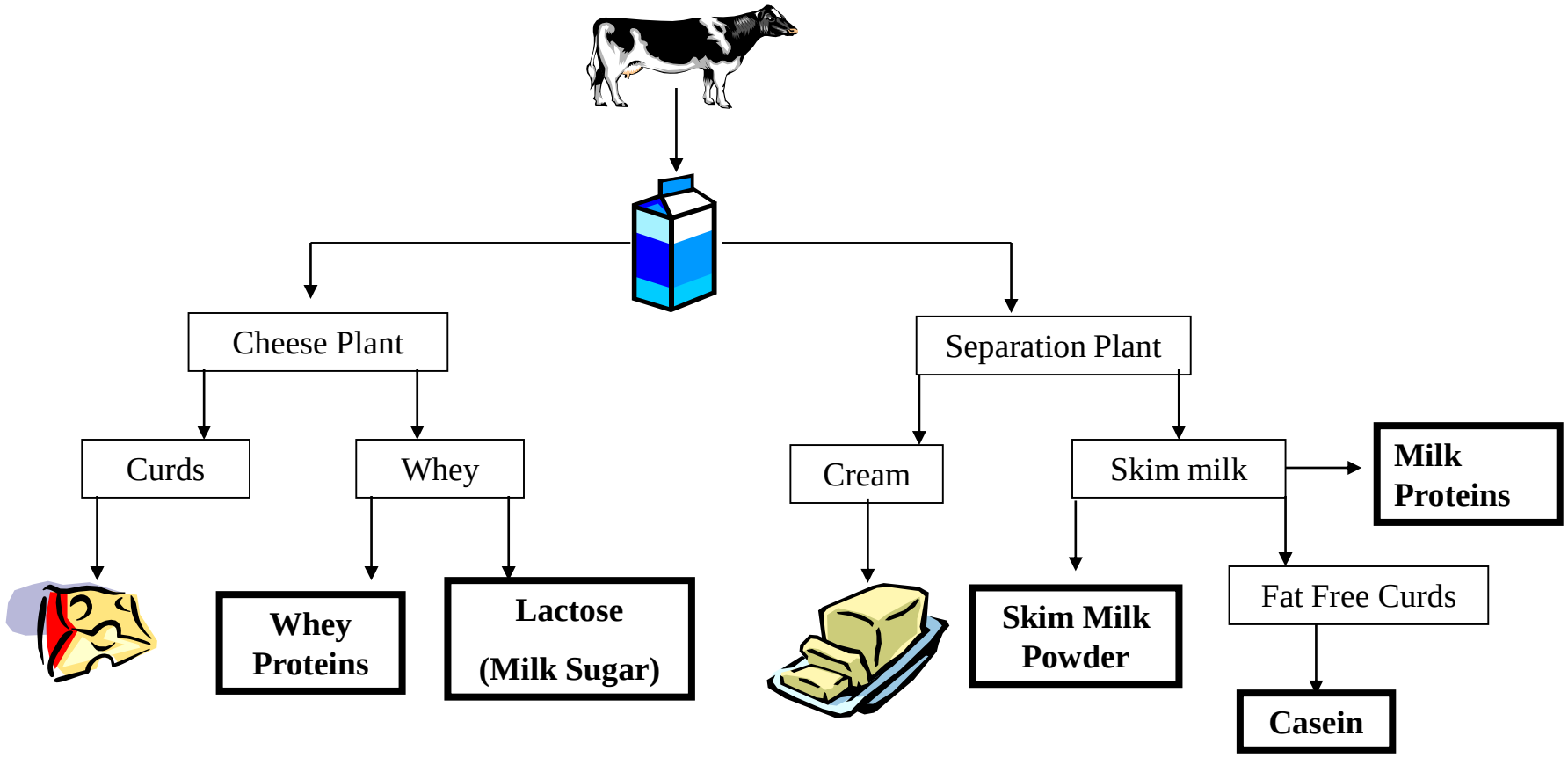

***Fig.*** *Production line for market milk with partial homogenisation.*

1 Balance tank
2 Product feed pump
3 Flow controller
4 Plate heat exchanger
5 Separator
6 Constant pressure valve
7 Flow transmitter
8 Density transmitter
9 Regulating valve
10 Shut-off valve
11 Check valve
12 Homogeniser
13 Booster pump
14 Holding tube
15 Flow diversion valve
16 Process control

- Milk
- Cream
- Skimmilk
- Standardised milk
- Heating medium
- Cooling medium
- Diverted flow

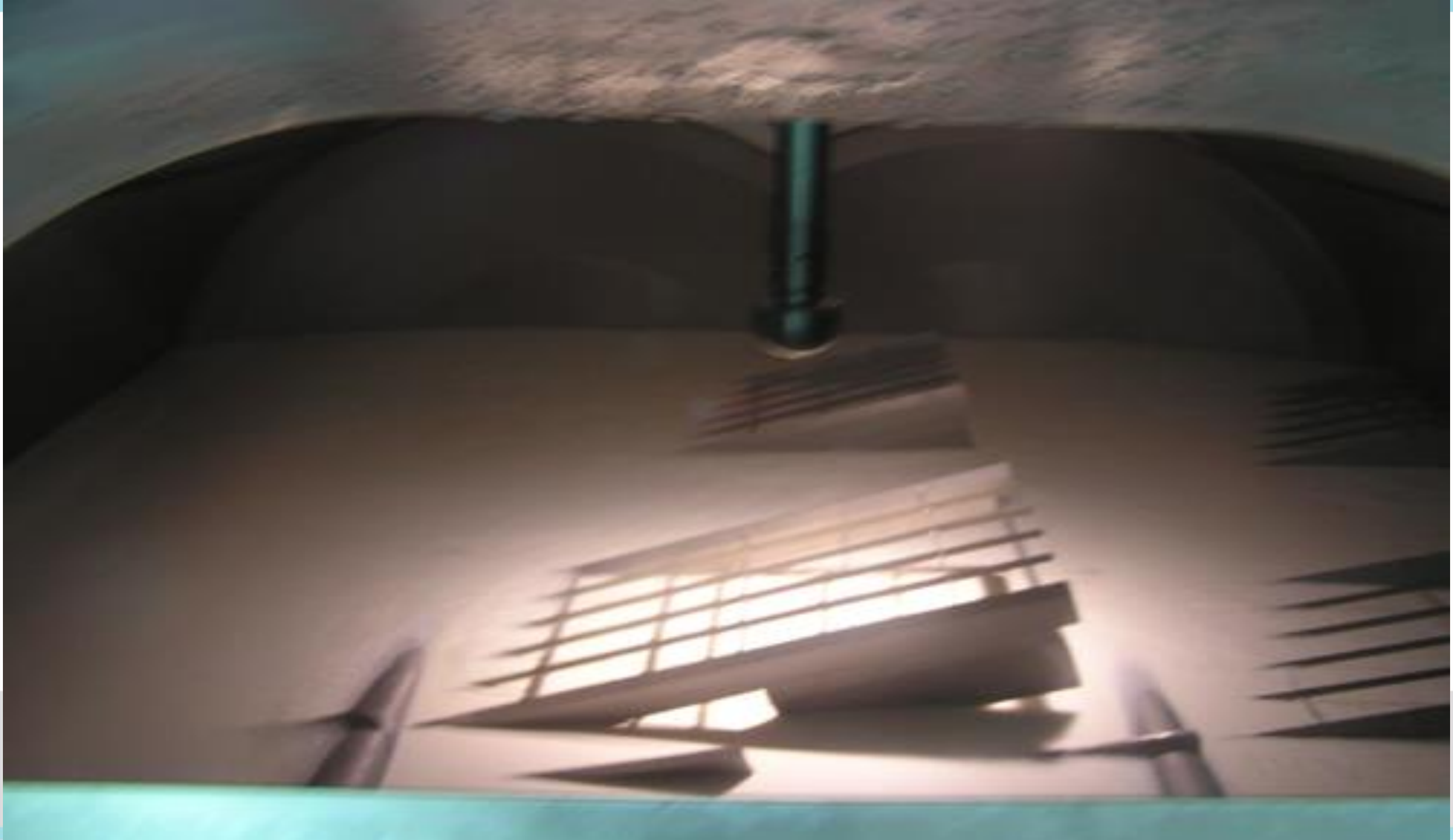
Techgen

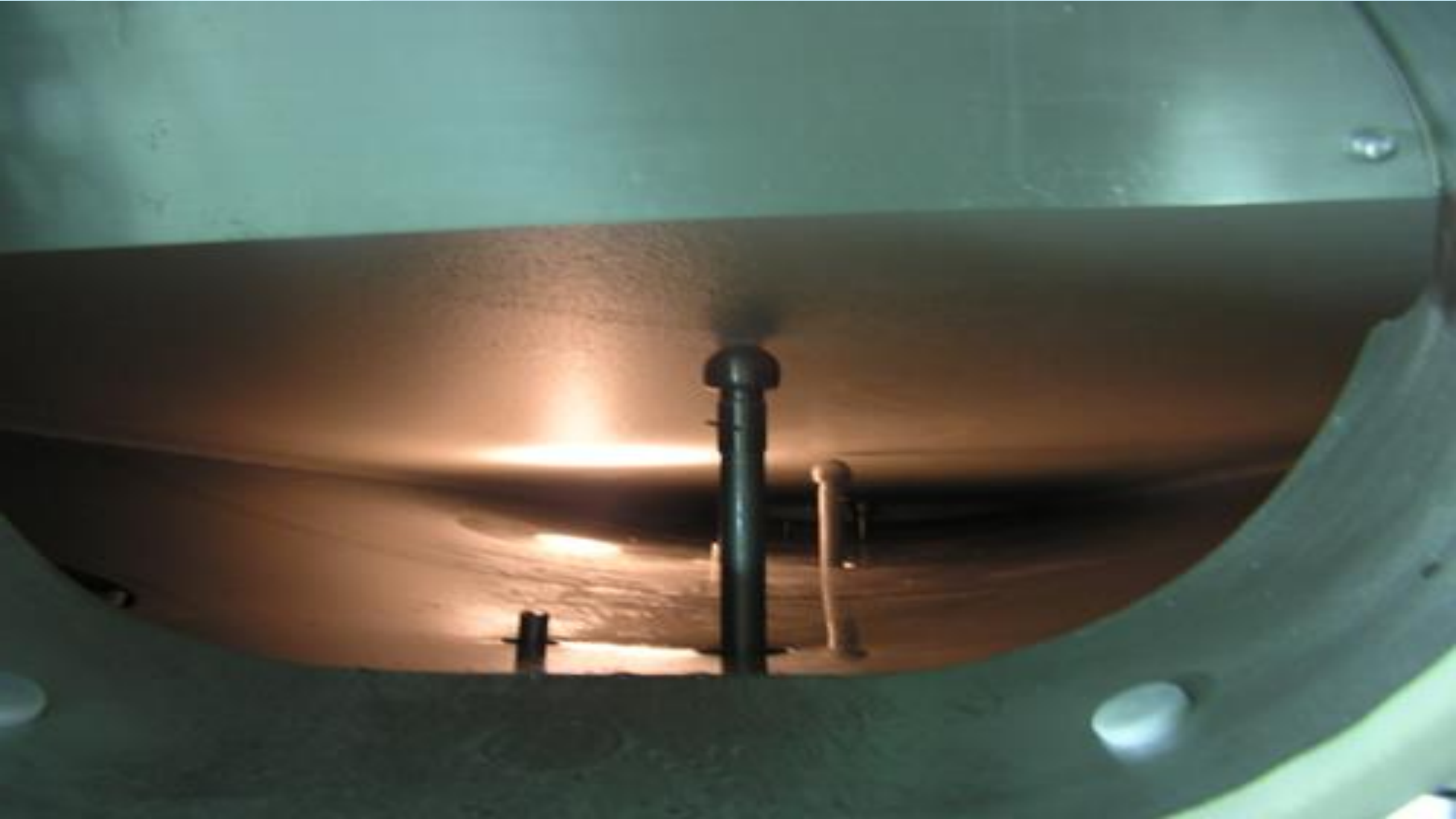
UNITED DAIRYMEN of IDAHO

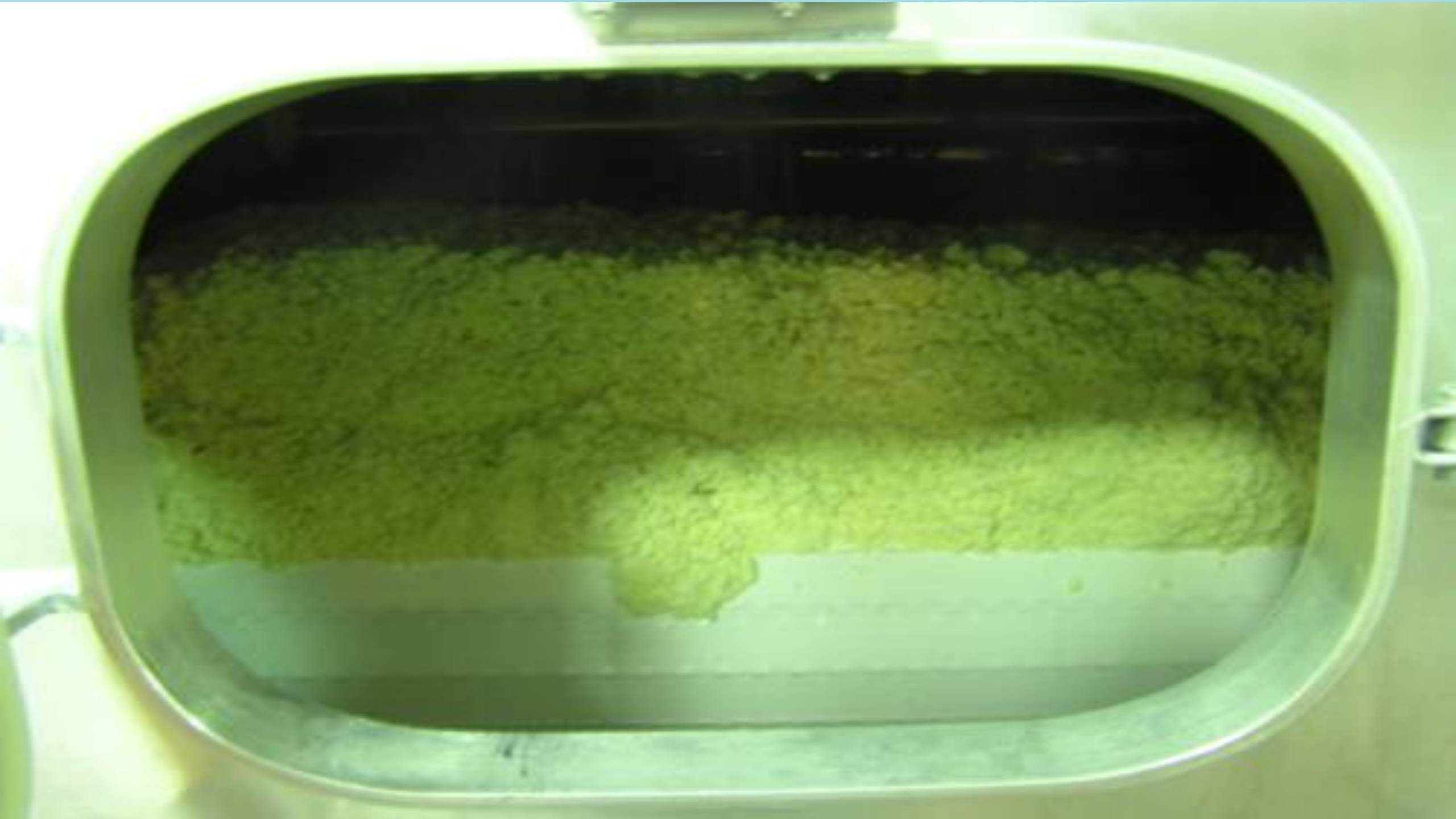


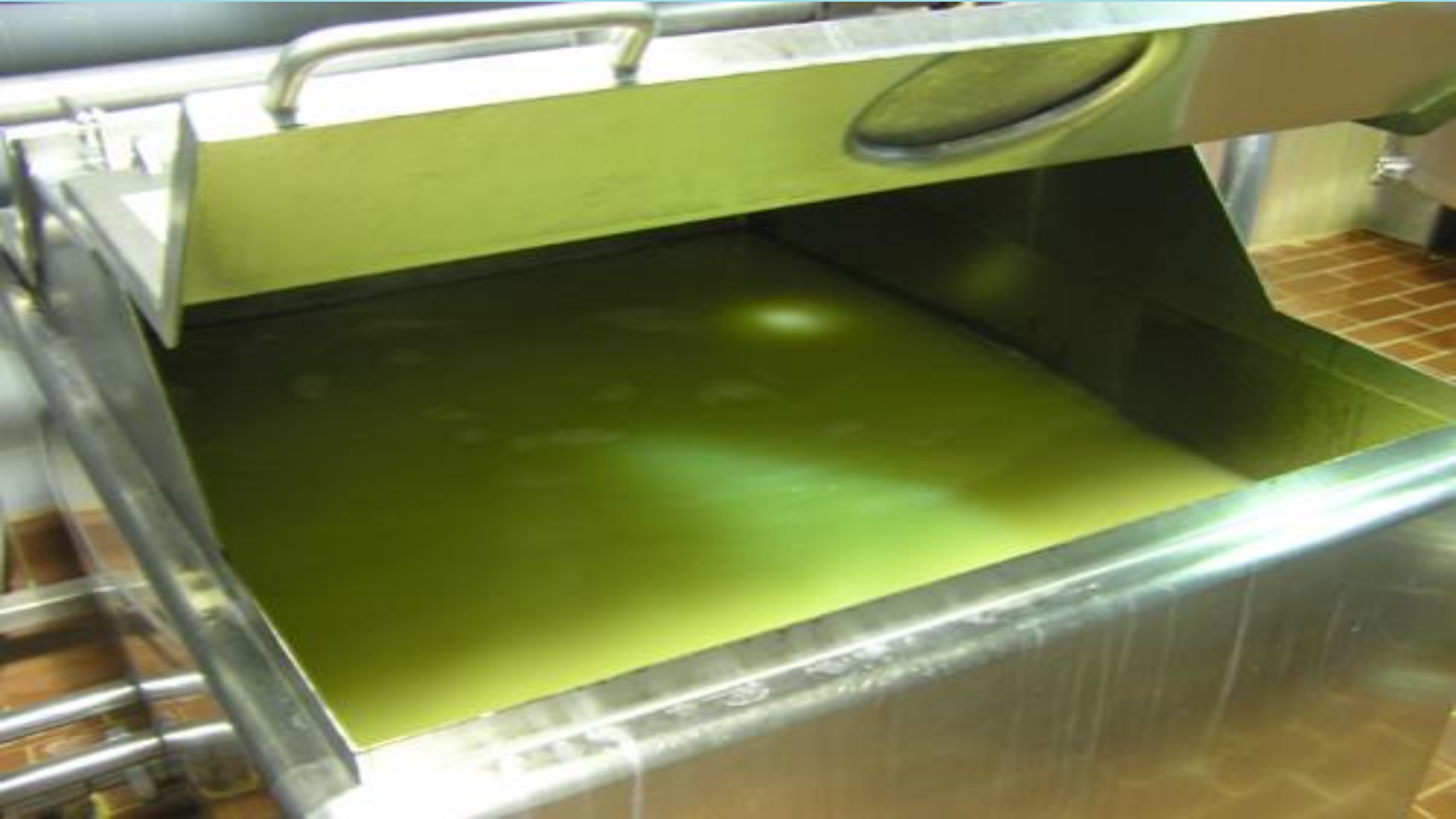

For use as ingredients in processed foods:

Ice Cream, Infant Formula, Nutritional Drinks, Coffee Creamers, Bakery Products, Processed Cheese Products, etc.

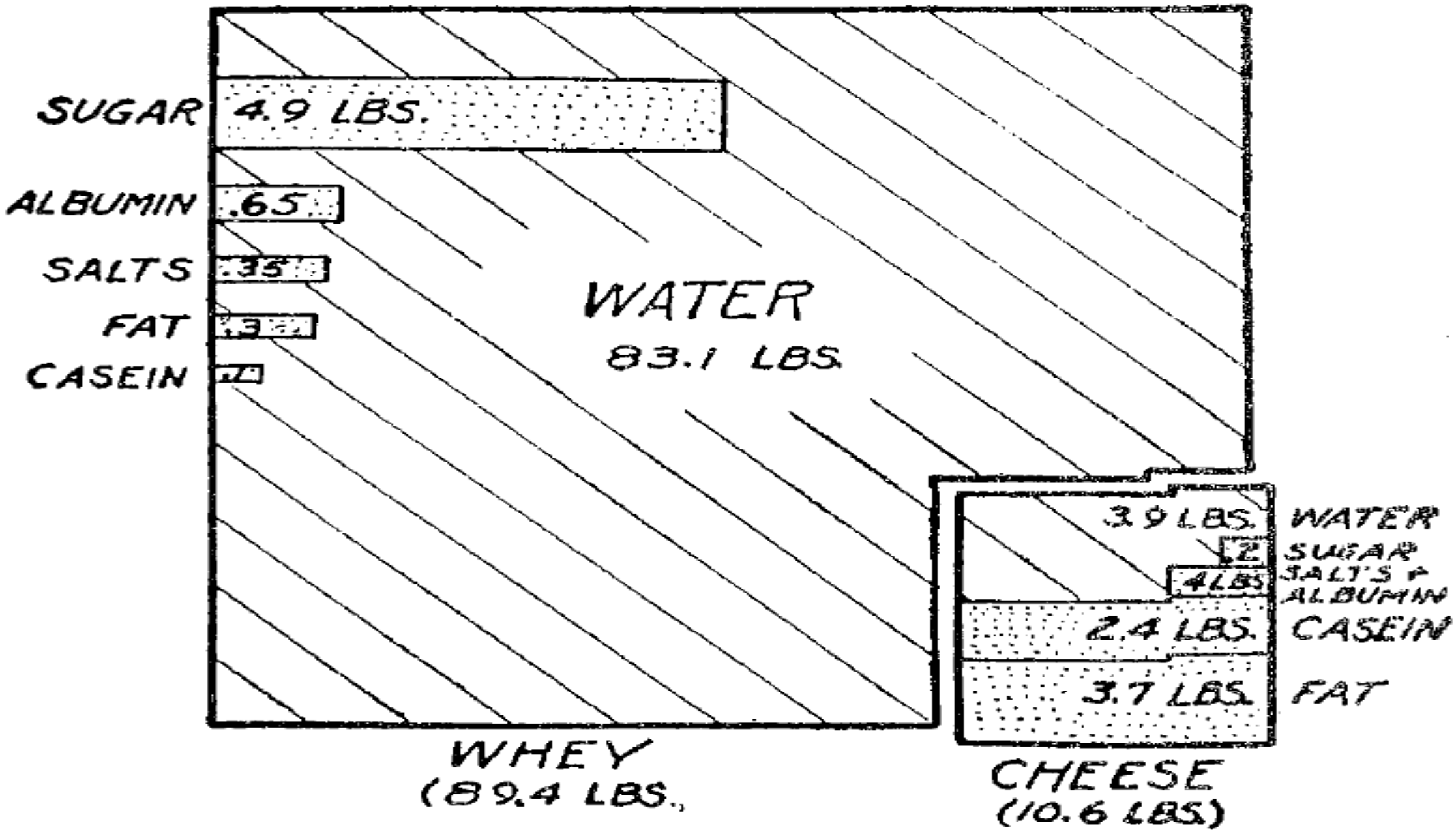









NOT AN

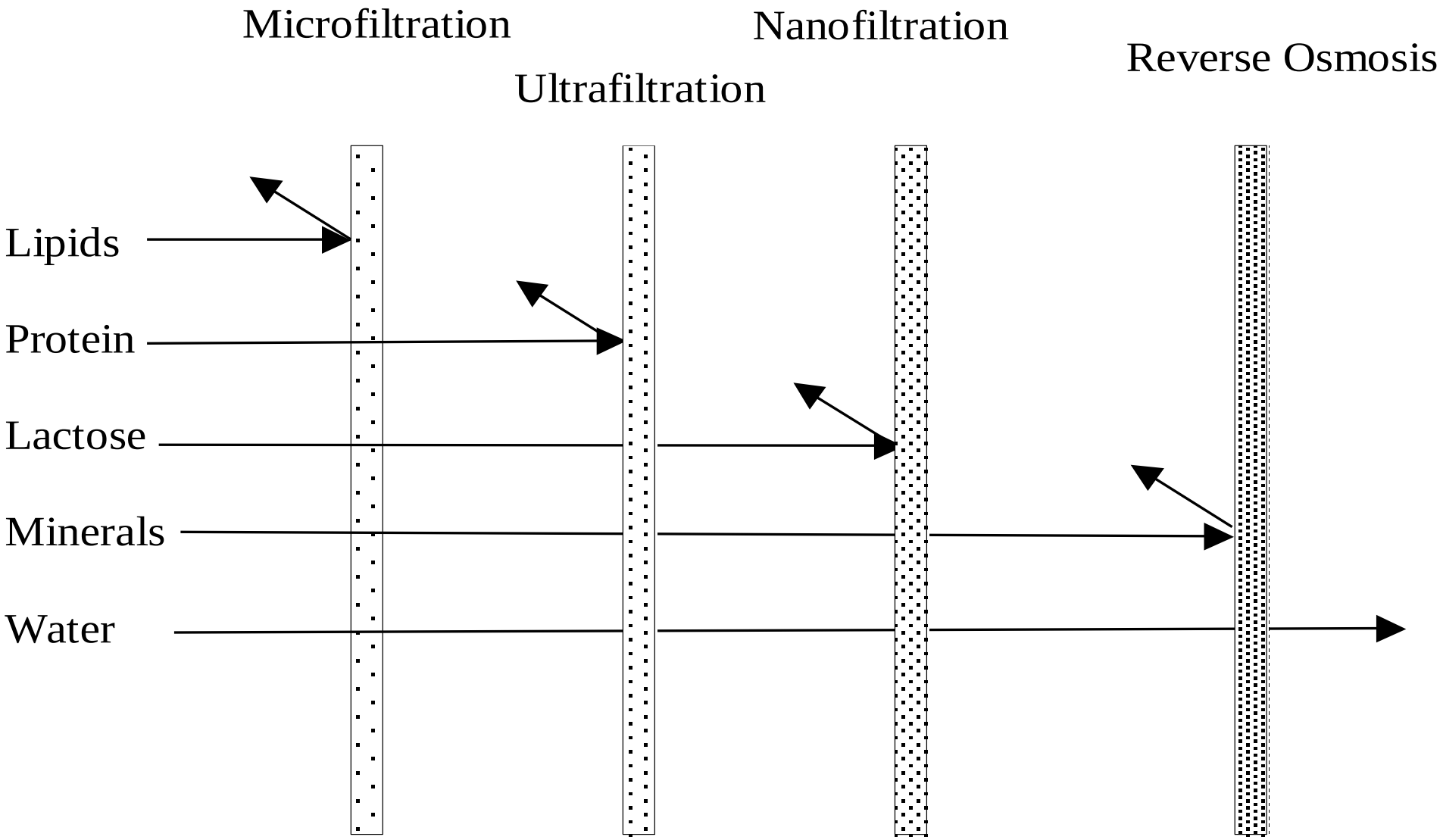

SUGAR
4.9 LBS.
ALBUMIN
.65
SALTS
.35
FAT
.3
CASEIN
.2
WATER
83.1 LBS.
WHEY
(89.4 LBS.)
3.9 LBS.
WATER
.2
SUGAR
.4 LBS.
SALTS + ALBUMIN
2.4 LBS.
CASEIN
3.7 LBS.
FAT
CHEESE
(10.6 LBS.)

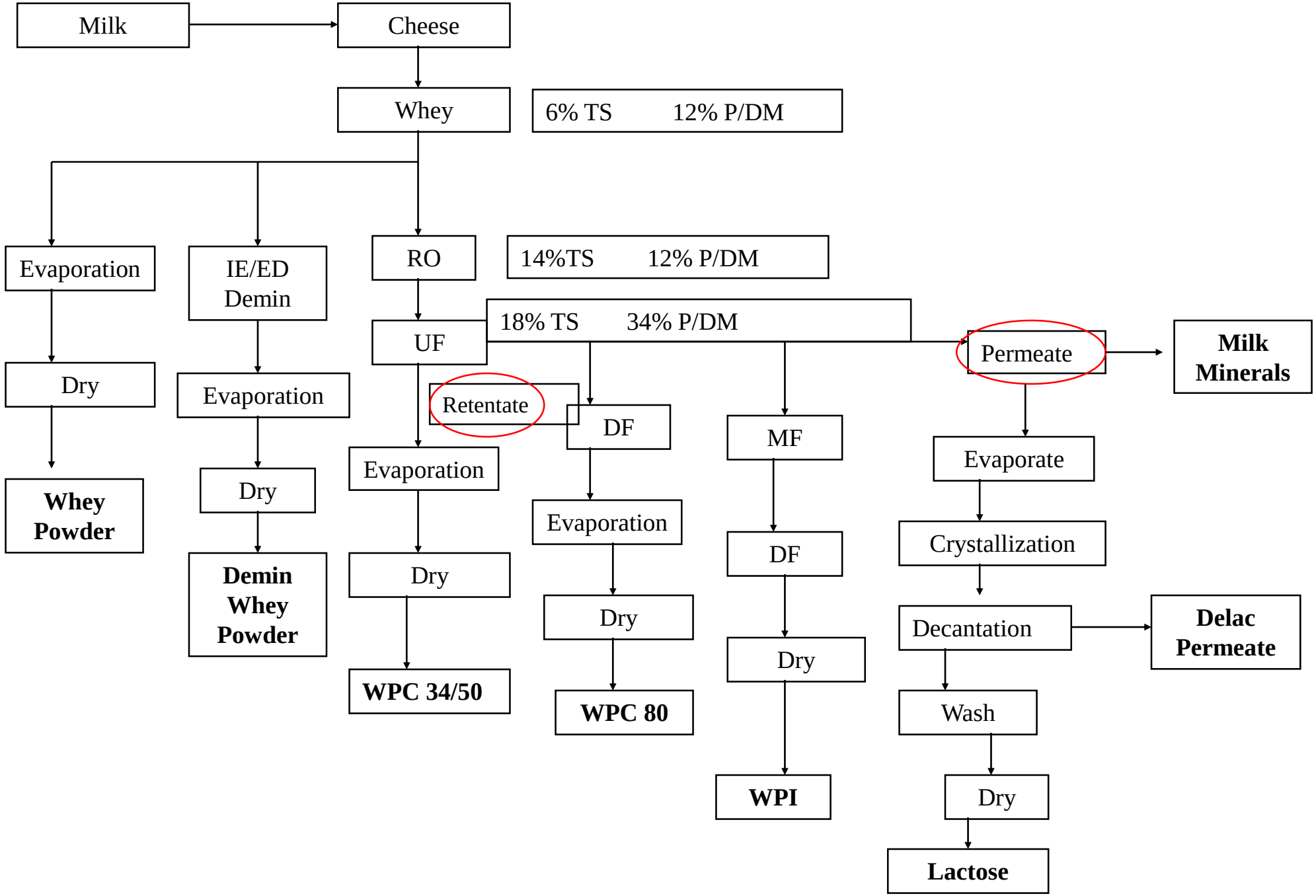
# Whey Composition

| | Sweet whey g/100g liquid | Sweet Whey g/100g solids |
|---|---|---|
| **Solids** | **6.88** | |
| **Protein** | **.85** | **12.35** |
| **Lipid** | **.36** | **5.2** |
| **Carbohydrate** | **5.14** | **74.7** |
| **Ash** | **.53** | **7.7** |

# Component Size Comparison

| Component | Micron |
|---|---|
| Water | .0003 |
| Cl-, Ca2+ | .0004 |
| Lactose | .0008 |
| Whey Proteins | .003-.005 |
| Casein Micelles | .025-.3 |
| Fat Globules | .1-10 |
| Bacteria | .2-8 |


Microfiltration
Ultrafiltration
Nanofiltration
Reverse Osmosis
Lipids
Protein
Lactose
Minerals
Water

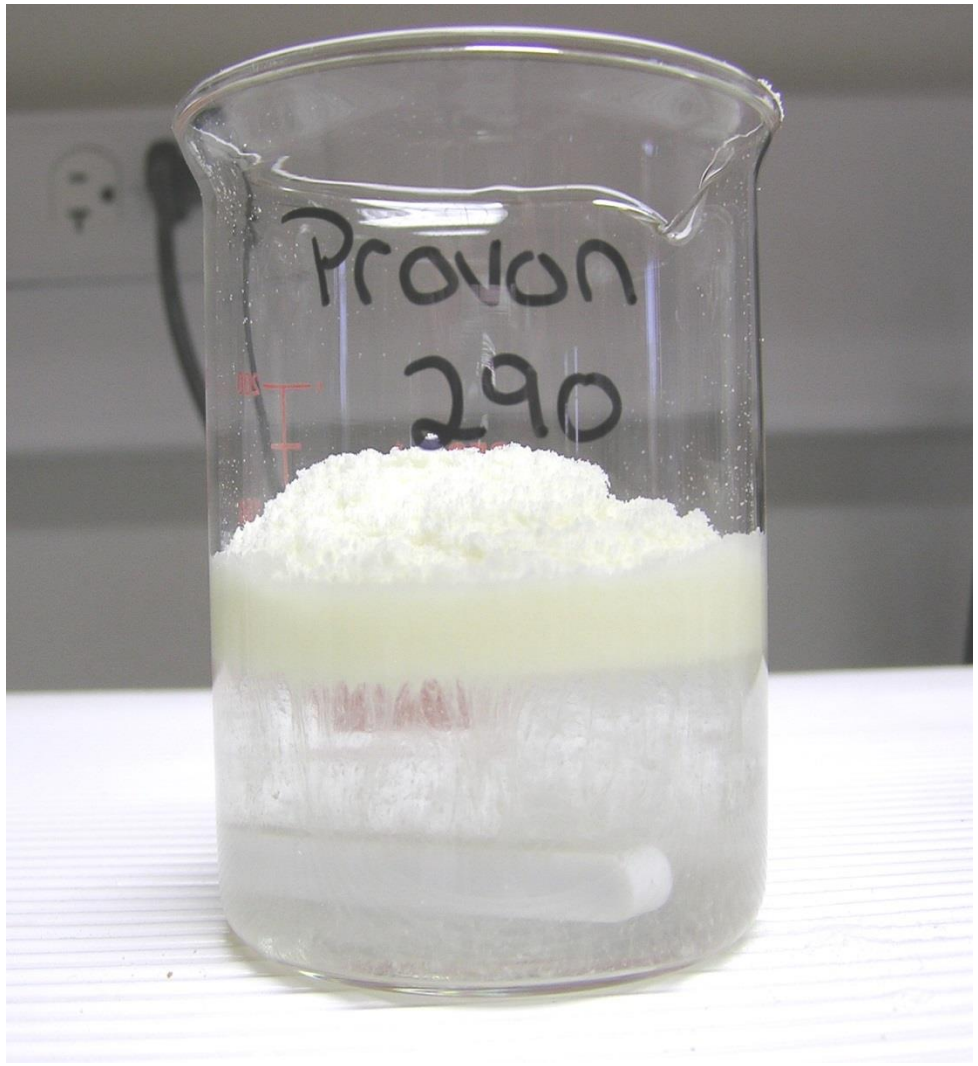

Milk
Cheese
Whey
6% TS 12% P/DM
Evaporation
IE/ED Demin
RO
14%TS 12% P/DM
Dry
Evaporation
UF
18% TS 34% P/DM
Permeate
Milk Minerals
Retentate
DF
MF
Evaporate
Whey Powder
Dry
Evaporation
Evaporation
Crystallization
Demin Whey Powder
Dry
Dry
DF
Decantation
Delac Permeate
WPC 34/50
Dry
Dry
Wash
WPC 80
WPI
Dry
Lactose

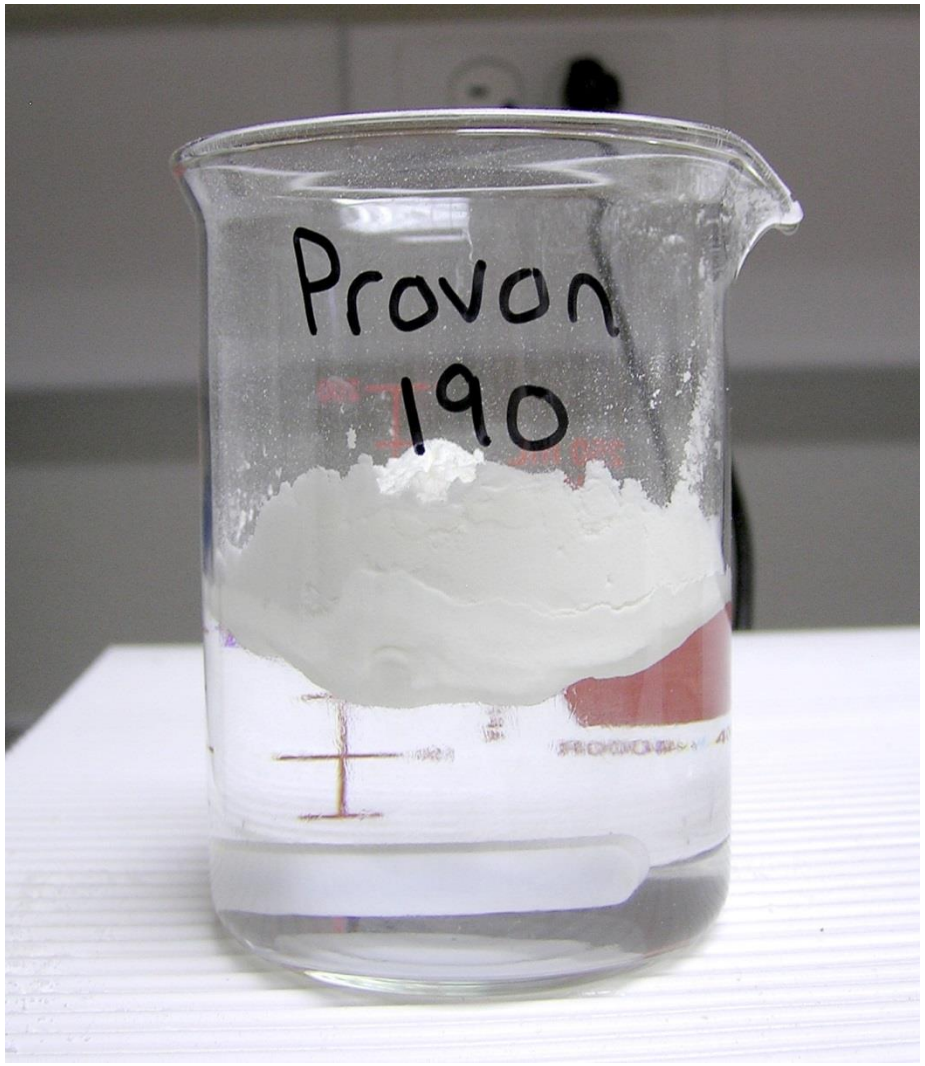
# Product Visual

Spray Dried WPI

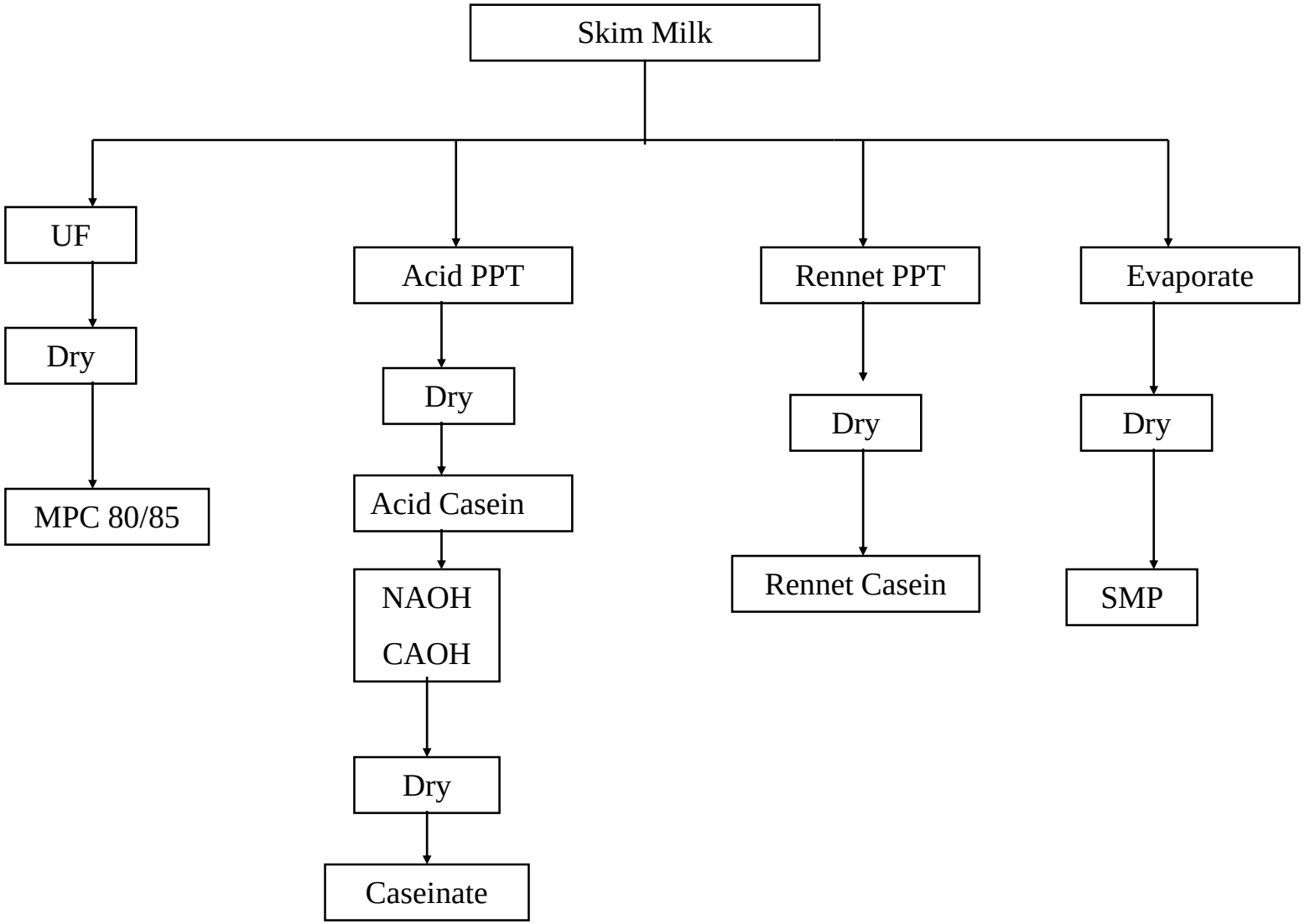
Agglomerated WPI

# Dispersability of agglomerated versus spray dried WPI



# MILK PROCESSING



# INGREDIENT COMPOSITION

| Ingredient | % Water | % Fat | % Protein | % Casein | % Whey | % Lactose | % Ash | % Ca |
|---|---|---|---|---|---|---|---|---|
| Milk | 87.4 | 3.5 | 3.2 | 2.5 | 0.7 | 4.9 | 0.7 | 0.12 |
| Skim Milk Powder | 4 | 1 | 35 | 28 | 7 | 52 | 8 | 1.2 |
| MPC 42 | 4 | 1 | 42 | 35 | 7 | 45 | 8 | 1.2 |
| Rennet Casein | 10 | .5 | 80 | 80 | - | 1 | 8 | 2.7 |
| Sweet Whey Powder | 4 | 1 | 12 | - | 12 | 73 | 8 | 0.7 |
| Delac Whey Powder | 4 | 2 | 23 | - | 23 | 56 | 16 | 0.85 |
| Demin Whey Powder | 4 | 2 | 13 | - | 13 | 80 | 1 | 0.08 |
| WPC 34 | 3.5 | 3 | 35 | - | 35 | 52 | 8 | 0.54 |
| WPC 50 | 3.5 | 4 | 50 | - | 50 | 35 | 5 | 0.5 |
| WPC 80 | 3 | 6 | 80 | - | 80 | 6 | 2 | 0.64 |
| WPI | 3.5 | 0.5 | 91 | - | 91 | 1 | 3 | 0.7 |
| Lactose | 0.15 | 0.1 | 0.2 | - | 0.2 | 99 | 0.1 | 0.1 |
| Milk Calcium | 6.0 | 1.0 | 7.0 | - | 7.0 | 7 | 73 | 23 |
| Lactoferrin | 3.0 | 0 | 95 | - | 95 | 0 | 1.5 | - |

# Protein Quality

UNITED DAIRYMEN of IDAHO

# Standard Nutritional Ratings

- PER (Protein Equivalence Ratio)

$$\text{PER} = \frac{\text{weight gain (g) of animal}}{\text{protein (g) intake by animal}}$$

- BV (Biological Value)

$$\text{BV} = \frac{\text{food N} - (\text{fecal N} + \text{urinary N})}{\text{food N} - \text{fecal N}} \times 100$$

- NPU (Net Protein Utilization)

$$\text{NPU} = \text{total digestibility (TD)} \times \text{BV}$$

# Standard Nutritional Ratings

- PDCAAS

$$\text{PDCAAS} = \frac{\text{limiting amino acid (mg/g protein)}}{\text{FAO/WHO amino acid (mg/g protein)}} \times \text{TD}$$

| protein | PER | NPU | BV | PDCAAS |
|---|---|---|---|---|
| corn | 1.2 | 52 | 33 | 0.42 |
| egg white | 2.5 | 83 | 88 | 1.00 |
| milk | 2.7 | 82 | 85 | 1.00 |
| whey | 3.4 | 93 | 100 | 1.00 |
| soy | 2.0 | 66 | 59 | 1.00 |