Milk composition, Milk quality, and Dairy products standards

Learning Objectives

- Proximate and component composition of milk
- Factors influencing milk quality and their significance
- Milk and milk product standards and implications

What is Milk?

- CFR Title 21, Part 131.110a
- "the lacteal secretion, practically free of colostrum, obtained by the complete milking of one or more healthy cows."

"Impacts product labeling and allowed ingredients in dairy products"

Milk – an amazing nutritious food

Forming Food Structures from milk

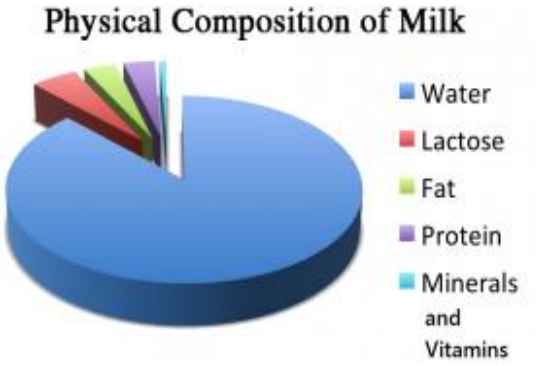
Drinkable, spoonable, sliceable, shredable, spreadable,, whipable

- Fluid Milk (Drinkable)

- Cheddar (sliceable gel)
- Yogurt (spoonable gel)
- Mozzarella (stretchable gel)
- Cream cheese (spreadable gel)
- Processed cheese (meltable gel)
- Parmesan cheese (grating gel)
- Cottage cheese (particulate gel)
- Whipped cream (foam)

Complex Composition of Milk

Proximate Milk Composition



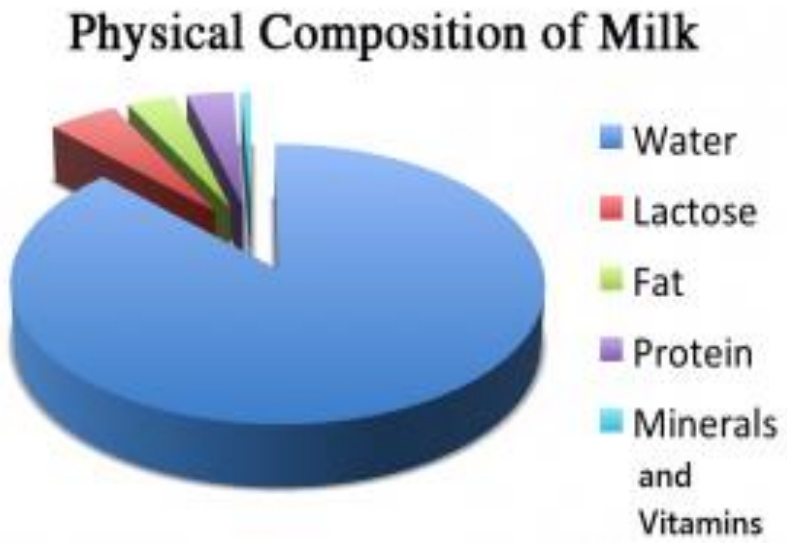
- Water (87.6%)
- Fat (lipids) (3.7%)
- Carbohydrates (lactose) (4.7%)
- Proteins (casein, whey proteins) (3.3%)
- Ash (salts, minerals) (0.7%)

Detailed information regarding all **2355** of the identified chemicals in bovine milk have been made freely available through a Web-accessible database called the Milk Composition Database or MCDB (http://www.mcdb.ca/).

J Agric Food Chem 2019 May 1;67(17):4897-4914. do i: 10.1021/acs.jafc.9b00204. Epub 2019 Apr 17.
Chemical Composition of Commercial Cow's Milk
PMID: 30994344 DOI: 10.1021/acs.jafc.9b00204

“Average” Proximate Composition of Raw Cow’s Milk

- Water 87.6%
- Fat (lipids) 3.7%
- Carbohydrates (lactose) 4.7%
- Proteins (casein, whey proteins) 3.3%
- Ash (Salts, minerals) 0.7%

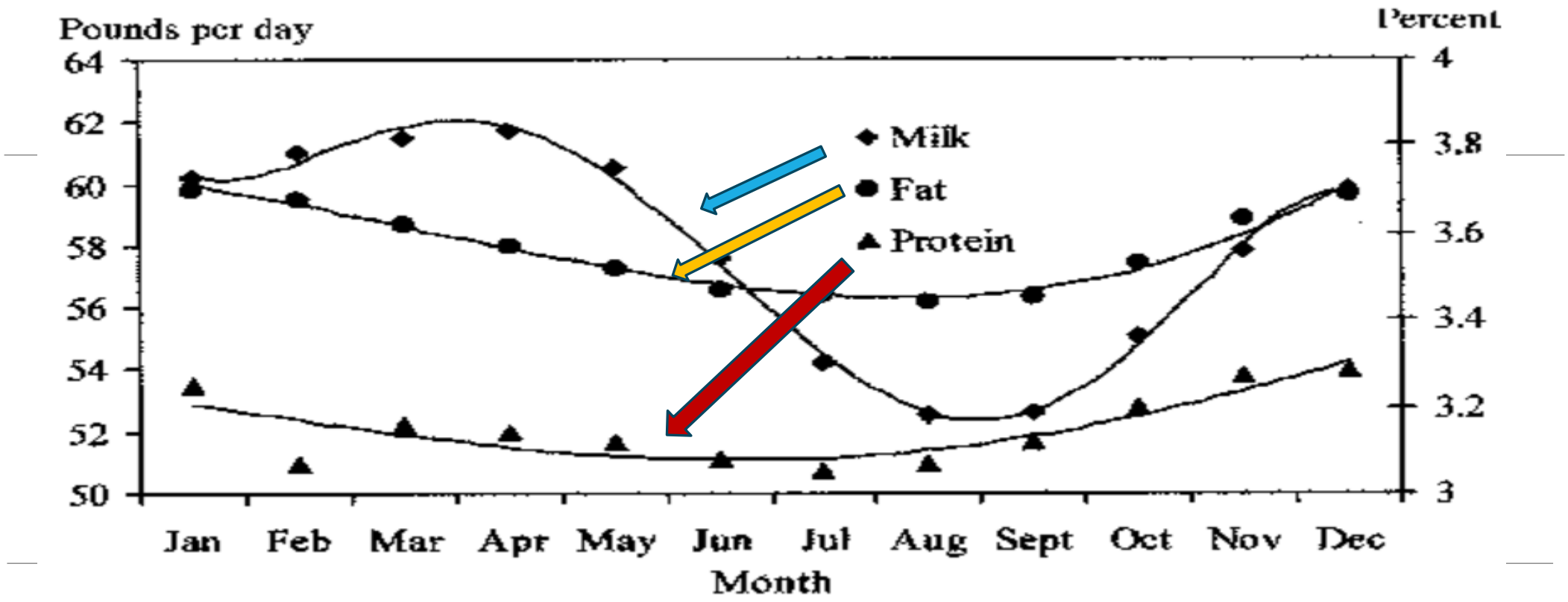


Milk Composition of Different Species

	Dry matter %	Fat %	Protein %	Carbohydrate (lactose) %	Ash* %
Human	12,4	3,8	1,0	7,0	0,2
Cow	12,6	3,7	3,4	4,7	0,7
Sheep	19,3	7,4	5,5	4,8	1,0
Goat	13,2	4,5	3,2	4,1	0,8
Buffalo	17,2	7,4	3,5	5,4	0,8
Camel	13,6	4,5	3,6	5,0	0,7
Mare	11,2	1,9	2,5	6,2	0,5
Donkey	12,0	1,8	2,5	6,1	0,5
Dog	24,9	10,5	12,2	1,3	0,9
Cat	17,9	3,3	9,1	4,9	0,6
Yak	17,7	6,7	5,5	4,6	0,9
Reindeer	33,3	16,9	11,5	2,8	1,4
Whale	37,5	22,0	12,0	1,8	1,7

Potential Sources of Variation in Bovine Milk Production (volume and composition)

- DAIRY MANAGEMENT PRACTICES
  - Herd management practices
    - Stage of lactation effects
    - Culling rates (animal age)
    - Genetics
    - Breed
  - Nutritional status of animal
    - Feed quality variation (grass vs TMR)
  - Weather
  - Health status of animal
    - milk quality
  - Milking procedures



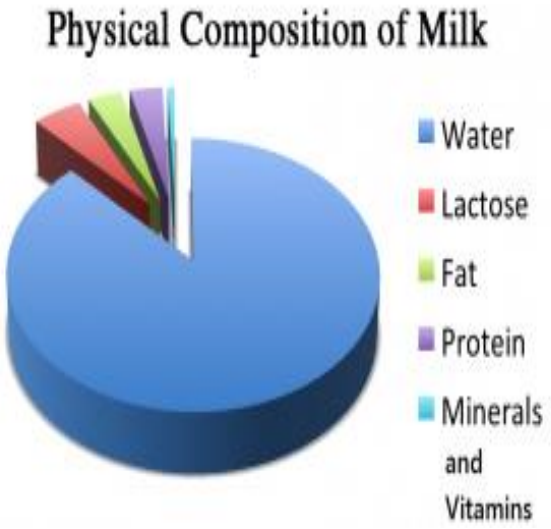
Seasonal Variation in Milk Composition

HARMON, 1994. J. DAIRY SCIENCE 77:2103.

“AVERAGE” Proximate Bovine Milk Composition

(Individual milk supplies vary in composition . . . standardization)

	Water	87.6%
	Lipid	3.7% (3.4 - 5.0%)
	Protein	3.3% (3.1 - 3.9%)
SNF	Carbohydrate (Lactose)	4.7% (4.6 - 5.0%)
SNF	Ash(mineral)	0.7% (0.68 - 0.72%)
	Total Milk Solids	12.4% (12.2 - 14.7%)



% Solids Nonfat (SNF) = % TMS - %fat = 12.4 -3.7 = 8.7

Significance of Proximate Composition Variation?

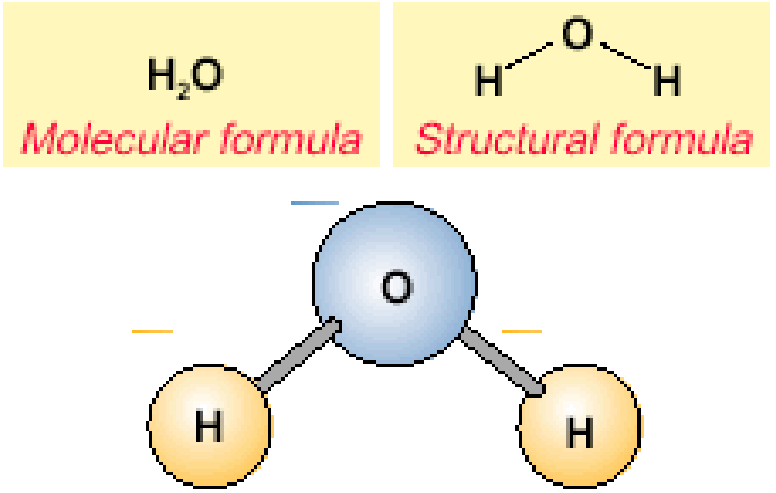
- Economics (payment on milk components . . . , fat, protein)
- Control of nutritional, functional and sensory properties of milk
- Composition control in finished dairy foods (e.g. cheese, yogurt, milk, etc.)
  - meeting regulatory standards
  - maximize consistency in quality (functionality)
    - (End User Performance))
  - finished product yields (Profitability)

Detailed Bovine Milk Component Composition and Properties

- Water
- Carbohydrates
- Lipids (Milkfat – triglycerides and fatty acids)
- Milk Proteins – caseins, whey proteins
- Milk minerals (ash)

Water (~87.6%)

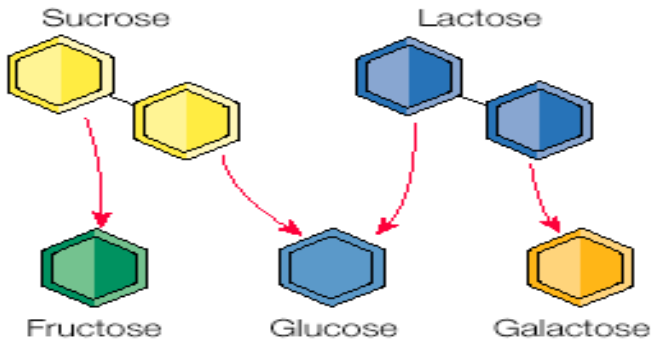
- in human milk 87%
- in bovine milk 85 -88%
- in reindeer 66.7%
- In gray seal 33.3%

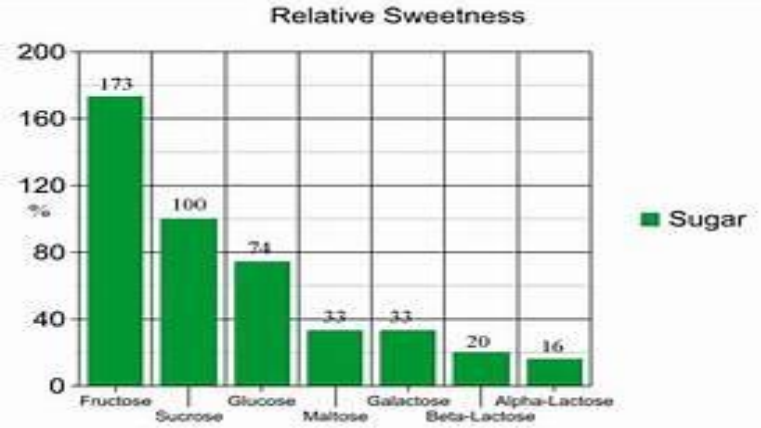


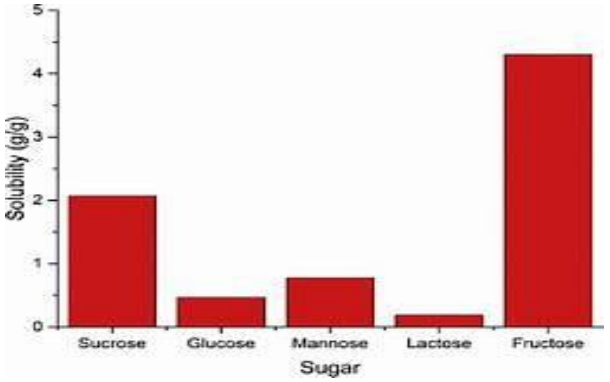
The solvent for the aqueous(serum) phase of dairy foods and contains sugar, proteins, some of the minerals in true solution or in suspension

Carbohydrates (~4.7%)

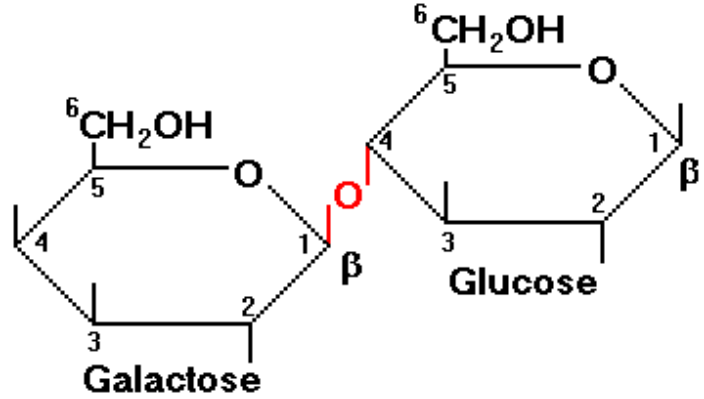
- Most of the CHO in milk is disaccharide, lactose
  - lactose = glucose + galactose)
  - Small amount of monosaccharide - glucose
- Lactose is :
  - 1/3 less sweet than sucrose
  - Less soluble than sucrose (sandiness in ice cream)
  - Fermentable CHO source
    - Lactose to Lactic acid
  - Reducing sugar – Browning reaction (flavor, darkening, insoluble)







Lactose



- Sugar found only in milk
- Slower digestion:
  - prolonged energy supply
  - lower glycemic index (measure of impact on blood glucose of a food)
- Lactose intolerance: inability to break down the disaccharide, lack of enzyme to split sugar (not an allergic reaction!)

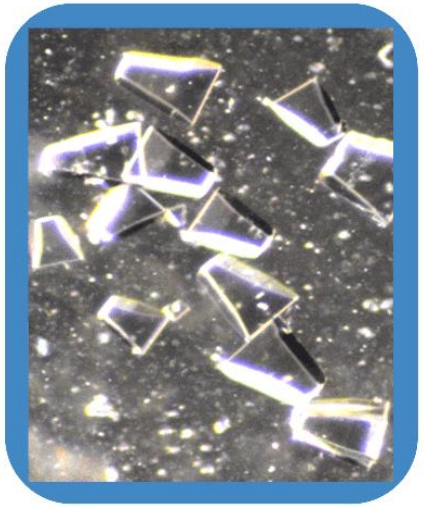
Lactose in Dairy Powders (milk and whey powders)

Crystalline Lactose:

- Alpha Lactose Monohydrate (non-hygroscopic)
- Beta-Lactose

Glassy, amorphous (non-crystalline lactose, hygroscopic)

- Changes in Temperature and Humidity during storage causes increased mobility of lactose glass and with sufficient time results in crystallization (caking)

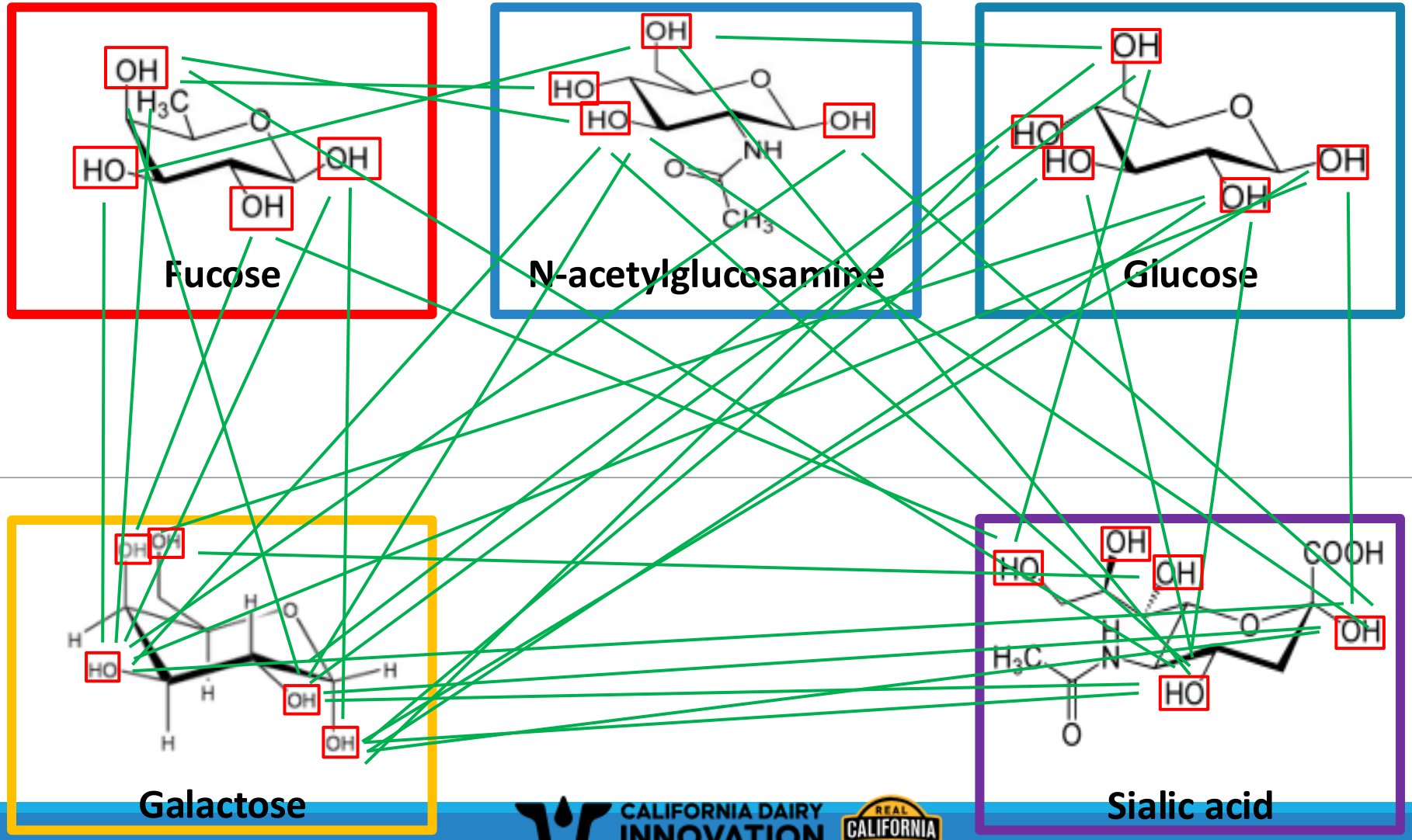


Oligosaccharides: what are they?

- **Oligosaccharides: indigestible carbohydrates consisting of 2-20 monomeric residues**
  - Found in: mammalian milks and plants
  - Synthesized in vivo (mammary gland)
  - Hydrolysis of higher polysaccharides (plants)

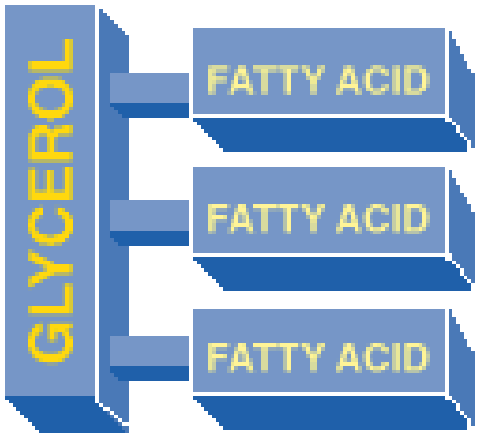
- **Serves as prebiotic benefit for gut health**

Natural milk oligosaccharides complexity associated with milkfat globule membrane(Barile, D.)



Milkfat (Lipids) (~3.7%)

Triglycerides



Saturated

Unsaturated

Table 2.4
Principal fatty acids in milk fat

Fatty acid	% of total fatty-acid content	Melting point °C	Number of atoms H	C	O	
Saturated						
Butyric acid	3.0 – 4.5	–7.9	8	4	2	Liquid at room temp-erature
Caproic acid	1.3 – 2.2	–1.5	12	6	2	
Caprylic acid	0.8 – 2.5	+16.5	16	8	2	
Capric acid	1.8 – 3.8	+31.4	20	10	2	Solid at room temp–erature
Lauric acid	2.0 – 5.0	+43.6	24	12	2	
Myristic acid	7.0 – 11.0	+53.8	28	14	2	
Palmitic acid	25.0 – 29.0	+62.6	32	16	2	
Stearic acid	7.0 – 3.0	+69.3	36	18	2	
Unsaturated						
Oleic acid	30.0 – 40.0	+14.0	34	18	2	Liquid at room temp-erature
Linoleic acid	2.0 – 3.0	–5.0	32	18	2	
Linolenic acid	up to 1.0	–5.0	30	18	2	
Arachidonic acid	up to 1.0	–49.5	32	20	2	

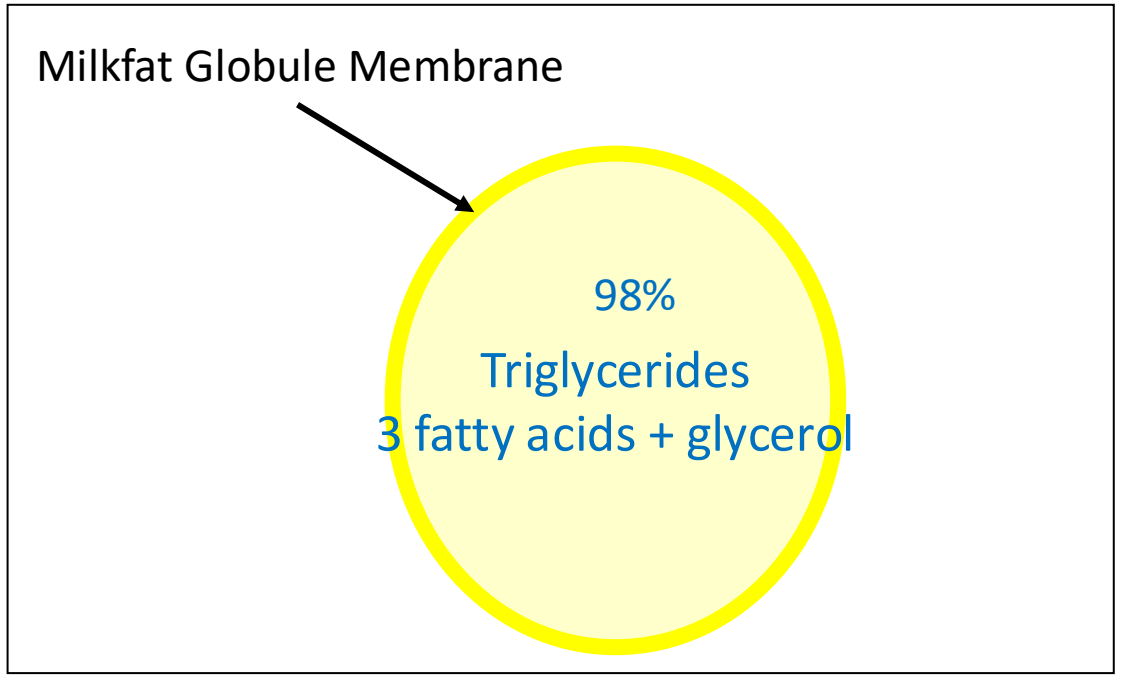
Very complex, many different triglycerides

Milkfat

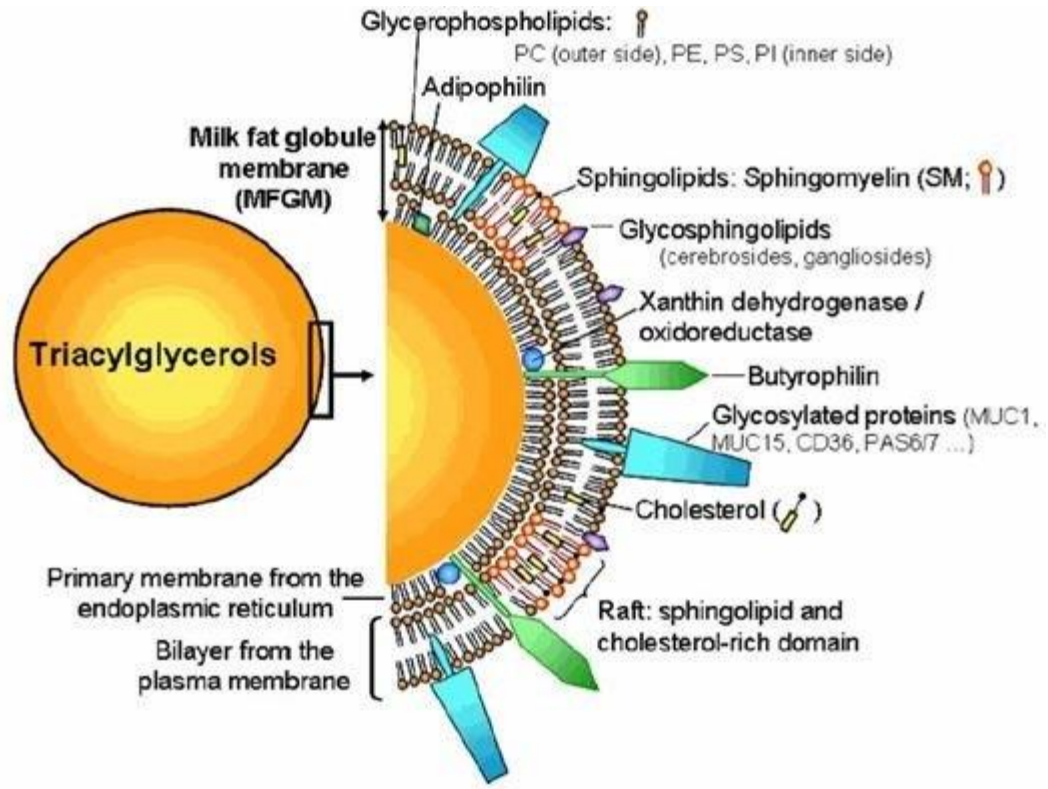
Broad Melting Range, Solid:Liquid fat Globule Size - 0.1 - 20 microns

Natural Milkfat Globule Membrane

- Phospholipids, sphingolipids, glycolipids
- Lipase Activity Creaming Phenomenon



Tetra Pak, 1995



Proteins (~3.3%)

High nutritional quality (compared to many plant proteins)

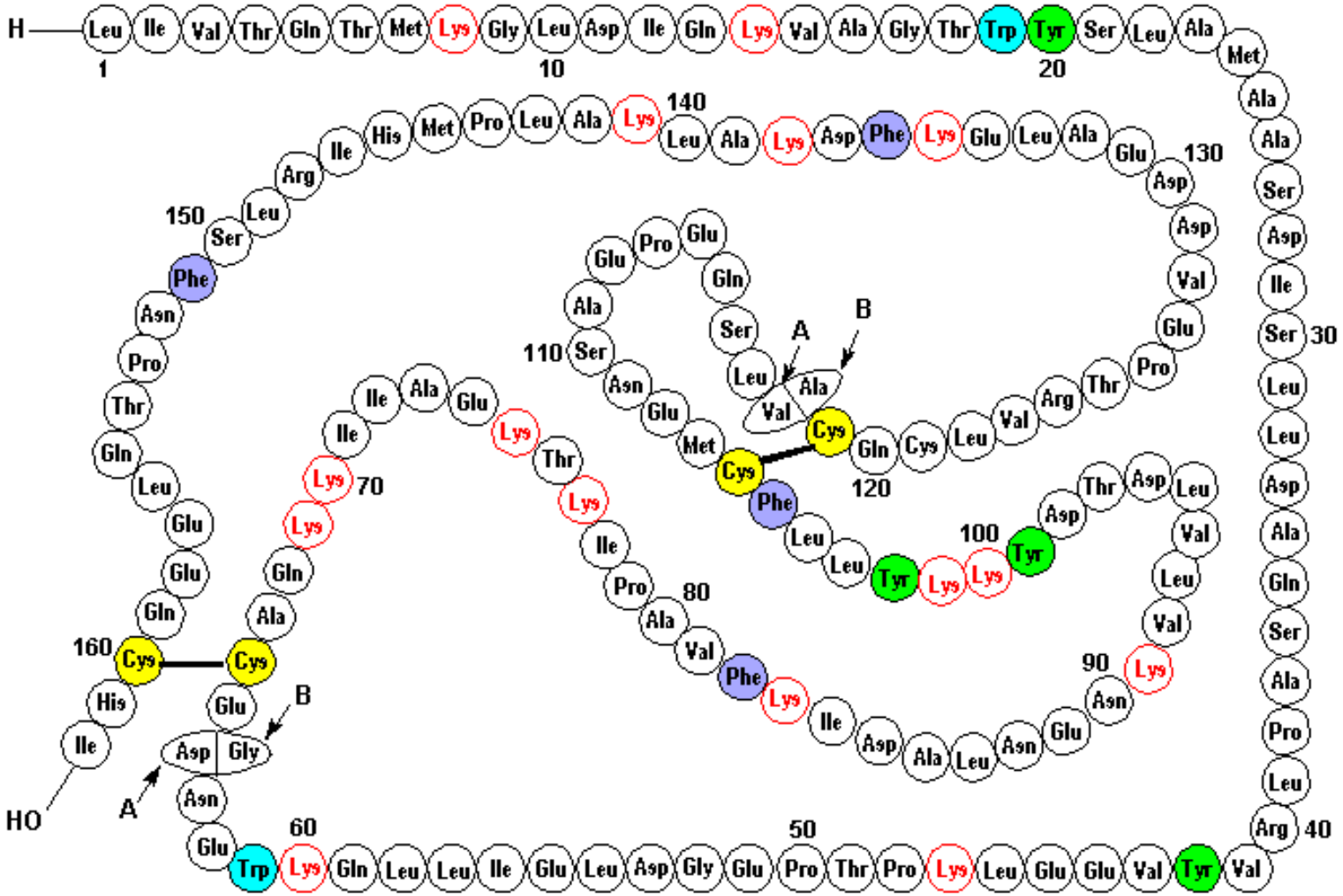
Complete Protein: Contains all essential amino acids

(20 different a. a., 9 essential a. a.)

Major Classes of Proteins in Milk

- **Caseins (75-80% total protein)**
  - Insoluble pH 4.6 @ 20C
- **Whey Proteins (20-25% total protein)**
  - Soluble pH 4.6 @ 20C

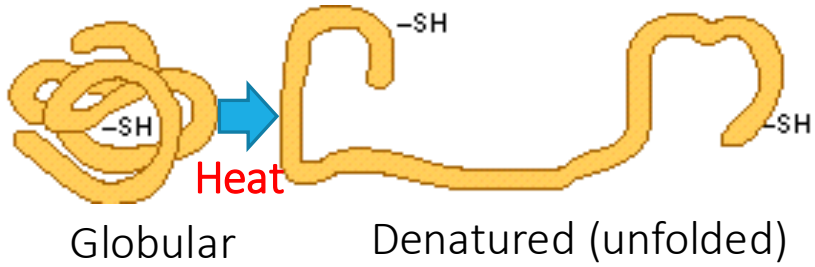
Proteins are: Chains of amino acids


H
HO
A
B
Cys
Cys
Cys

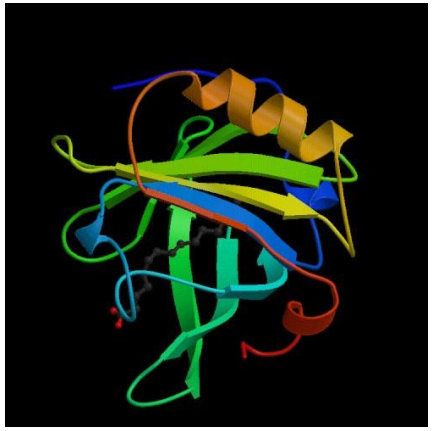
MILK PROTEINS – Whey (serum) Proteins

Whey Proteins (approx. 20-25% total protein)

- Globular protein structure
- Soluble Proteins
- Free Sulfhydryl compounds (cooked, “eggy” flavor)
- High in branched chain amino acids
  (Leucine, Isoleucine, Valine)

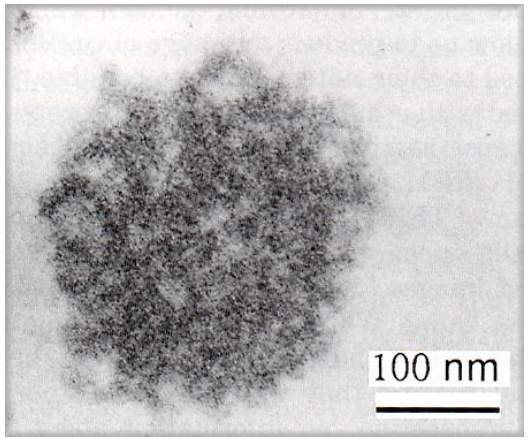


β-Lactoglobulin



- Globular three dimensional protein structure
- Soluble @ pH 4.6 @ 20C
- Will not coagulate in presence of chymosin
- Unstable at high temperatures (denature and become more reactive (aggregate, become insoluble (increase viscosity. . . Gel . . . .precipitate))

MILK PROTEINS - Casein



Casein (75-80% total protein)

- Micelles (particle suspended in milk)
- Calcium Phosphate Bridges

Donald J. McMahon & William R. McManus
Western Dairy Center
Department of Nutrition and Food Sciences
Utah State University, Logan 84322-8700

- Insoluble @ pH 4.6 (cottage cheese)
- Coagulates in presence of chymosin (Cheddar, Mozzarella, Swiss, Monterey Jack
- Heat stable (at pH of milk)
- Micelle structure
  - Calcium delivery system of milk
- Proteolysis can create flavors (desirable and undesirable bitter peptides)

Tetra Pak, 1995

Average concentration of proteins in bovine milk

Component	Grams/Liter	% of Total Protein
Total Protein	**33**	**100**
Total casein	**26**	**79.5**
α_{s1}-Casein	10	30.6
α_{s2}-Casein	2.6	8.0
β-Casein	9.3	28.4
κ-Casein	3.3	10.1
Whey Proteins	**6.3**	**19.3**
α-Lactalbumin	1.2	3.7
β-Lactoglobulin	3.2	9.8
Bovine Serum Albumin (BSA)	0.4	1.2
Immunoglobulins	0.7	2.1
Proteose peptone	0.8	2.4

MILK MINERALS (ash) (0.7%)

- Includes sodium, potassium, magnesium, calcium, inorganic phosphate, citrate

- Nutrition and Health (bone health, metabolic activity)

Product Stability/Instability of milk (proteins)

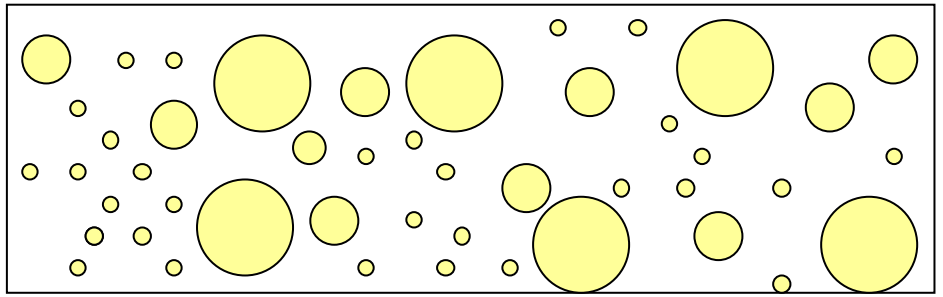
Minerals deposits (quality, productivity)

- More calcium in milk than is soluble
- 1/3 calcium is soluble and 2/3 is colloidal
- Heat shifts calcium from soluble to insoluble form
  - Heat transfer Biofilm …Accumulation of other milk components ….Accumulation of microbes . . .

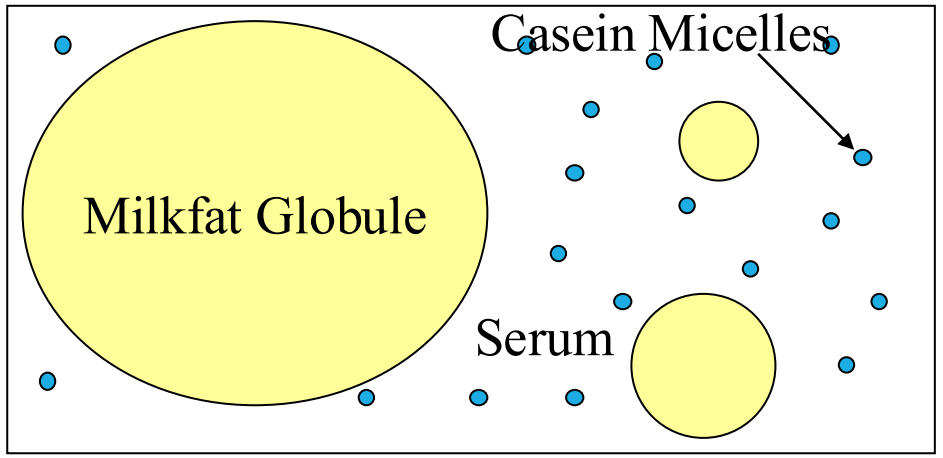
Milk Physical Properties (colloid, emulsion, solution)

1X
Opaque, white liquid

1000X
Milkfat globules



10,000X
Milkfat globules
Casein micelles
Whey proteins
Other soluble and colloidal constituents



Size: milkfat globules>casein micelles>whey proteins>lactose>minerals>water molecules

Raw Milk Quality

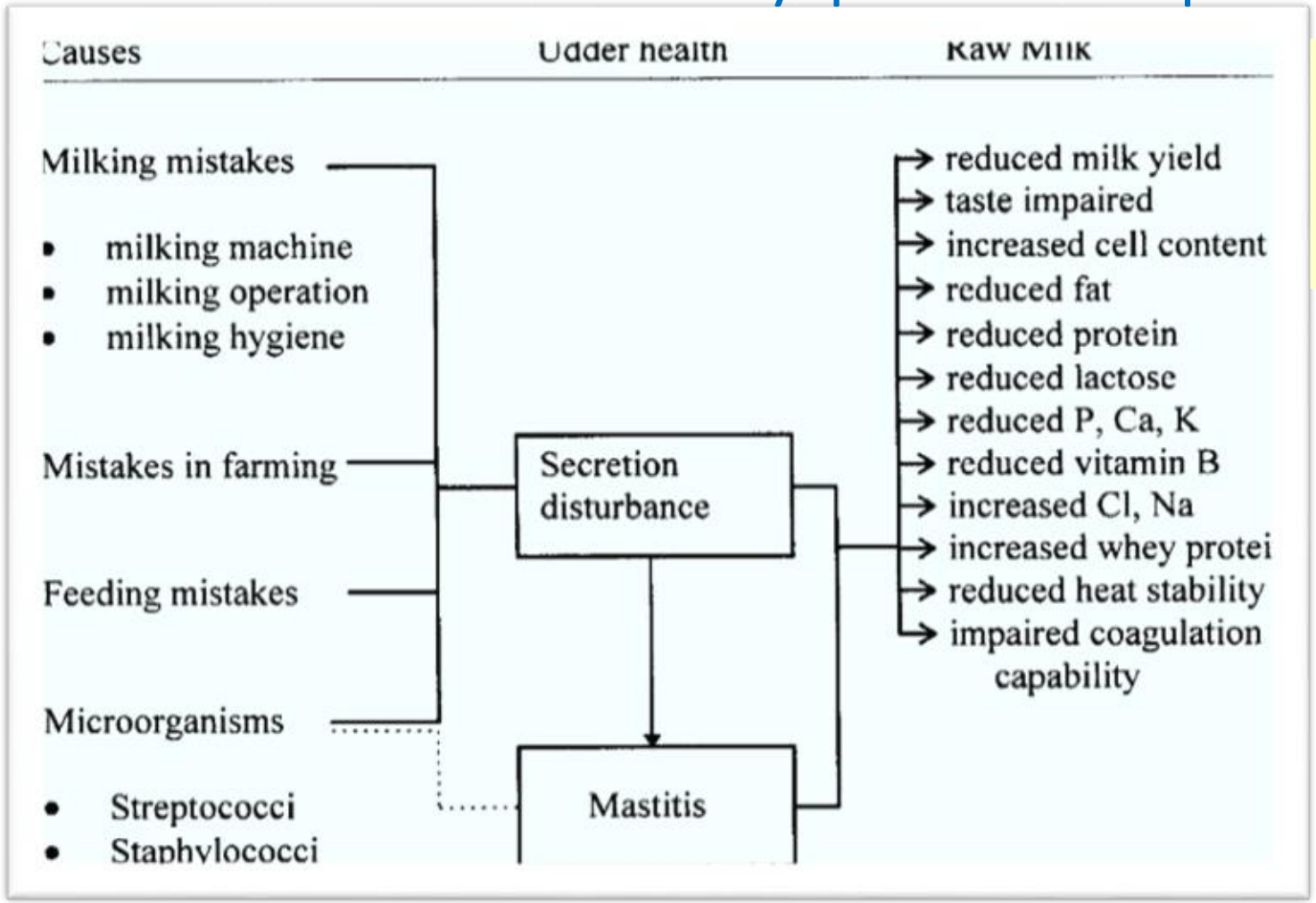
- Milk production practices
  - nutrition, milking practices, animal status, farm environment
- Udder health
  - mastitis – sub-clinical, clinical – somatic cell count)
- Farm hygiene and milk storage practices
- Adulteration

Raw milk quality

Raw milk quality is influenced by:

1. Chemical composition
2. Chemical and physical characteristics (e.g., acidity, density, viscosity, etc.)
3. Microbial quality
4. Absence of pathogenic microorganisms
5. Absence of disease, somatic cells, toxins
6. Absence of foreign matter

Influence of mastitis (udder infection) on milk and dairy product quality



Effects on milk and dairy products

- Sensory properties
- Shelf life
- Functional properties

Effects on cheesemaking

- Starter culture growth
- Weak curd
- Moisture retention, composition control
- Low cheese yields

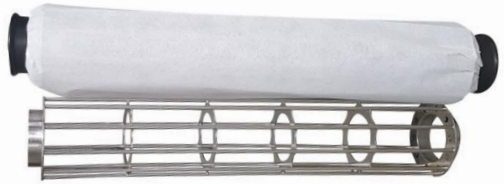
Ensuring Raw Milk Quality: Storage of Raw Milk

- Milk must be cooled to 40°F (4°C) or lower within two hours of milking
- It should be held at this temperature for no more than 48 hours before processing.

Bacteriological Standards for raw and pasteurized milk

	Standard	Federal	California
Grade "A" Raw Milk for Pasteurization	Bacterial (Standard Plate Count) Limits	Not. to exceed 100,000 per ml	Not to exceed 50,000 per ml
	Somatic Cell Count	Not to exceed 750,000 per ml	Not to exceed 600,000 per ml
	Coliform	No Standard	Not to exceed 750 per ml
	Laboratory Pasteurized Count	No Standard	Not to exceed 750 per ml
Grade "A" Pasteurized Milk	Standard Plate Count	Maximum 20,000 per ml	Maximum 15,000 per ml
	Coliform	Maximum 10 per ml	Maximum 10 per ml

What is Sediment?



Sediment may come from milking, and claws dropping off picking up dust and debris from the milking parlor floor of the udder not being cleaned well.

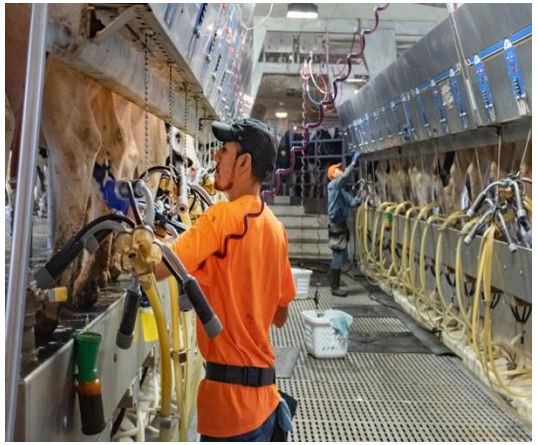
Sediment is removed by milk filters (on farm) and the clarifying separator (plant); however, everything that comes along with the sediment such as bacterial contaminants can impact quality and may not be removed

The Dairy Farm Environment

National Dairy Farmers Assuring Responsible Management (FARM)

FARM Program focuses on five areas – Animal Care, Antibiotic Stewardship Biosecurity, Environmental Stewardship and Workforce Development.

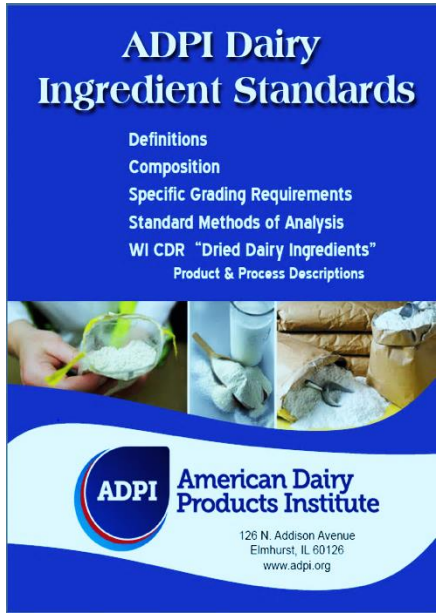
- Cattle housing
- Milking systems
- Milk storage
- Milk transport



https://nationaldairyfarm.com/what-is-farm/

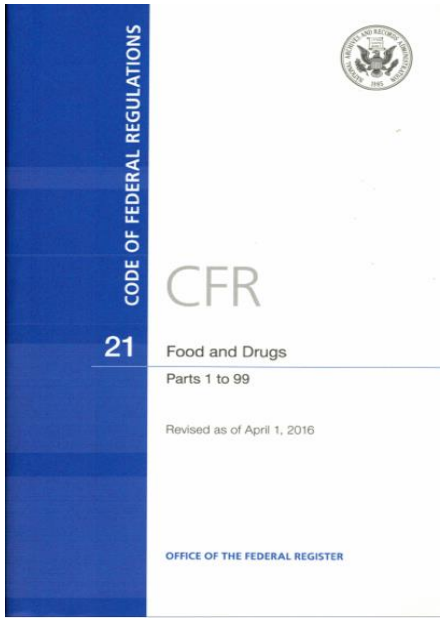
Dairy Standards & Regulations

https://leginfo.legislature.ca.gov/faces/codesTOCSelected.xhtml?tocCode=FAC&tocTitle=+Food+and+Agricultural+Code+-+FAC

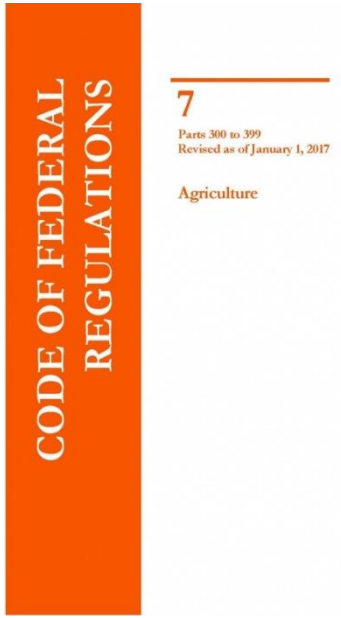


http://www.adpi.org/DairyProducts/tabid/62/Default.aspx

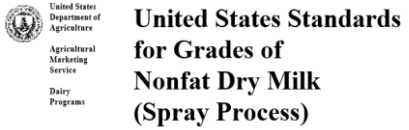
Industry Standards
Not enforceable

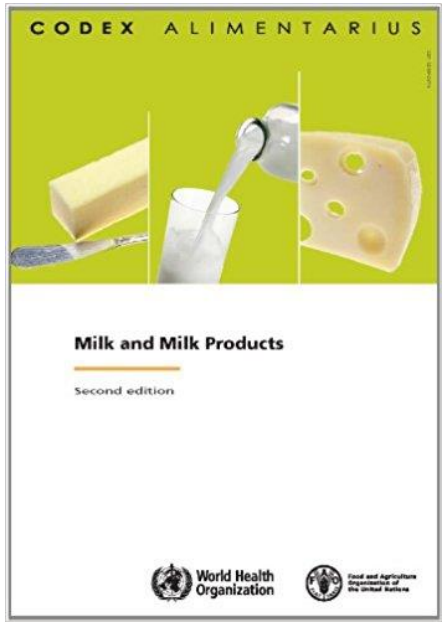


https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm
(see Ch 1 - Part 1-199)



https://www.gpo.gov/fdsys/granule/CFR-2011-title7-vol3/CFR-2011-title7-vol3-part58





http://www.fao.org/docrep/015/i2085e/i2085e00.pdf

Fluid Milk Compositional Standards

	Standard	Federal	California
Grade A Pasteurized Milk	Milkfat Minimum	3.25%	3.5% *
	Milk Solids-Not-Fat (SNF), minimum	8.25%	8.7% *
	Total Milk Solids	No Standard	12.2% Minimum
Grade A Reduced Fat Milk	Milkfat	Maximum 2.1% No Minimum	Maximum 2.1% Minimum 1.9%
	SNF, minimum	8.25%	10.0%
Grade A Lowfat Milk	Milkfat	Maximum 1.2% No Minimum	Maximum 1.1% Minimum 0.9%
	SNF, minimum	8.25%	11.0%
Grade A Nonfat Milk	Milkfat	0.20%	0.20%
	SNF, minimum	8.25%	9.0%

Standards of Identity

- FDA has 300 identity standards in 20 categories of food
- Approximately 40% of food identity standards are for dairy foods.
- FDA standards of identify specify minimum and maximum requirements, optional ingredients, and prohibited ingredients

Standards of Identity

Defining Dairy Foods & Ingredients

Specifies:

- Name(s) of ingredient or food
- Certain descriptors
- Composition
- Allowed ingredients
- Manufacturing Processes
- Some microbial quality parameters
- Methods of analysis

Regulating Milk and Dairy Products Labels

Rules for labelling milk and dairy products are set in the Code of Federal Regulations in the Food Drug and Cosmetic Act. In 1990 the Nutritional Labeling and Education Act was enacted which gave FDA the responsibility to set nutritional guidelines and formats for all packaged food, and set requirements for nutritional claims such as low calorie, low sodium, low fat.

CDFA Dairy Food Safety is responsible for reviewing labels to assure products sold in the state meet regulatory guidelines. Their website is: https://www.cdfa.ca.gov/ahfss/Milk_and_Dairy_Food_Safety/Label_Review.html

What have we learned?

- Properties and percentages of milk and milk components
  - fat (triglycerides), protein (casein, whey protein), carbohydrate (lactose), ash (minerals), water
- Factors influencing milk quality and their significance
  - Microbiological, chemical, physical
- Milk and milk product standards and implications
  - Legal definitions, labeling, standards of identity, resources

Thanks for your attention!

Questions? Comments?

Milk composition, Milk quality, and Dairy products standards