Milk

- ***WHAT IS MILK***? U.S. Code of Federal Regulations, Title 21, Vol. 8, Chpt 1, Pt 1240, subpart A, Section 1240.3(j), Release 13
- "Milk is the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows. Milk that is in final package form for beverage use shall have been pasteurized or ultrapasteurized, and shall contain not less than 8 1/4 percent milk solids not fat and not less than 3 1/4 percent milkfat. Milk may have been adjusted by separating part of the milkfat therefrom, or by adding thereto cream, concentrated milk, dry whole milk, skim milk, concentrated skim milk, or nonfat dry milk. Milk may be homogenized."

Milk

Protein-rich water with an emulsion of protein-coated fat globules

Water phase (aqueous):

Slightly acidic water (pH ~6.6)

Protein bundles

Lactose

Fat phase:

Droplets of oil with a protein shell

Mixtures

Homogeneous

Pure substances

Solutions

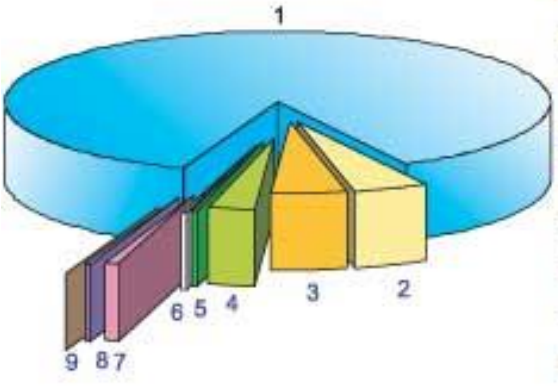
Heterogeneous

Bulk mixtures, melange

Suspension/colloid, emulsion

Emulsifiers and amphiphiles

Milk Composition



1 Water	86.6 %
2 Fat	4.4 %
3 Lactose	4.6 %
4 Casein	2.7 %
5 Whey protein	0.6 %
6 NPN	0.1 %
7 Minerals	0.7 %
8 Salts	0.17 %
9 Vitamin and enzymes	0.13 %

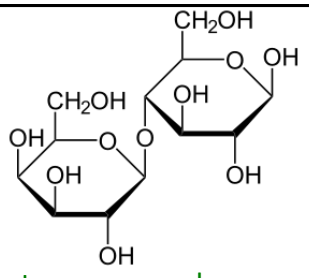
NPN – Non-protein nitrogenous compounds

Science of Cooking – BCBT100
Summer 2016 - Bodwin

Sources of milk:

Species	Water	Fat	Casein	Whey	Lactose
Human	87.1	4.6	*0.4*	0.7	**6.8**
Cow	87.3	4.4	2.8	*0.6*	4.6
Buffalo	82.2	7.8	3.2	*0.6*	4.9
Goat	86.7	4.5	2.6	*0.6*	4.4
Sheep	82.0	7.6	3.9	0.7	4.8
Horse	**88.8**	*1.6*	1.3	1.2	6.2
Rat	*79.0*	**10.3**	**6.4**	**2.0**	*2.6*
Donkey	**88.3**	*1.5*	*1.0*	1.0	**7.4**
Reindeer	*66.7*	**18.0**	**8.6**	**1.5**	*2.8*
Camel	86.5	4.0	2.7	0.9	5.4

Lactose



- Disaccharide - glucose and galactose prepared as separate molecules and condensed into “milk sugar” through the secretory cells
- Ability to digest (metabolize or “break down”) lactose requires a special enzyme – lactase
- Lactase is produced in gut by children but levels decrease in adults.
- Northern Europeans maintain levels but only 30% of others can produce significant quantities

Lactose Intolerance

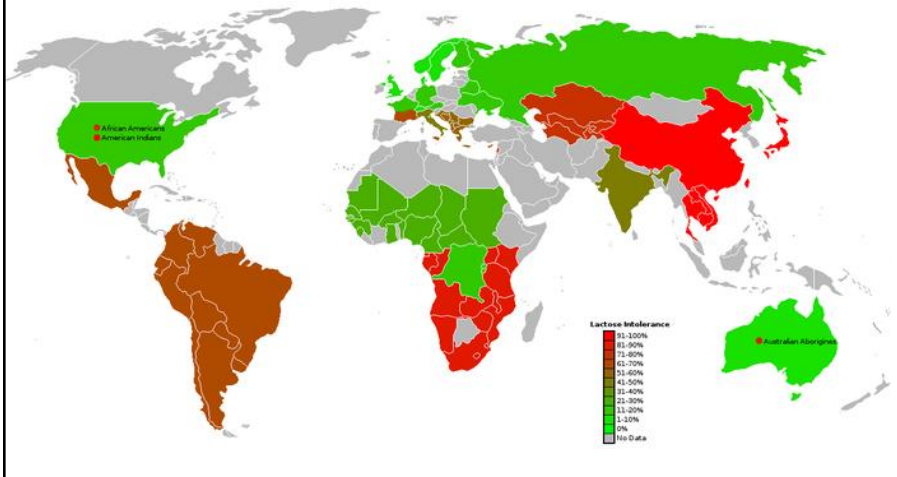


Image: http://www.oliverbenjamin.net/dudespaper/wp-content/uploads/2009/06/lactose-intolerance-map.jpg

Lactose Intolerance

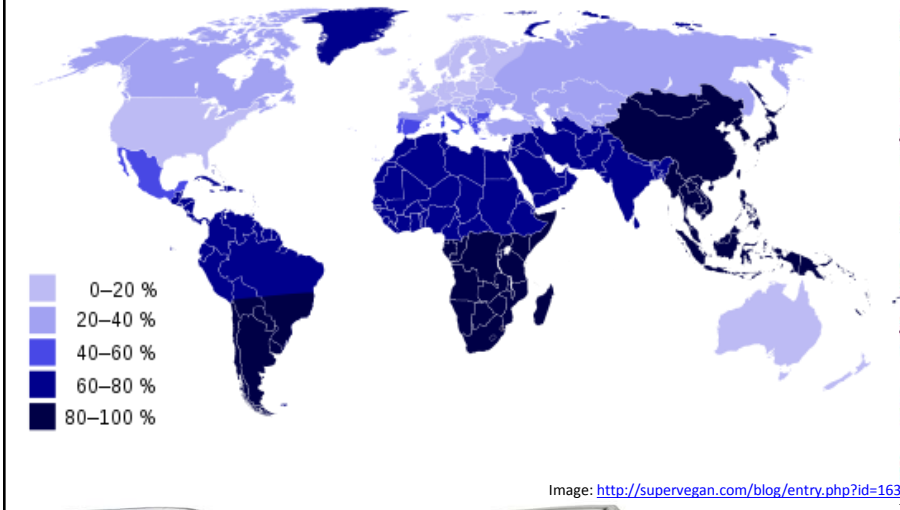
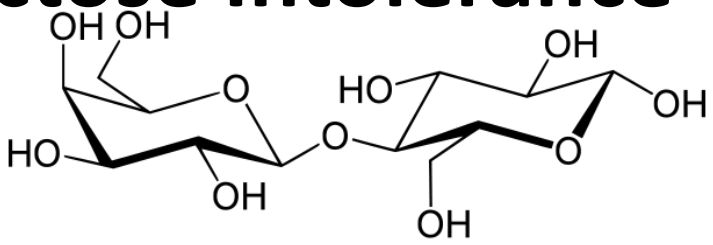


Image: http://supervegan.com/blog/entry.php?id=1638

Lactose Intolerance



Lactase – hydrolytic enzyme

Lactose passes through to gut

- *Draws water in (osmosis)*
- *Bacterial digestion – $CH_4(g)$, $CO_2(g)$*
- *Cramps, gas, diarrhea*

Image: http://en.wikipedia.org/wiki/File:Beta-D-Lactose.svg

Purpose of Lactose

Glucose

- *Protected as disaccharide*
- *Energy source*

Galactose

- *Neural tissue*
- *Make brains…*

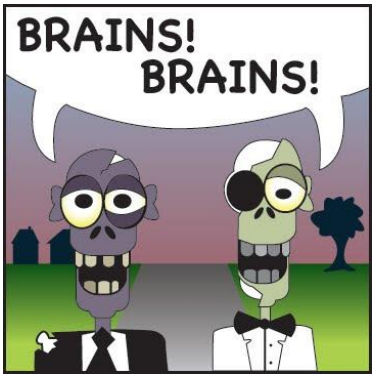


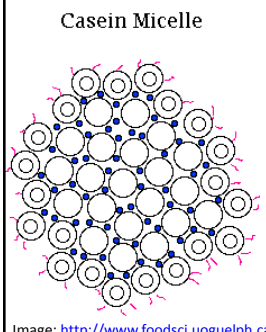
Image: http://blogity-blah-blah-blog.blogspot.com/2012_01_01_archive.html

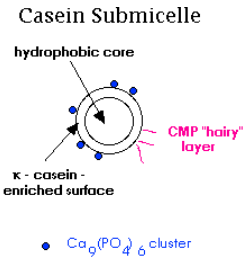
Milk Protein - Casein

- Major single protein produced in most milk
- Key characteristics of casein
- Heat stable – well folded protein
- "floats" in micelle form (globs of protein arranged to keep the protein in solution)
  - Hydrophobic portion of protein in middle
- Calcium binds tightly to this protein – helps to carry calcium into the blood system!
- Four main forms of Casein – one "caps" micelles limiting the size
- At pH levels above 4.5, proteins are negatively charged and repel.
- When acid increases to pH lower than 4, proteins denature and are not charged – thus they bind to each other and "curdle"
- Body builders sometimes use this as a "slow-digesting protein" (why)

Casein Micelles

kappa-Casein coating
Calcium-binding





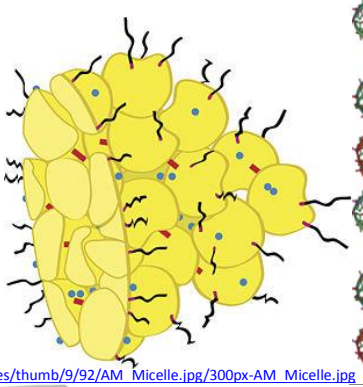


Image: http://www.foodsci.uoguelph.ca/deicon/casein.gif

Image: http://openwetware.org/images/thumb/9/92/AM_Micelle.jpg/300px-AM_Micelle.jpg

Milk Protein - Whey

- Soluble in acidic aqueous phase
- Many whey proteins are immunoglobins (antibodies for the young animal)
- Lactoglobin has several sulfur atoms – provides flavor and odor to cooked milk
- Proteins in whey are used for animals as source of nutrition
- Under more extreme conditions than casein, whey proteins can form small clots – ricotta cheese
- These proteins help make ice cream… creamy

Milk Fat

Globules of fat in a phospholipid and protein shell (Emulsifiers)

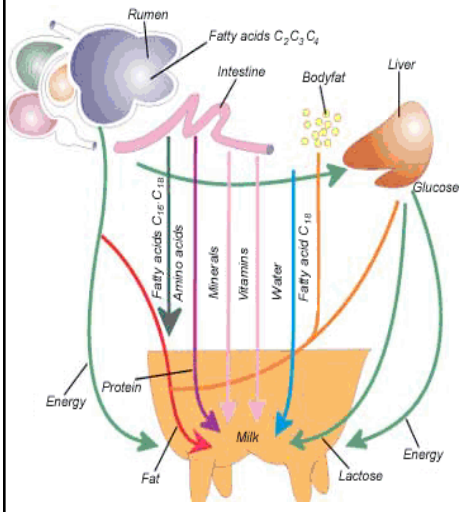
Homogenization

Heat-stable globules

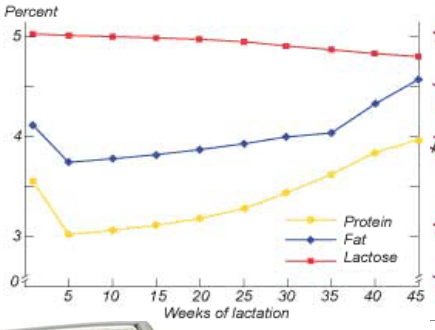
Cold breaks fat globules – ice, ice, baby

Fat soluble vitamins – A, D, E, K

Variations in Milk



Breed	Fat %	Casein %	Whey %	Lactose %
Brown Swiss	3.8	2.63	0.55	0.72
Holstein	3.56	2.49	0.53	0.73
Jersey	4.97	3.02	0.69	0.77

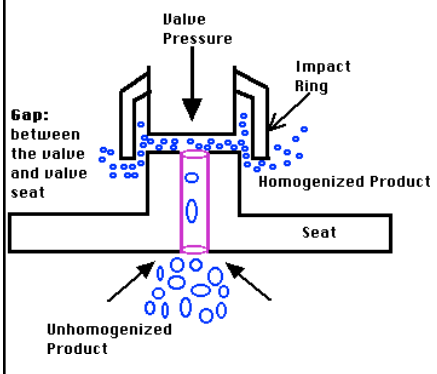


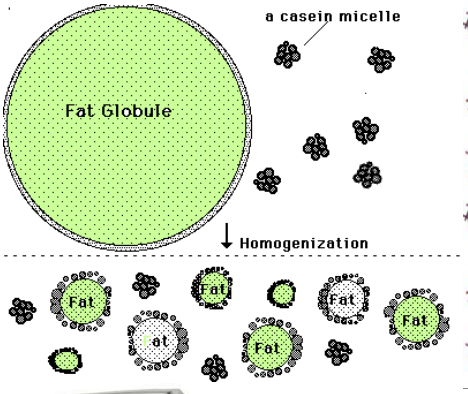
- Delaval.com

Homogenization

Increase surface area

Casein proteins coat – Negative





Sphere Math

Volume = $^4/_3 \pi r^3$

Surface area = $4 \pi r^2$

1 sphere, 2cm radius

Volume = $^4/_3 \pi (2cm)^3 = 34cm^3$

Surface = $4 \pi (2cm)^2 = 50.cm^2$

Break into 2 spheres:

Volume of each = $17cm^3 = {}^4/_3 \pi (x)^3 \rightarrow x = 1.6cm$

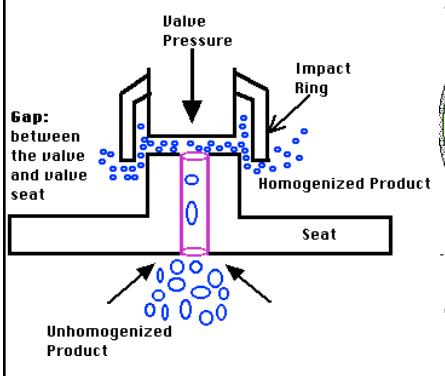
Surface of each = $4 \pi (1.6cm)^2 = 32cm^2$

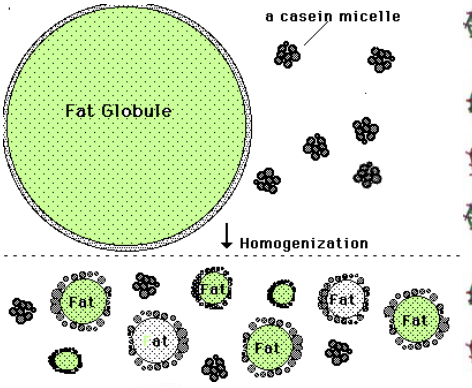
Total surface = $64cm^2 \rightarrow$ too much!

Homogenization

Increase surface area

Casein proteins coat – Negative





Pasteurization

Hot enough to sterilize, not cook

Batch = 145°F, 30 minutes

HTST = 162°F, 15 seconds

UHT = 265°F, 1-3 seconds

Cooked flavor due to sulfur cmpds

Foams

Heterogeneous Mixtures

Air in solid or liquid

Milk foams

Protein and/or fat and/or sugar

Milk Foams

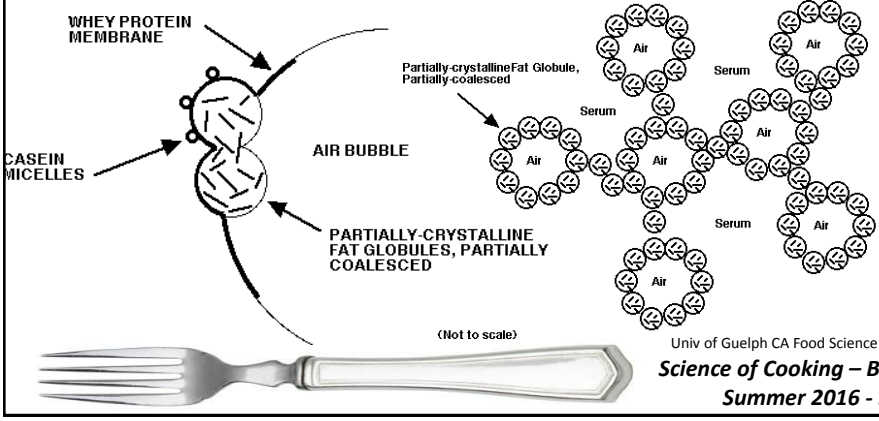
Frothed Milk or "Espresso Foam"

- Protein-based foam
- Heat from steam denatures milk protein (whey)
- Denatured proteins tangle, form net around air
- Not stable – as water drains, bubbles collapse

Milk Foams

Whipped Cream

- Fat-based foam
- Mechanically shearing fat globules
- Homogenization without the extra casein



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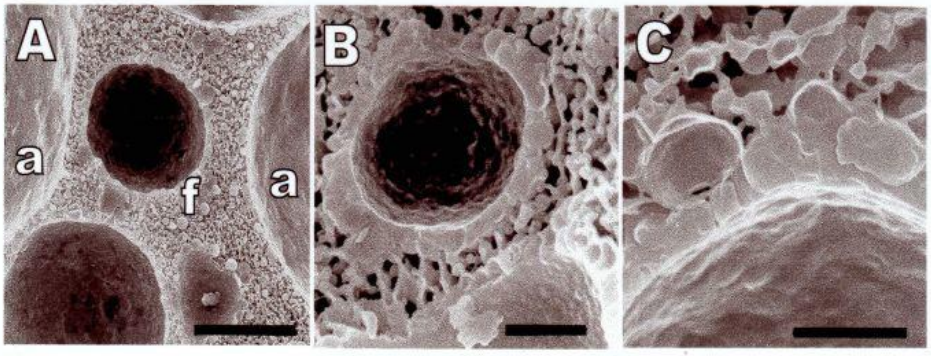
Whipped Cream



The structure of whipped cream as determined by scanning electron microscopy. A. Overview showing the relative size and prevalence of air bubbles (a) and fat globules (f); bar = 30 um. B. Internal structure of the air bubble, showing the layer of partially coalesced fat which has stabilized the bubble; bar = 5 um. C. Details of the partially coalesced fat layer, showing the interaction of the individual fat globules. Bar = 3 um.

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Whipped Cream

Cold, cold, cold – Keep fat solid

Don't over-whip

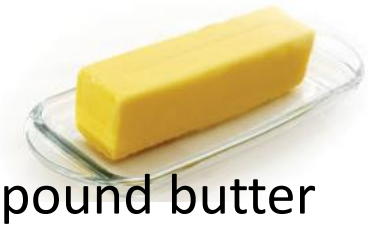
Let's whip!

Over-whipped!

Fat globules combine = butter

Water and whey = buttermilk
"modern" buttermilk
Add protein and acid

Butter



80% milkfat
21 pounds milk = 1 pound butter

"Churning" = mechanical shearing
of fat globules

Finishing

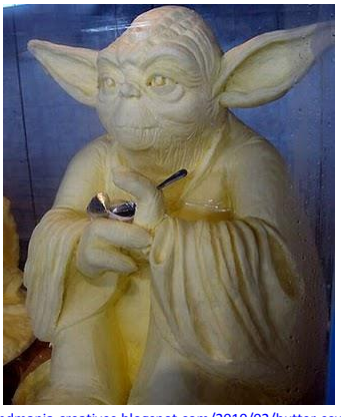
Butter

Salted Butter

- Reduces spoilage
- Add salt or soak in brine

Sweet Cream Butter

- No salt



Color?

Image: http://funandmania-creatives.blogspot.com/2010/02/butter-sculptures.html

Butter

Cultured Butter

- Bacteria added
- Acidified

Diacetyl – "butter flavor"

- Used in butter substitutes
- Inhibits enzymes that protect against oxidative damage
- Exposure risk for workers and heavy "fake butter" eaters (popcorn)

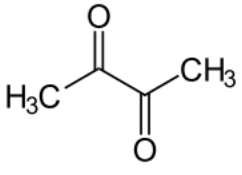


Image: http://en.wikipedia.org/wiki/Diacetyl

Cooking with Butter

Lemon Butter

- Add lemon and sugar

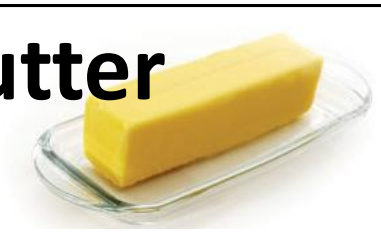
Restaurant trick

- On steaks, and just about anything else

Clarified Butter

- Heat to evaporate water (gently!)
- Milk solids (proteins) separate
- Used to flavor, fry or garnish – almost pure fat
- Popcorn!
- Ghee – south Asia

Imitating Butter



Fake Butter

- Emulsified vegetable oils
- Added sugars and proteins – scorch easily
- Not good for cooking

Margarines

- "Partially hydrogenated" vegetable fat
- Tallow from beef fat mixed with milk {traditional "oleo margarine"}
- Saturated fats