MILK

Food Material Science 2010/11
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Definition

- The normal secretion of the mammary glands of all mammals (Potter & Hotchiss, 1996).
- Milk is a complete food for the new born.
- High density of nutritious components.

The average composition of milk

Constituent	Concentration ($g\,l^{-1}$)		Proportion solids (%)
Fat	37.0		28.9
Protein: casein	27.6	34.0	26.6
whey protein	6.4		
Non-protein nitrogen	1.9		1.5
Lactose	48.0		37.5
Ash	7.0		5.5
Total solids	127.0		100.0

Source: Muir & Banks (2003)

The classification of milk protein

- Casein --- phosphoprotein
  - α_{s1}-casein
  - α_{s2}-casein
  - β-casein
  - κ-casein
  - γ-casein
- Whey protein
  - β -lactoglobulin
  - α-lactalbumin
  - Minor proteins: blood serum albumins, immunoglobulins, lactoferrin, transferrin, vitamins-binding proteins, protease peptone 3, enzimes, etc.

CASEIN MICELLE

- Protein
  - Casein
  - Proteose pepton
- Salts
  - Ca
  - Phosphate
  - Citrate
  - K, Mg, Na
- Water
- Enzymes (lipase, plasmine)

Composition and structure of milk fat

FAT GLOBULE

Glycerides

- triglycerides
- diglycerides
- monoglycerides

Fatty acids

Sterols

Carotenoids

Vitamins A,D,E,K

Water

MEMBRAN

Water

Protein

Phospholipids

Cerebrosides

Glycerides

Fatty acids

Sterols

Other lipids

Enzymes

- alkaline phosphatase
- xanthine oxidase
- many others

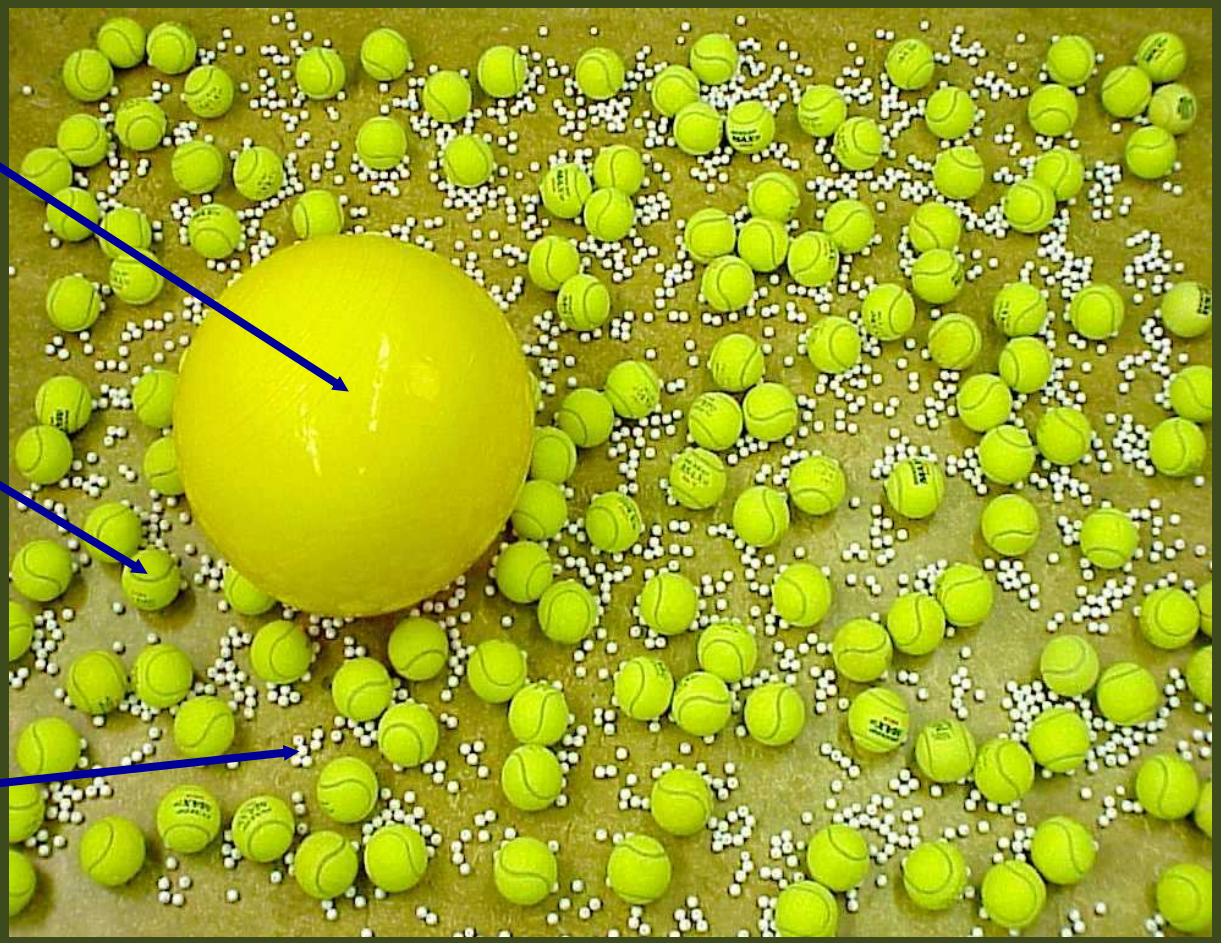
Cu and Fe

Milk composition

fat globule

casein micelle

whey protein



Other milk constituents

LEUKOCYTE

Many enzymes

e.g. katalase

Nucleic acids

Water

LIPOPROTEIN PARTICLE

Lipids

Protein

Enzymes

Water

SERUM

Water	**Organic acids**	**Proteins**
Carbohydrates	citrate	casein
lactose	formate	β-lactoglobuline
glucose	acetate	α-lactalbumine
others	lactate	serum albumin
Minerals	oxalate	immunoglobulines
Ca, bound	others	proteose pepton
Ca, ions	**Gases**	**NPN**
Mg	oxygen	peptides
K	nitrogen	amino acids
Na	**Lipids**	urea
Cl	glycerides	ammonia
phosphate	fatty acids	**Enzymes**
sulfate	phospholipids	acid phosphatase
bicarbonate	cerebrosides	peroxidases
Trace elements	sterols	many others
Zn/Fe/Cu and many	**Vitamins**	**Phosphoric esthers**
others	B vitamines	**Others**
	ascorbic acid	

Properties of the main structural elements of milk

	fat	casein micelles	globular proteins	lipoprotein paricles
Main component(s)	**Fat**	**Casein, water salts**	**Serum proteins**	**Lipids, proteins**
To be considered as	Emulsion	Fine dispersion	Colloidal solution	Colloidal dispersion
Content (% dry matter)	4	2.8	0.6	0.01
Volume fraction	0.04	0.1	0.006	10^{-4}
Particle diameter	0.1 – 10 µm	20 – 300 nm	3 – 6 nm	10 nm
Number per ml	10^{10}	10^{14}	10^{17}	10^{14}
Surface area (cm^2/ml milk)	700	40.000	50.000	100
Density (20 ^{0}C; kg/m^3)	900	1100	1300	1100
Diffusion rate (mm in 1 h)	0.0	0.1 – 0.3	0.6	0.4
Isoelectric pH	~3.8	~4.6	4 – 5	~4

Milk quality

- Factors that determine the quality of fresh milk (standard indicators) are:
  - **Total solid contents**, including protein (min. 2.7%), fat (min. 3%), solid non fat (min. 8%). Raw milk is purchased by weight, but processed milk is sold by volume.
  - Freezing point
  - Density

Milk quality

- Some factors can influence the quality of milk, including:
  - Feed
  - Genetic
  - Climate
  - The health status of cattle
  - Milking process and storage
  - Post harvest handling

Colostrum

- Colostrum is the secretion produced over the first few days after parturition. The components of colostrum are synthesised in the mammary gland over several days prior to parturition.
- Colostrum is rich in special nutrients for the newborn.
- Colostrum contains more mineral salts and protein and less ash than later milk. Ca, Na, Mg, P, and chloride are higher in colostrum but K is lower.
- The most remarkable difference between colostrum and milk is the high concentration of immunoglobulins (Ig's) in colostrum. Ig's are related to passive immunity against gut pathogens.

Colostrum

- Colostrum has a higher level of -carotene, imparting an intense yellow colour, and a high level of somatic cells.
- Recently there has been a lot of commercial interest in colostrum because of its elevated levels of bioactives, especially growth factors, and there is a wide range of literature supporting the health benefits of colostrum
- Colostrum is 10 times more expensive than milk powder.

Fresh Milk Deterioration

- Milk can deteriorate fast since milk contains high nutrient contents such as carbohydrate, fat and protein which required by bacteria to grow.
- Moreover, pH of milk is close to neutral pH. This is very suitable for the growth of microorganisms.
- Lastly, since most of microorganism (mesophilic and psychotrophic bacteria) can grow very well at room temperature, fresh milk stored in room temperature is susceptible to microbial deterioration.

Fresh Milk Deterioration

- Many of the psychrotrophic bacteria isolated from milk produce extracellular enzymes that degrade milk fat and protein (proteolysis and lypolysis).
- Bacterial lipase causes serious degradation of milk fat.
- Beside microbial degradation, fresh milk also susceptible to enzymatic degradation. Raw milk has an abundance of lipoprotein lipase, an enzyme that will rapidly hydrolyse milk fat to free fatty acids (FFAs).
- Some of these FFAs have low organoleptic thresholds and produce odors and flavors (rancid, bitter, soapy or unclean).

Creaming

- Since the specific gravity of lipids and skim milk is 0.9 and 1.036, respectively, the fat globules in milk held under quiescent conditions will rise to the surface under the influence of gravity, a process referred to as creaming.

- The rapid rate of creaming is due to the strong tendency of the fat globules to cluster due to the effect of indigenous immunoglobulin M which precipitates onto the fat globules when milk is cooled (cryoglobulins).

Creaming

- Large globules rise faster than smaller ones, collide with them and form aggregates. The clusters of globules rise rapidly and therefore the creaming process is accelerated as the globules rise and clump.

- Creaming is inhibited by reduction of the fat globule size by homogenisation. The milk fat globules are reduced in size by pumping at very high pressure (up to 400 bar) through a small slit. The size reduction results in an increase in specific surface area .

UHT vs Pasteurized Milk

- Generally, there are two heat treatment given to fresh milk, i.e. pasteurization and sterilization using ultra high temperature (UHT).
- Pasteurization is done at 63°C for 30 min **or** 72-75°C for 15-20 s (high temperature short time - HTST). Pasteurization is used mostly to kill Gram-negative psychrotrophs bacteria, but only has little effect on extracellular degradative enzymes.
- While UHT is done at 135 - 140°C for a few seconds. It can kill both pathogen and spoilage microorganisms. The most heat resistant pathogenic spore – *C. botulinum* and some enzymes also can be inactivated.

UHT vs Pasteurized Milk

- UHT products are commonly stored at room (ambient) temperature and good quality products should be microbiologically stable.
- Nevertheless, chemical reactions and physical changes will take place which will change the quality of the product. These include oxidation reactions, Maillard browning and chemical and physical changes which may give rise to age-thickening and gelation.

UHT vs Pasteurized Milk

- In pasteurization, thermoduric bacteria and spore forming bacteria can survive. *Bacillus cereus* spores are relevant here, being the main pathogen which will survive pasteurization and grow at low temperature. It will certainly cause spoilage in heat-treated milk.
- Enzymes in raw milk may give rise to problems in pasteurized milk. For example, indigenous lipases may give rise to soapy off-flavors. However, it is unlikely that bacterial lipases and proteases, which are very heat resistant, will cause problems in pasteurized milks because of their relatively short shelf-life and refrigerated storage conditions.

Milk & Dairy Products Adulteration

- Watering of milk
- Milk of different species
- Addition of non-dairy protein
- Altering the casein/whey protein ratio
- Addition of buttermilk or whey powder to milk powder
- Addition of vegetable or animal fats to milk fat
- Addition of reconstituted milk to fluid milk
- Non-authorized preservatives.

Milk & Dairy Products Adulteration

Analytes of indicative value for the detection of adulteration of milk and milk products

Milk component	Source of adulteration	Analyte(s)
Fat	Non-dairy fat or oil Buttermilk added to milk	Fatty acids Triglycerides Phospholipids Sterols Fat-soluble vitamins
Protein	Non-dairy proteins Milk of a different species Whey added to milk Heat load	Caseins Whey proteins Glucomacropeptide Casein bound-P Protein-N Denatured proteins
Lactose	Water Heat load	Freezing point Furosin Lysinoalanin HMF Glycosylated proteins
Minerals	Water	Freezing point

Milk Coagulation

- Desirable coagulation of milk can be seen in dairy products processing such as cheese, yoghurt, etc.
- Undesirable coagulation occur in liquid milk. It can caused by lactic acid (produced by bacteria) --- the reduction of pH or by physical separation (due to density difference) such as creaming, flocculation or coalescence --- see emulsion chapter).

Milk Coagulation

- Milk protein, such as whey protein and casein have important role in coagulation.
- The example of desirable coagulation:
  - Acidification forms the basis of production of all fermented milks. The gels of fermented milks, such as yoghurt, are formed by acidification of milk. As the pH is reduced, the casein precipitates selectively. The first signs of aggregation occur around pH 5 and once the pH falls to 4.6 all the casein becomes insoluble.

Milk Coagulation

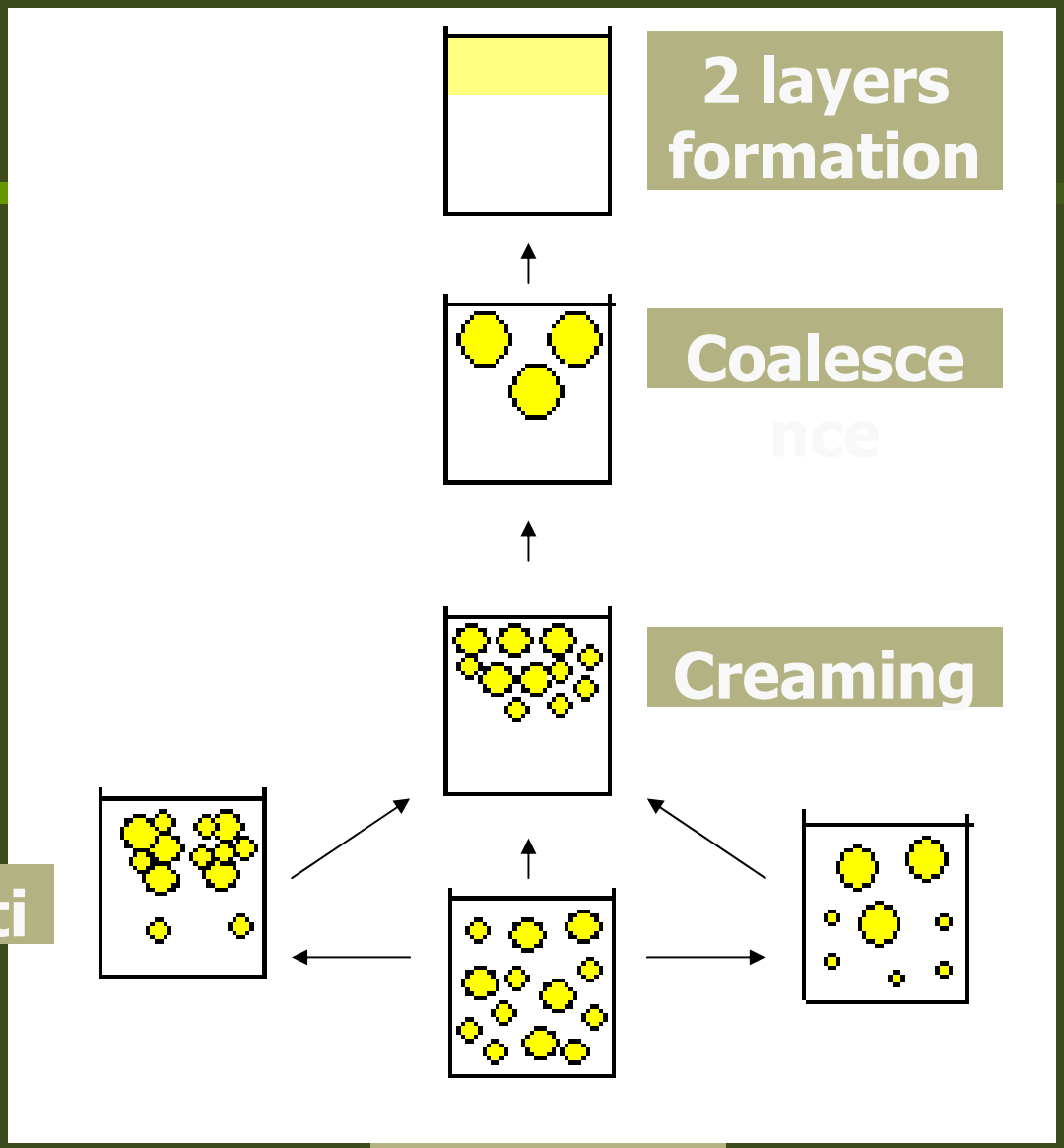
- Some factors influence coagulation, including:
  - pH
  - Temperature
  - Heat treatment
  - Casein concentration
  - The presence of salt

Emulsion

- Milk proteins have excellent emulsifying properties.
- Milk is categorized as o/w emulsion, since the oil part is dispersed in the water.
- Milk proteins, both caseinates and whey proteins, are surface active, they are absorbed rapidly to the oil-water interface, forming stable emulsions.

Emulsion

- The primary processes leading to emulsion instability are:
  - Creaming – refers to the gravitational separation of emulsified droplets to form a densely packed phase without change in droplet size.
  - Flocculation – denotes the aggregation of droplets via interactions between adsorbed proteins.
  - Coalescence – an increase in droplet size, gradually results in separation of the oil and aqueous phases.


2 layers formation
Coalesce
nce
Creaming
Flocculati on
Kineticall y stable

Whipping & Foaming

- As milk proteins are surface active, they have the ability to adsorb to the air-water interface during foam formation.
- Foams are most commonly formed by mechanically dispersing air into a solution containing surface-active agents. A rapid diffusion of the protein to the air-water interface to reduce surface tension, followed by partial unfolding of the protein is essential for the formation of protein-based foams.

Whipping & Foaming

- Caseinates generally give higher foam overruns but produce less stable foams than whey protein concentrates (WPC).
- The foaming properties are influenced by many factors, including:
  - protein concentration,
  - level of denaturation,
  - ionic strength,
  - preheat treatment and
  - presence of lipids.

The Changes of Milk Flavor

- Deterioration of milk flavor can be caused by degradation milk fat and protein.
- Rancidity is a common indicator of the forming of undesirable flavor.
- Factors stimulating the off-flavor in fresh milk:
  - Light
  - Ion metals
  - Transferred from cow to milk
  - Microorganisms
  - Enzymatic reactions

(See the additional paper – taken from *Dairy Processing Improving Quality, p.141*)

Thank You….