MILK

• Milk: milk is the secreted fluid of the mammary glands of female mammals;

• today the term «milk» refers to cow’s milk, otherwise it is specified (e.g. sheep milk, goat milk);

• it is a white, yellow-white opaque liquid, its color being due to absorption and scattering of light by milk protein micelles and fat globules;

• it is slightly sweet and its odor and flavor are normally faint;

• in the first days after delivery colostrum (or first milk) is produced: it contains less lactose and fats and more proteins (lots of lactoalbumins and less casein) than milk; it is rich in minerals, vitamin A and contains antibodies to protect the newborn against diseases.

• Cows produce 10-50 liter of milk in a day for 200-220 days after the delivery;

• within a day, the milk obtained in the evening has an higher fat content;

• It is a whole food, containing all the nutrients: protein, lipid, carbohydrate, mineral, vitamin, all in variable amount depending on the animal, the feeding, the lactation period, etc. It is in fact the only meal of the newborn, but it is also important in the diet of adults, particularly in case of disease.
CHEMICAL-PHYSICAL PROPERTIES

Milk is an **aqueous dispersion** composed by:

- A **solution** of: lactose, lactoalbumin, lactoglobulin, minerals, hydrosoluble vitamins;

- A **suspension** of tricalcium phosphate, caseins (the main protein of vaccine milk), cells, microrganisms;

- An **emulsion** of lipids, liposoluble vitamins.
• **Fresh milk is almost neutral** (pH = 6.6-6.7) due to the presence of buffering systems as \( \text{KH}_2\text{PO}_4 - \text{K}_2\text{HPO}_4 \) and mixture of basic and acid proteins, but along with time it gets acid due to the fermentation of lactose producing lactic acid by milk ferment. Fermentation is rapid at 30-40 °C, while it is quite slower at 0°C; anyhow a protein having antimicrobial activity is naturally found (lactenin) in milk.

*Colostrum vs milk composition*
CHEMICAL COMPOSITION

- Water (87.5%)
- Lipids (3.2-3.9%)
- Nitrogen substances (2.9-3.3%)

NFS (8.8%)
- Carbs (4.6-5%)
- Mineral, organic acids (1%)
- Vitamin
- Gas

Proteins (94%)
- Casein 80%
- Whey Protein 20%

Non protein nitrogen substances (aminoacids, urea, creatin, ammonia,...)
- β-lactoglobulin 20%
- α-lactalbumin 54%
- Serum albumin 6%
- Immunoglobulin 12%
- Lactoferrin 8%

Percent

Lactose
Fat
Protein

Weeks of Lactation
Proteins

In women milk contains **1.63 % protein** ⇒ Body Weight (BW) of the newborn is doubled in **180 days**

in cows milk contains **3.1 % protein** ⇒ BW is doubled in **47 days**

in rabbits milk contains **14 % protein** ⇒ BW is doubled in **6 days**

**Growth velocity** in newborn is **proportional** to the **proteins and calcium content** of milk

- The main vaccine protein (lactoglobulin, lactalbumin, casein) can be allergenic.

**Caseins** (**α_s1, α_s2, β, k, γ:** 50, 30, 15, 5%)

- They don’t coagulate by heating (140°C for 20-60 min would be needed), while they do by acidification (they have low pI) or by proteolitic enzymes activity;

- they are mainly aggregated as casein micelles and casein complexes: macromolecular complexes (diameter: 50-300 nm) encompassing mineral salts (Ca and Mg phosphate and citrates);

- only up to 10 % of total caseins is present as monomer;

- milk color and opacity are due to the property of micelles of reflecting light and to the presence of suspended substances (fatty globules, caseins);
they have not tertiary structure thus they don’t denaturate by heating; also secondary structures are interrupted due to the frequent presence of proline; this characteristic causes the hydrophobic portions to be exposed, rendering these molecules insoluble in water and causing their aggregation;

• due to their micellar aggregation, they can be separated by centrifuge;

• K is the only casein containing a glycosyl moiety, thus being hydrophilic and stabilizing the other caseins; in the production of cheese, when the enzyme rennin breaks K casein into two peptides, one of them being hydrophobic (paracasein K), this one destabilizes casein micelles making them aggregate and coagulate;

• in normal conditions K casein has a colloidal-protective role, hampering micelles aggregation.
Whey proteins

- They are finely dispersed and more stable, they don’t coagulate by acidification, nor by enzymatic action;
- they don’t separate by centrifuge;
- they are mainly globular proteins;
- they coagulate by heating (denaturation);
- contain more sulphur aa and less glutamic acid and proline;
- they have high biologic value, quite superior to that of casein.

<table>
<thead>
<tr>
<th>Protein Type</th>
<th>Protein N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human milk</td>
<td>53%</td>
</tr>
<tr>
<td>Whey proteins</td>
<td></td>
</tr>
<tr>
<td>Vaccine milk</td>
<td>17%</td>
</tr>
</tbody>
</table>

β-Lactoglobulin

- 8 genetic variants;
- it represents about 20% of whey proteins in vaccine milk (biologic role in ruminant: fat metabolism), while it is scarcely present in human milk.
**α-Lactoalbumin**

- It is 4% of the total proteins in vaccine milk (and 20% of the whey proteins) while it is 23% of proteins in human milk (42% of the whey proteins);
- high biologic value: only ovoalbumin (egg protein) has an higher biologic value;
- it has a bacteriostatic activity;
- it is a subunit of the enzyme lactose-synthetase allowing the transfer of galactose in the mammary glands.

**Other proteins**

**Serum albumin (6% of total protein in vaccine milk)**

It derives from the blood of the animal, it is important since it allows to recognize the origin.

**Lactoferrin**

It transports iron (two atoms per molecule).

**Immunoglobulins**

- They derive from blood;
- they are responsible for the immunologic properties of milk;
- they are very abundant in colostrum
**Proteose-peptone (PP)**

They are formed through the proteolysis of β-casein.

**Enzymes (oxidases, catalases, peroxidases, transaminases, amylases, lipases, phosphatases, proteases, lysozyme).**

- in fresh crude milk, some of them still work;
- some are useful to verify the extent of the thermal treatments;
- lysozyme, lactoperoxidases have a bacteriostatic action;
- lipases, proteases are involved in dairy products process transformations.

**Lipids**

- In whole vaccine milk they are about the 3.5 %.
- Fatty globules are complex biologic systems having diameter 3-5 μm with inside triacyl glycerides and outside a lipoproteic film 0.02 μm thick.
- Globules have a lower density with respect to water thus they emerge after standing, forming a layer of cream at the surface;
milk has one of the most complex lipid mixture found in nature, the main components are:
- triglycerides (95 %),
- mono and diglycerides (2 %),
- free fatty acids (0.1-0.4 %),
- phospholipids (0.8-1 %),
- sterols (0.2-0.4 %).

Among fatty acids, even if in low amount, also short chain, odd number, branched, trans-, hydroxy- and keto-acids are found.

### Percentages of the main fatty acids in vaccine and human milk

<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>Vaccine milk</th>
<th>Human milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyric (C₄)</td>
<td>4.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Capronic (C₆)</td>
<td>2.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Caprylic (C₈)</td>
<td>1.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Capric (C₁₀)</td>
<td>2.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Lauric (C₁₂)</td>
<td>3.2</td>
<td>4.7</td>
</tr>
<tr>
<td>Myristic (C₁₄)</td>
<td>11</td>
<td>7.9</td>
</tr>
<tr>
<td>Palmitic (C₁₆)</td>
<td>28.1</td>
<td>26.6</td>
</tr>
<tr>
<td>Palmitoleic (C₁₆:1n7)</td>
<td>2.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Stearic (C₁₈)</td>
<td>10</td>
<td>8.3</td>
</tr>
<tr>
<td>Oleic (C₁₈:1n9)</td>
<td>25</td>
<td>7.3</td>
</tr>
<tr>
<td>Linoleic (C₁₈:2n6)</td>
<td>3</td>
<td>6.7</td>
</tr>
</tbody>
</table>
• UFA eaten by ruminants are saturated by bacteria in rumen, that’s why in vaccine milk high percentages of SAFA are found, differently from monogastric animals; anyhow adding seed oils rich in PUFA in the cattle’s feeding, it is possible to reduce the percentage of saturated fatty acids in vaccine milk.

**Carbohydrates**

• Lactose is almost the only carb found in milk;

• vaccine milk contains 4.5 g/100 g;

• lactose must afford galactose to the newborn in order to build nerve structures;

• other sugars are found in traces: glucose, galactose, phosphorylated sugars, oligosaccharides.

• **Lactose synthesis**: it takes place in cells of mammary tissue starting from hematic glucose and galactose (deriving from the transformation of glucose). The complex lactose-synthetase (formed by the enzyme galactosyltransferase and by $\alpha$-lactoalbumin) allows the formation of the bond between glucose and galactose.
**Vitamins**

- Milk contains all the vitamins in variable amounts, the main are:
  
  - **Vitamins A and carotenoids**
  - **Other liposoluble vitamins**
  - **Vitamins B₁, B₂, B₅, B₁₂**
  - **Hydrosoluble**

  - Their content is strongly reduced after thermal treatments

**Minerals**

- They are about 1 % (0.75 % as ash);
- they derive from blood, but they are filtered in the mammary glands in order to obtain concentration needed by the newborn for the growth;
- among macroelements **K, Ca, citrates, phosphates prevail**;
- among microelements, the most significant are **Zn, Mg, Fe, Cu**: after the first six months from the birth, Fe and Cu are no more sufficient for the nutritional requirements to the newborn, thus they must be supplemented by diet;
- some metals can be present as contaminants.
Other constituents

- **cells (blood and mammary skin)**

- **microorganisms**: some hundreds to some thousands per ml of milk just taken aseptically by wholesome animals.

- **Organic acids**: Orotic acid ($B_{13}$ vit.), citric acid (buffering activity), lactic, acetic acids.

\[ \text{Orotic acid} \quad \text{Citric acid} \]

20-100 mg/l in vaccine milk
PROCESSING OF MILK

Milk

Direct consumption

Dairy industry

Natural milk:

Crude milk

Thermically treated milk (pasteurized, UHT, sterilized).

Special milks: skim, concentrated, powder, delactosated, supplemented, etc.
PASTEURIZED MILK

*Thermal treatments are needed to improve milk durability and to kill disease-causing microorganisms*

It is treated at **72 °C for 15 sec** or at equivalent conditions (T, t) (low pasteurization).

- **Negative phosphatase**
- **Positive peroxidase**

**Thermal treatment** → **Rapid cooling T<6° C**

- **Local origin, crude milk.**
- **Foreign origin, possible weak heating (60-65° C) before transportation.**
Heat treatment (low or high pasteurization)

- **Preheating** at 40-45°C in exchanger (using heat of pasteurized output milk)
- **Homogenization**, to reduce fat globules size by applying \( P = 150-350 \) bar
- **Degasation**, at 45°C, under vacuum, to eliminate bad odours

**Pasteurization** is HTST (High Temperature, Short Time): it can be Low (75-80°C / 15-20”) or High (135-150°C / 1-3”) depending on the desired durability of the product.

**Sterilization** (120°C 15-20 min on packaged milk) is rarely performed.

Currently **alternative technics** (like bactotherm process or microfiltration, high pressure treatment) are also applied.
HEATING OF MILK: EFFECTS AS DEPENDING ON (T, t)

- 1-3: pasteurization (1-high temperature, 2-short time, 3-long time);
- 4-5: UHT (4-indirect, 5-direct);
- 6-sterilization;
- a-killing pathogenic microorganisms (Tubercle bacilli as labelling organism);
- b-c: inactivation of alkaline/acid phosphatase
The final milk’s nutritional values depend on the extent of the thermal treatment:

- **Pasteurized within 48 h from milking**
  - **UHT milk**
  - **Pasteurized fresh milk**
- **From selected farming and pasteurized after a limited time from the milking**
  - **High quality pasteurized fresh milk**

<table>
<thead>
<tr>
<th></th>
<th>Skim milk (fat&lt;0.3%)</th>
<th>Half skim (1.5-1.8%)</th>
<th>Whole (3-3.5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline phosphatase</td>
<td>negative</td>
<td>negative</td>
<td>negative</td>
</tr>
<tr>
<td>Peroxidase</td>
<td>negative</td>
<td>positive</td>
<td>positive</td>
</tr>
<tr>
<td>Whey-proteins</td>
<td>min. 11%</td>
<td>min. 14%</td>
<td>min. 15.5%</td>
</tr>
<tr>
<td>Fat</td>
<td>variable</td>
<td>variable</td>
<td>3.5%</td>
</tr>
<tr>
<td>Total protein</td>
<td>28g/l</td>
<td>28g/l</td>
<td>min. 32g/l</td>
</tr>
</tbody>
</table>

Only whole milk

To be consumed by the sixth day subsequent to thermal treatment