

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
- “the lacteal secretion obtained from one or more healthy milk-producing animals, e.g. cows, goats, sheep, and water buffalo, including, but not limited to, the following: lowfat milk, skim milk, cream, half and half, dry milk, nonfat dry milk, dry cream, condensed or concentrated milk products, cultured or acidified milk or milk products...”



Science of Cooking – BCBT100
Spring 2014 - Bodwin

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



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Mixtures

Homogeneous

Pure substances

Solutions

Heterogeneous

Bulk mixtures, melange

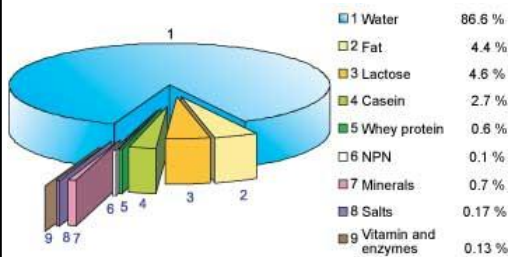
Suspension/colloid, emulsion

Emulsifiers and amphiphiles



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Milk Composition



NPN – Non-protein nitrogenous compounds

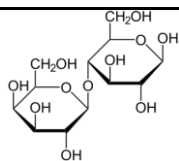
Science of Cooking – BCBT100
Spring 2014 - Bodwin

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

Science of Cooking – BCBT100
Spring 2014 - Bodwin

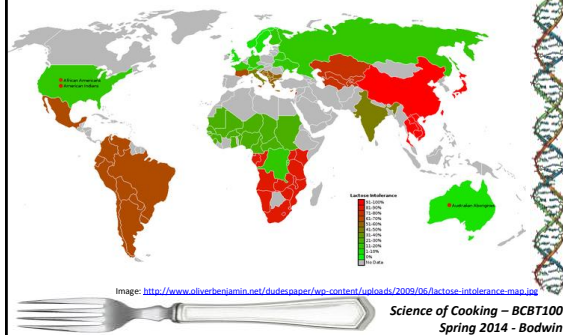
Lactose



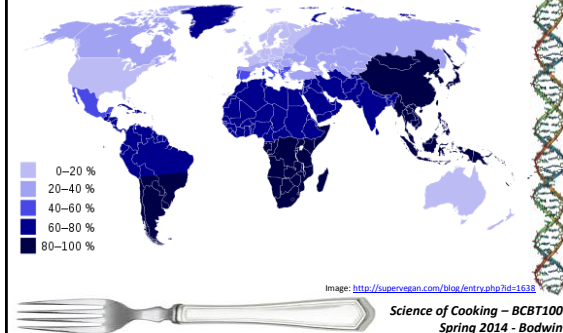
- Disaccharide - glucose and galactose prepared as separate molecules and condensed into "milk sugar" through the secretory cells
- Ability to digest (metabolize or "break down") lactose requires a special enzyme – lactase
- Lactase is produced in gut by children but levels decrease in adults.
- Northern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

Science of Cooking – BCBT100
Spring 2014 - Bodwin

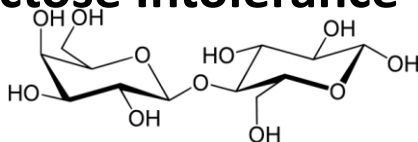
Lactose Intolerance



Lactose Intolerance



Lactose Intolerance



Lactase – hydrolytic enzyme

Lactose passes through to gut

Draws water in (osmosis)

Bacterial digestion – $\text{CH}_4(g)$, $\text{CO}_2(g)$

Cramps, gas, diarrhea

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

Science of Cooking – BCBT100
Spring 2014 - Bodwin

Purpose of Lactose

Glucose

Protected as disaccharide

Energy source

Galactose

Neural tissue

Make brains...

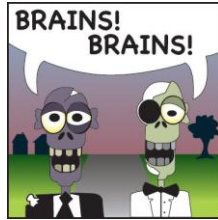


Image: http://bloggy-blah-blah.blogspot.com/2012_01_01_archive.html



Science of Cooking – BCBT100
Spring 2014 - Bodwin

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 acid 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)



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Casein Micelles

kappa-Casein coating

Calcium-binding

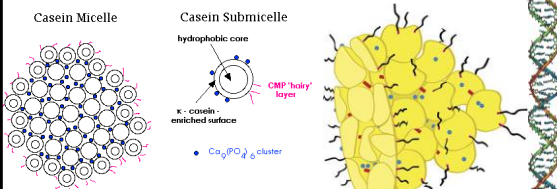


Image: <http://www.foodsci.uoguelph.ca/deisen/casein.gif>

Image: http://openwetware.org/images/thumb/9/92/AM_Micelle.jpg/200px-AM_Micelle.jpg



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Milk Protein - Whey

- Soluble in acidic aqueous phase
- Many whey proteins are immunoglobins (antibodies for the young animal)
- Lactoglobulin 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

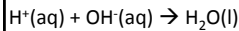


Science of Cooking – BCBT100
Spring 2014 - Bodwin

Acids and Bases

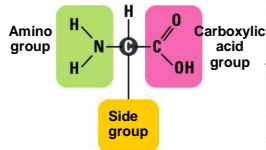
Acids = increase concentration of hydrogen ion (H^+) when dissolved in water

Bases = decrease concentration of hydrogen ion (H^+) when dissolved in water (increase OH^- concentration)



"Neutralization"

pH scale



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Acids and Bases

Acids taste sour

Bases are slippery to the skin

- Muscle acid – lactic acid
- Vinegar – acetic acid
- Fruit acid – citric acid
- Oxalic acid – used in candy with citric acid



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Milk Fat

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

Homogenization

Heat-stable globules

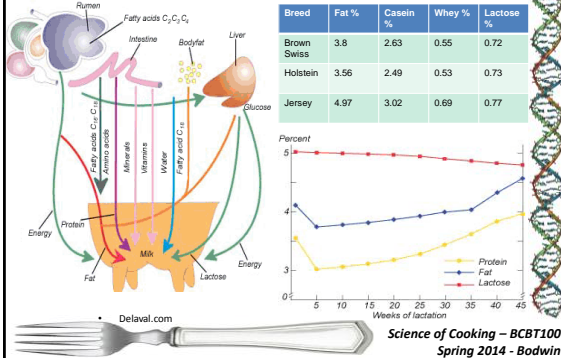
Cold breaks fat globules – ice, ice, baby

Fat soluble vitamins – A, D, E, K



Science of Cooking – BCBT100
Spring 2014 - Bodwin

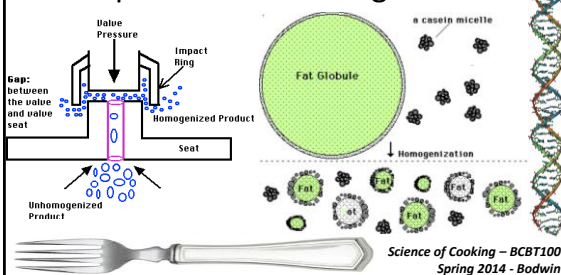
Variations in Milk



Homogenization

Increase surface area

Casein proteins coat – Negative



Sphere Math

$$\text{Volume} = \frac{4}{3} \pi r^3$$

$$\text{Surface area} = 4 \pi r^2$$

1 sphere, 2cm radius

$$\text{Volume} = \frac{4}{3} \pi (2\text{cm})^3 = 34\text{cm}^3$$

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

Break into 2 spheres:

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

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

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

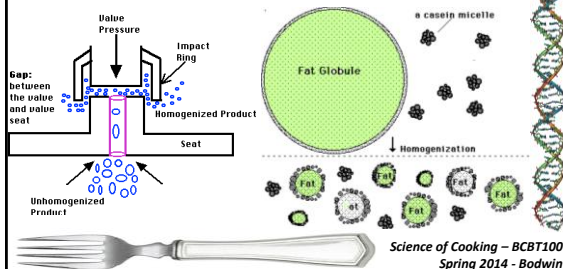


Science of Cooking – BCBT100
Spring 2014 - Bodwin

Homogenization

Increase surface area

Casein proteins coat – Negative



Science of Cooking – BCBT100
Spring 2014 - Bodwin

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



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Foams

Heterogeneous Mixtures

Air in solid or liquid

Milk foams

Protein and/or fat and/or sugar



Science of Cooking – BCBT100
Spring 2014 - Bodwin



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



Science of Cooking – BCBT100
Spring 2014 - Bodwin



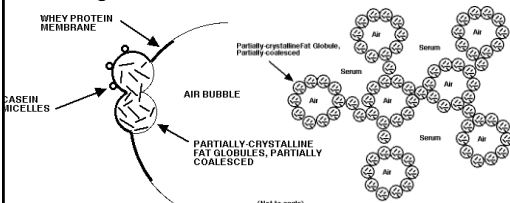
Milk Foams

Whipped Cream

Fat-based foam

Mechanically shearing fat globules

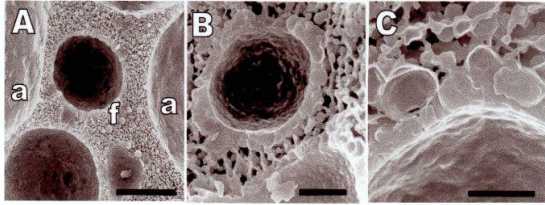
Homogenization without the extra casein



Univ of Guelph CA Food Science
Science of Cooking – BCBT100
Spring 2014 - Bodwin



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 μ m. B. Internal structure of the air bubble, showing the layer of partially coalesced fat which has stabilized the bubble; bar = 5 μ m. C. Details of the partially coalesced fat layer, showing the interaction of the individual fat globules. Bar = 3 μ m.

Univ of Guelph CA Food Science



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Whipped Cream

Cold, cold, cold – Keep fat solid
Don't over- whip

Let's whip!



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Over-whipped!

Fat globules combine = butter

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



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Butter

80% milkfat

21 pounds milk = 1 pound butter

“Churning” = mechanical shearing
of fat globules

Finishing



Science of Cooking – BCBT100
Spring 2014 - Bodwin



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>
Science of Cooking – BCBT100
Spring 2014 - Bodwin



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)

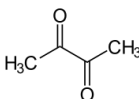


Image: <http://en.wikipedia.org/wiki/Diacetyl>
Science of Cooking – BCBT100
Spring 2014 - Bodwin



Cooking with Butter

Lemon Butter

Add lemon and sugar

Restaurant trick

On steaks, and just about anything else

Clarified Butter

Melt heat to evaporate water (gently!)

Milk solids (proteins) separate

Used to flavor, fry or garnish – almost pure fat

Popcorn!

Ghee – south Asia



Science of Cooking – BCBT100
Spring 2014 - Bodwin



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



Science of Cooking – BCBT100
Spring 2014 - Bodwin



Fermentation

Yogurt

Bacteria “digestion” of lactose

Impact on lactose intolerance?

Produces lactic acid

Impact on properties?

Streptococcus salivarius – thermophilus

More active at lower acid concentration (higher pH)

Lactobacillus delbrueckii – bulgaricus

More active at higher acid concentration (lower pH)

High acetaldehyde production – green apples



Science of Cooking – BCBT100
Spring 2014 - Bodwin



Yogurt properties

Stabilizes milk for storage

Lactoglobulin (a whey protein)

facilitate casein networks

Similar to fat globules in whipped cream

Casein networks hold aqueous phase rather than air

Probiotic bacteria

Contributes to and enhances intestinal flora

Aids digestion

Read the label!



Science of Cooking – BCBT100
Spring 2014 - Bodwin

What should yogurt contain?



Image: <http://cheeseforum.org/forum/index.php?topic=546.0>

Science of Cooking – BCBT100
Spring 2014 - Bodwin

What should yogurt contain?



Image: <http://topnotes.org/CurrentComments/GutCheck/June-08.htm>

INGREDIENTS: MILK (SKIM MILK, CONCENTRATED SKIM MILK, MILK SOLIDS), WATER, FRUIT 7.5% (STRAWBERRY), HALAL GELATINE, MODIFIED STARCH (1442), FRUCTOSE, NATURAL COLOURS (120,163), FLAVOURS, SWEETENERS (951,950), ENZYME (LACTASE), PRESERVATIVE (202), FOOD ACID (331), LIVE YOGURT CULTURES (CONTAINS ACIDOPHILUS AND BIFIDUS CULTURES), PHENYLETHANOLINE, CONTAINS PHENYLALANINE

STRAWBERRY
LOW FAT FRUIT
YOGURT
200g

Image: <http://www.nestle.com.au/Nutrition-Health-Wellness/Fact-Sheets/Decoding-Food-Labels>

Science of Cooking – BCBT100
Spring 2014 - Bodwin

What should yogurt contain?

INGREDIENTS: CULTURED GRADE A MILK. CONTAINS ACTIVE YOGURT AND L. ACIDOPHILUS CULTURES.

**** MEETS NATIONAL YOGURT ASSOCIATION CRITERIA FOR LIVE AND ACTIVE CULTURE YOGURT**

A COMPANY OF THE DANONE GROUP



© 1998 THE DANON CO., INC.

KEEP REFRIGERATED



Image: <http://bare5.com/acrosv-labelingredients-guide/>

Image: <http://journalofgrammarians.blogspot.com/2011/07/greek-yogurt.html>



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Why all the thickeners?

Texture

Smoother

Limit separation

Fat replacement

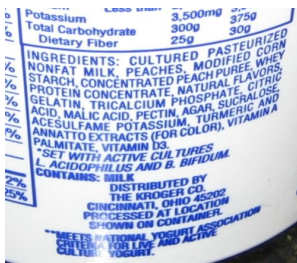


Image: <http://cheeseforum.org/forum/index.php?topic=546.0>



Science of Cooking – BCBT100
Spring 2014 - Bodwin

Making Yogurt

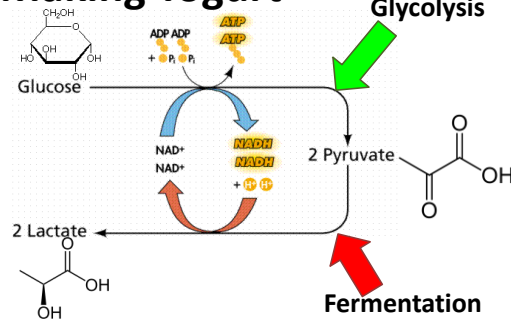


Image: <http://www.emc.maricopa.edu/faculty/farabee/2008/2008bookbkc.html>



Science of Cooking – BCBT100
Spring 2014 - Bodwin

