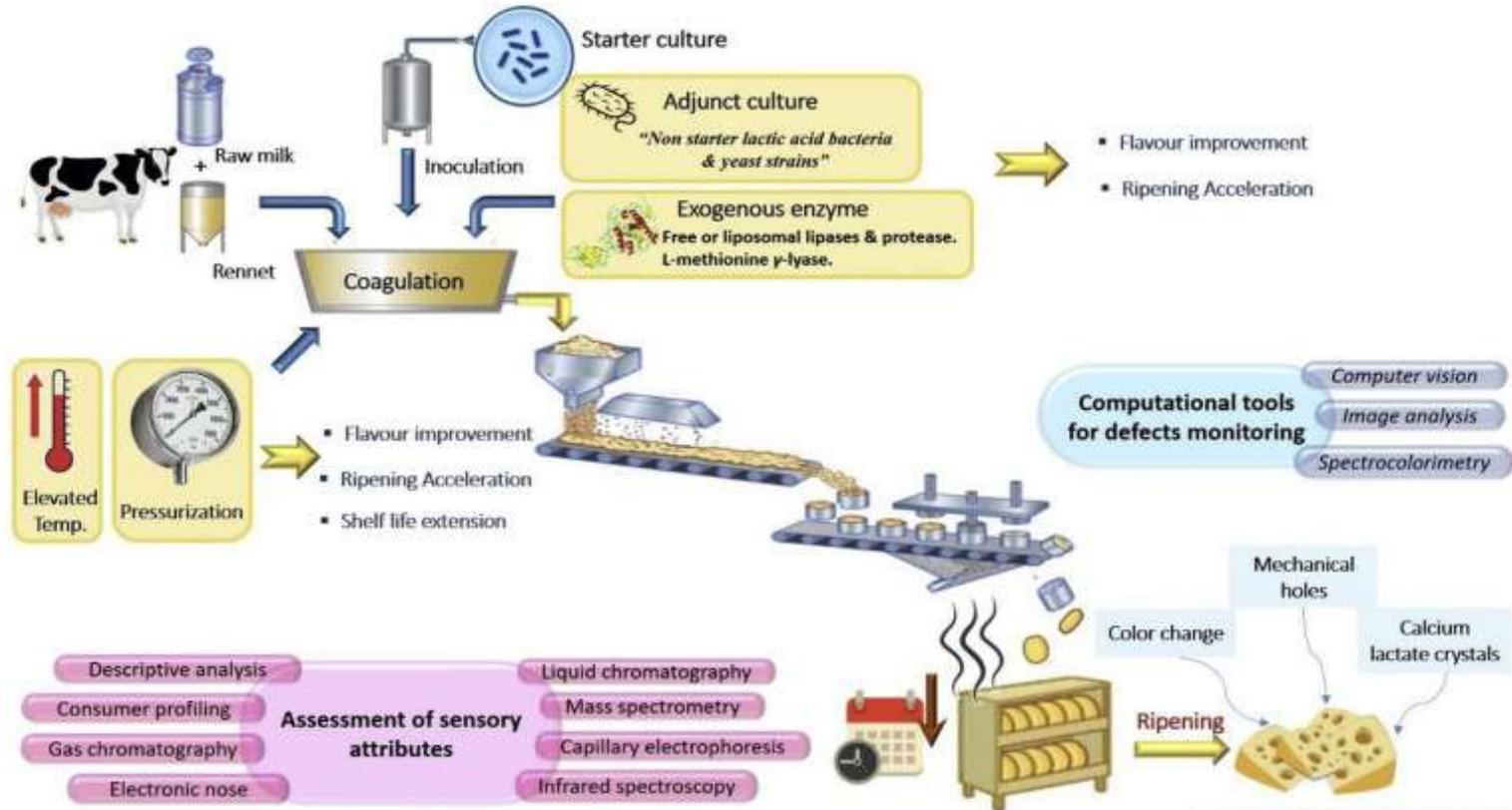


# Chemical, physical, microbiological and sensory changes during cheese ripening



# Unique characteristics of each cheese variety are determined by curd manufacturing operations but these characteristics are largely developed during ripening process.



- ❖ Ripening involves microbial and chemical changes, responsible for development of typical characteristics in cheeses.
- ❖ Microbial changes involve death and lysis of starter cells, development of non-starter microflora and growth of secondary microflora.
- ❖ Ripening causes softening of cheese texture due to hydrolysis of casein matrix, change in pH and change in water binding ability of curd.
- ❖ Primary events during cheese ripening are **metabolism of residual lactose, lactate metabolism, proteolysis and lipolysis.**

## **Metabolism of Residual Lactose:**

- **LAB is added in the form of starter culture to cheese metabolize lactose to lactate.**
- **Rate and extent of acidification influence texture of curd by controlling rate of demineralization.**
- **pH of cheese curd is determined by extent of acidification during manufacturing process. This influences the solubility of casein, which in turn affects the texture of curd.**
- **pH also affects the activity of enzymes involved in ripening, thereby having an indirect effect on cheese texture and flavor development.**

- **Most of lactose is lost in whey during cheese manufacturing.**
- **Low levels of lactose remains in curd. This residual lactose is converted to L-lactate during early stages of ripening by action of starter bacteria. Rate of conversion is dependent on temperature and salt in-moisture levels of curd. Starter activity is stopped very quickly at end of manufacturing operations due to low pH, salt addition and lesser amount of fermentable lactose.**
- **Lactose that remains unfermented by starter is probably metabolized by NSLAB flora present in curd and they convert the residual lactose to D-lactate.**

## **Lactate Metabolism:**

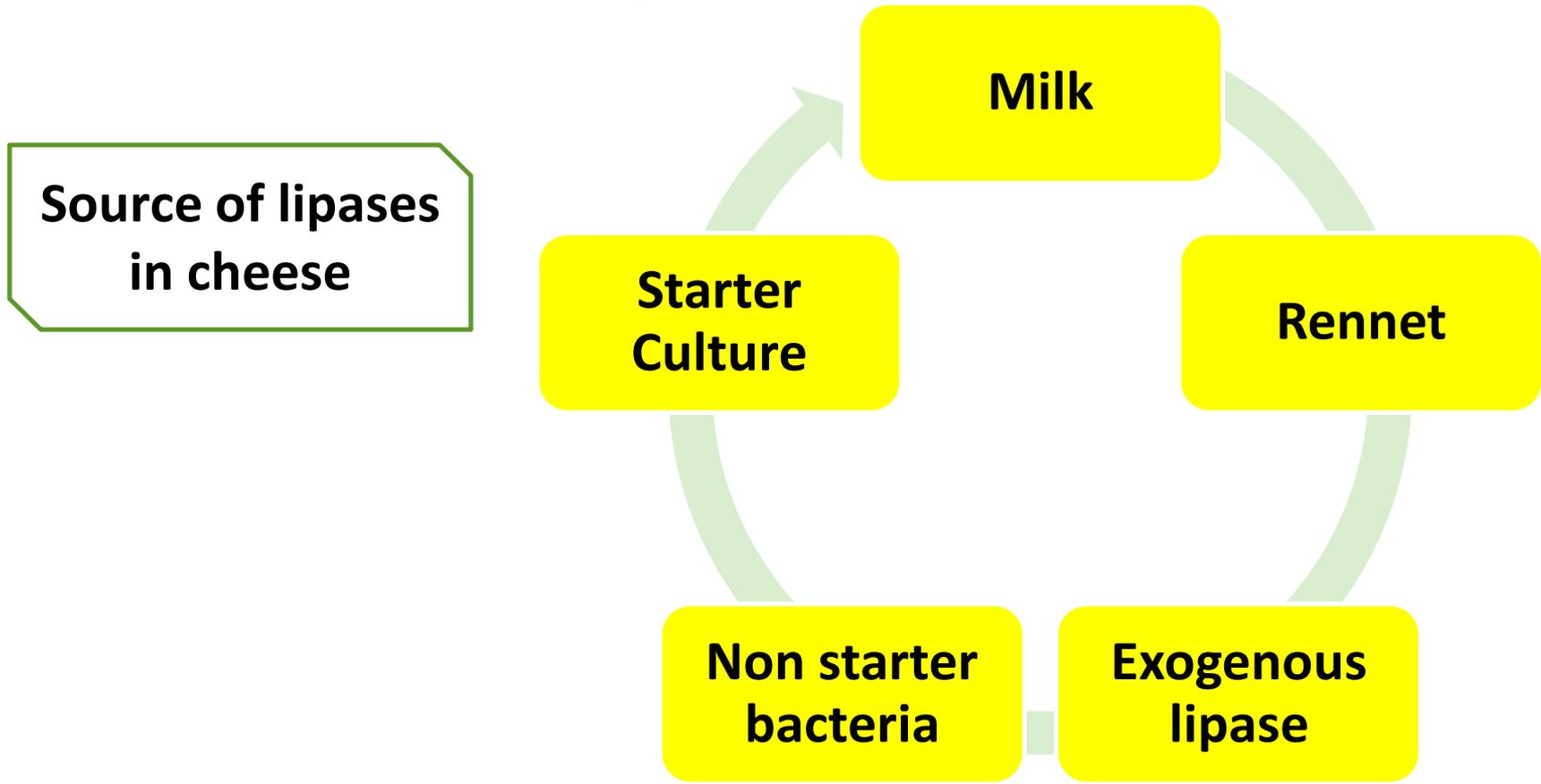
- **Lactate produced by fermentation of residual lactose serves as an important substrate for reactions occurring during cheese ripening.**
- **L-lactate can be racemised to D-lactate by NSLAB flora. D-lactate is less soluble than L-lactate which results in formation of Ca-D-lactate crystals. These crystals are not harmful but they appear as white specks on surface of mature cheese.**
- **Lactose can be metabolized to acetate, ethanol, formate and CO<sub>2</sub> depending on population of NSLAB and availability of O<sub>2</sub>.**

- In cheese wrapped with film, oxidation of lactate occurs to lesser extent due to low level of O<sub>2</sub>.
- Late gas blowing is caused by anaerobic metabolism of lactate by *C. tyrobutyricum* to butyrate and H<sub>2</sub>. The release of H<sub>2</sub> causes cracks in cheese during ripening.



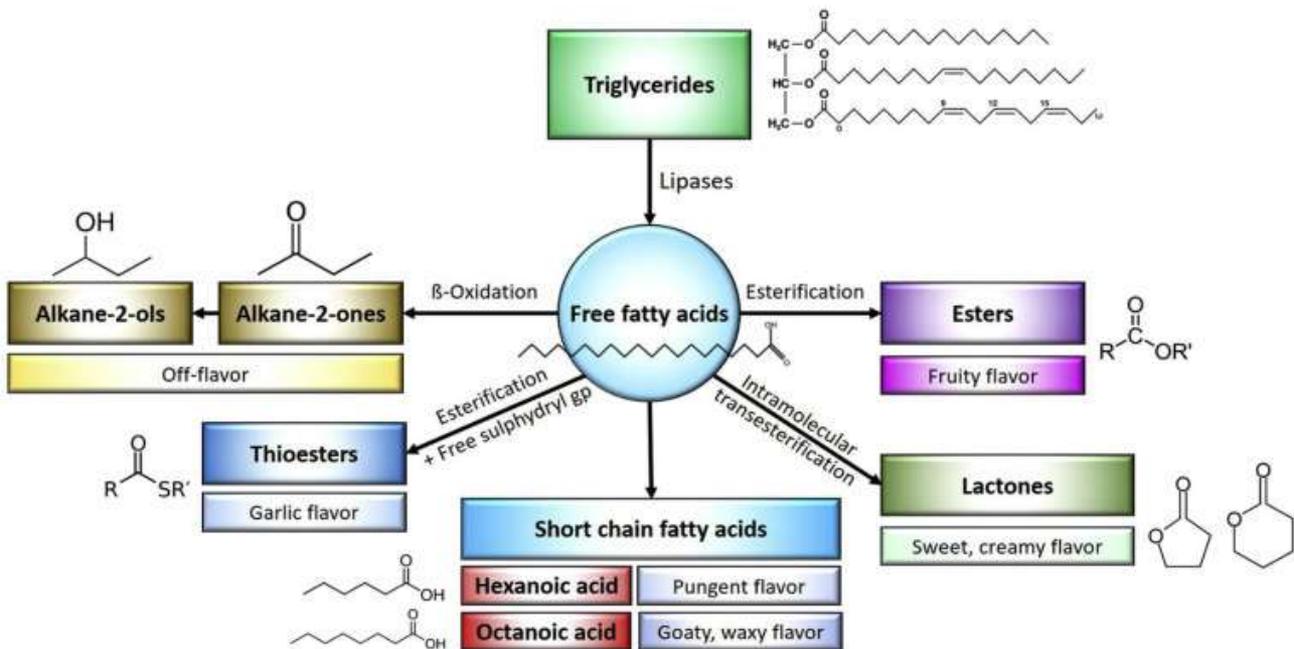
## Lipolysis:

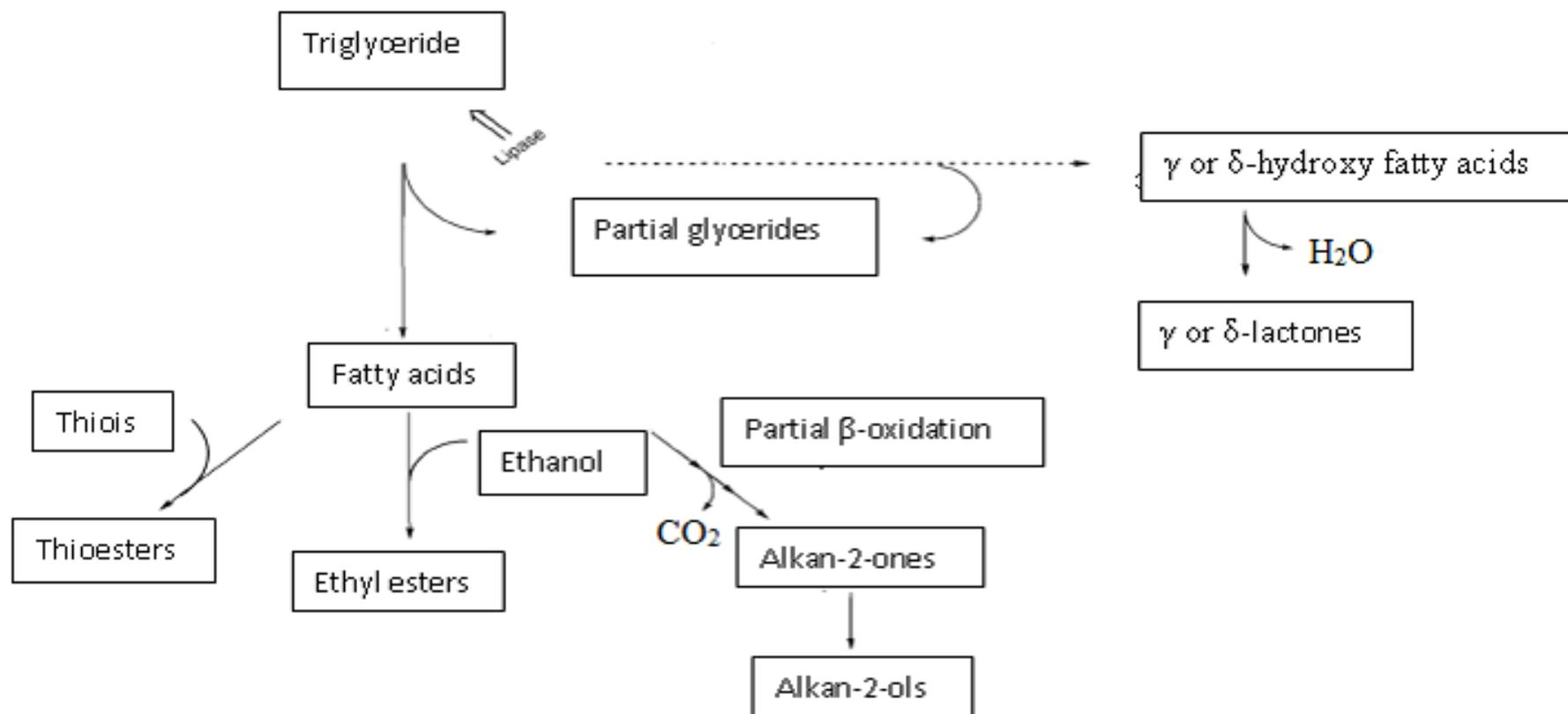
- Milk fat essential for development of correct flavor in cheese ripening.
- Lipids may undergo oxidative/hydrolytic degradation in foods but redox potential of cheese is very low, so hydrolytic degradation of lipids takes place. Triglycerides are hydrolyzed by lipases which result in formation of fatty acids.



- **Low level of lipolysis is required for development of flavor but excessive lipolysis causes rancidity.**
- **Lipolysis of milk fat results in production of free fatty acids which contribute to flavor of cheese and act as precursors for development of other secondary fat-derived flavor compounds (esters, lactones, ketones and aldehydes).**
- **Fatty acid esters are produced by reaction of fatty acids with an alcohol (ethyl esters being common). Thioesters are formed by reaction of fatty acid with thiol compound formed via the catabolism of sulphur-containing amino acids.**

- Fatty acid lactones are formed by intramolecular esterification of hydroxyacids;  $\gamma$  - and  $\delta$ -lactones contribute to flavor. n-methyl ketones are formed by the partial  $\beta$ -oxidation of fatty acids.
- Liberation of short and medium chain fatty acids from milk fat by lipolysis contribute directly to cheese flavor. Flavour is very extensive in some hard Italian varieties and blue mold cheeses. Excessive lipolysis causes rancidity in Cheddar and Gouda.

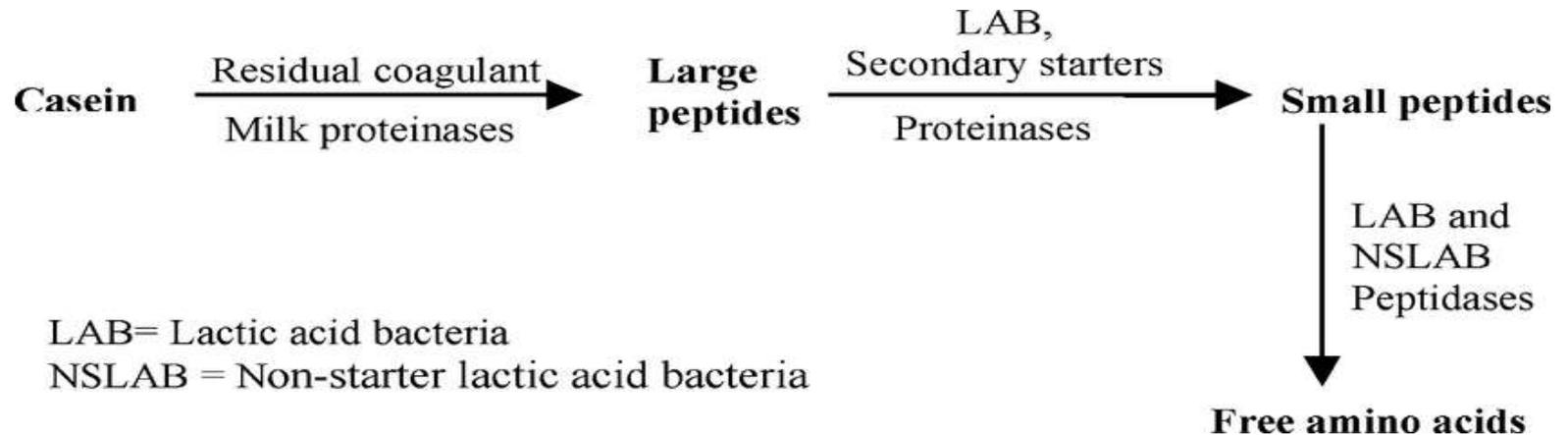




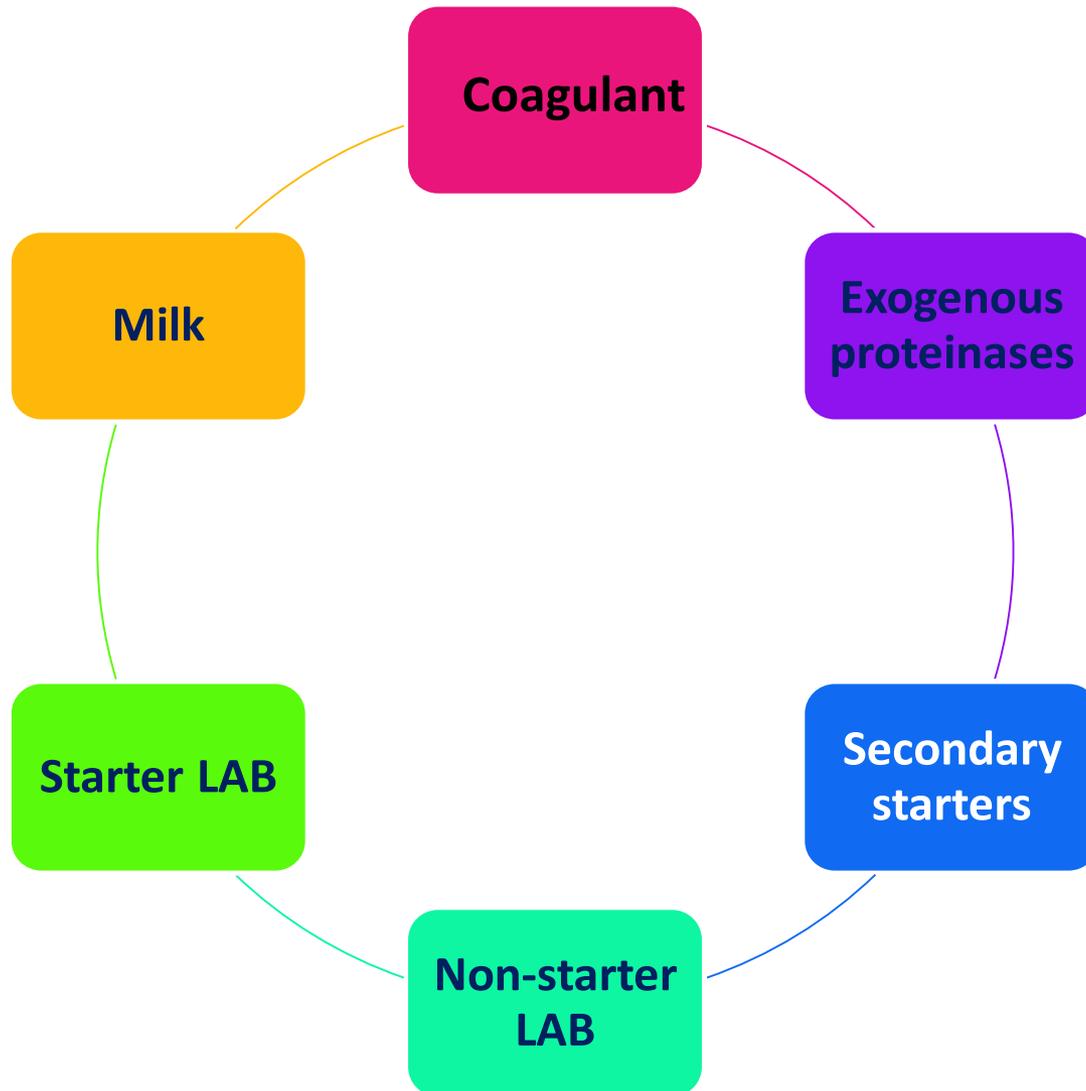
**Production of flavor compounds from fatty acids during cheese ripening**

# Proteolysis:

- Extent of proteolysis is used as an index of cheese ripening and quality of cheese.
- Contributes towards development of texture and flavor.
- Textural changes (softening of cheese curd) occur due to breakdown of protein network and release of carboxyl and amino groups resulting in binding of more water thus, decrease  $a_w$ .
- Proteolysis leads to formation of peptides and free amino acids contributing to cheese flavor. These amino acids also act as precursors for many reactions (transamination, deamination, decarboxylation, desulphuration, catabolism of tyrosine, phenylalanine, tryptophan etc.) and generate flavor compounds.

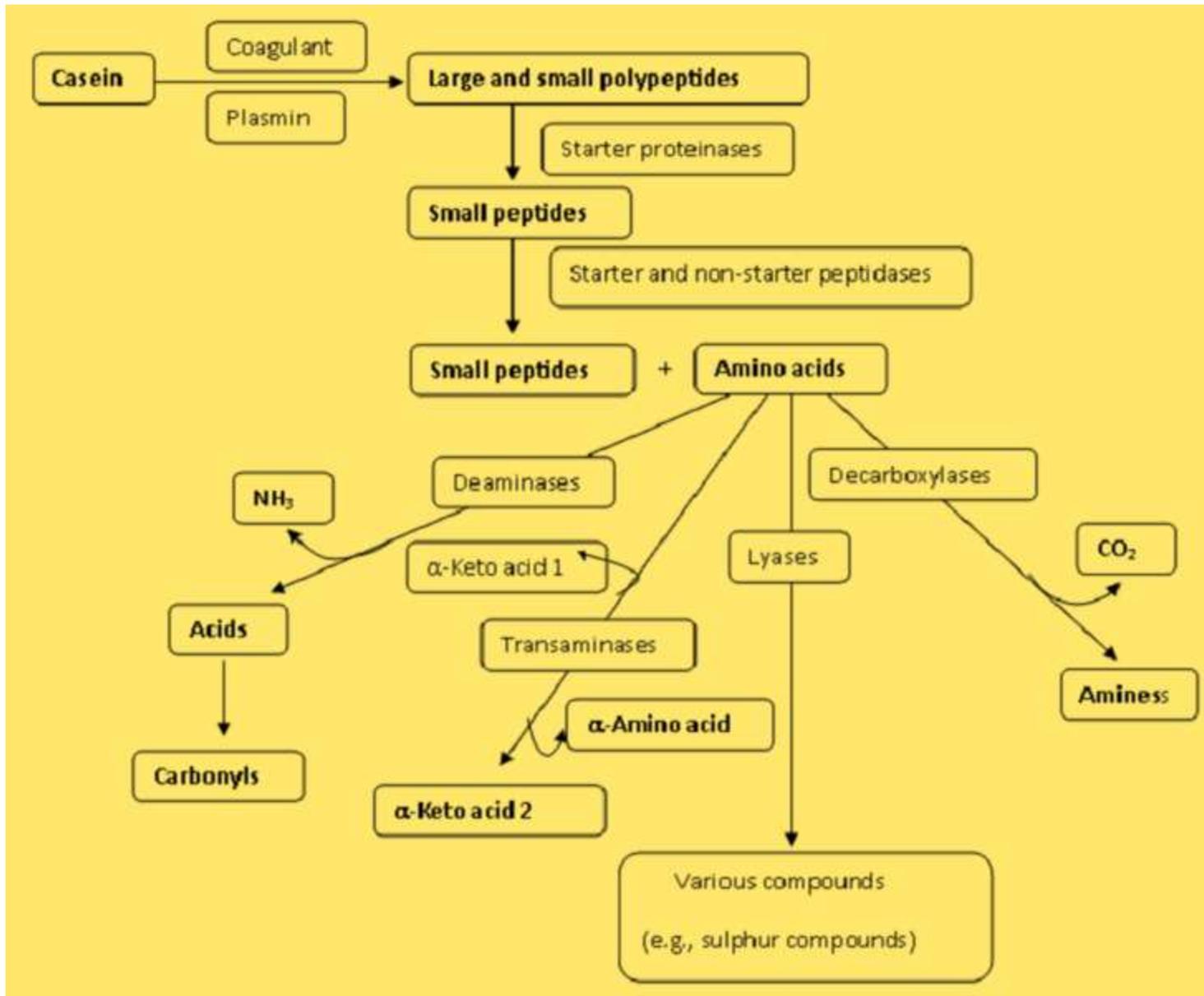


# Proteinases and peptidases originate from following sources

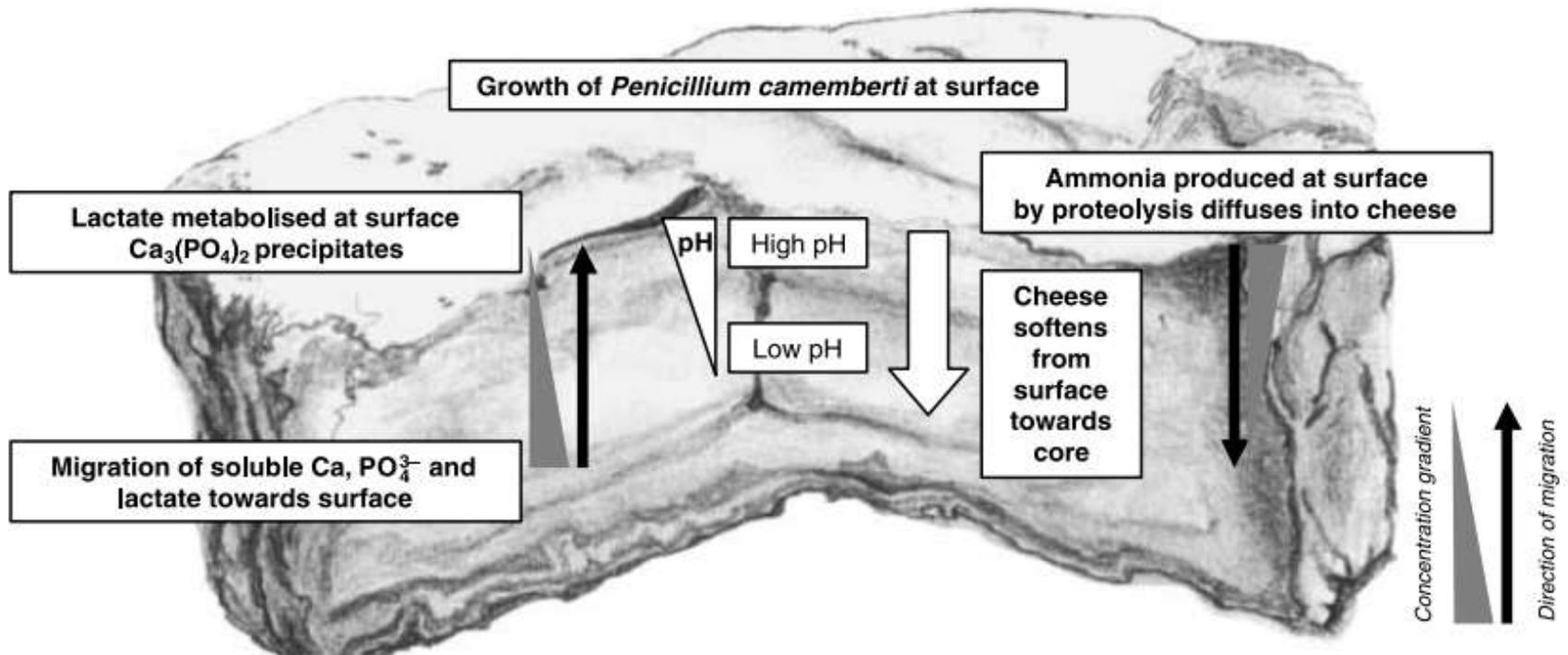


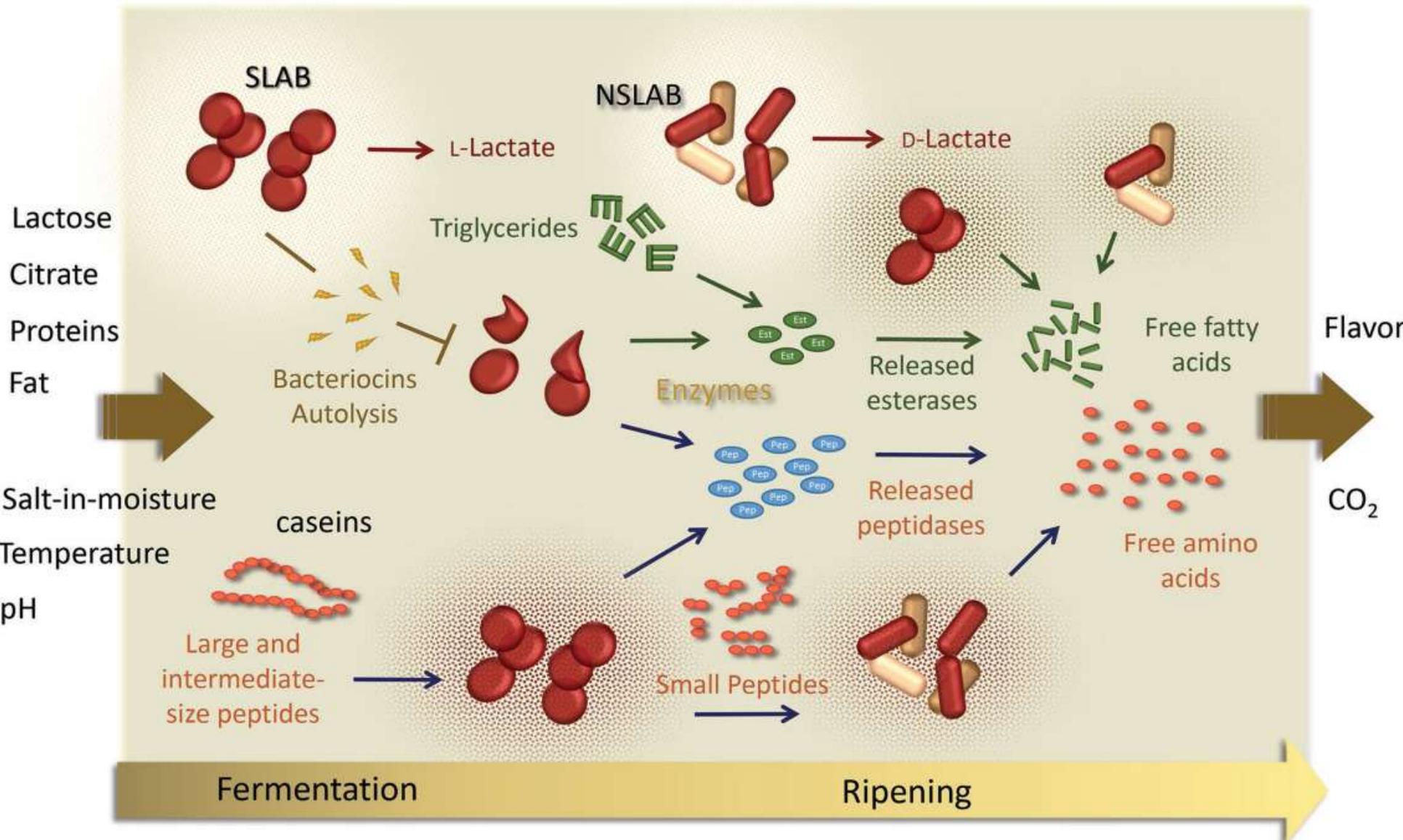
- **Casein is initially hydrolyzed by residual coagulant, often chymosin, which results in formation of large and intermediate -sized peptides. Peptides then hydrolyzed by enzymes derived from starter and non-starter microflora of cheese.**
- **Production of small peptides and amino acids is caused by microbial proteinases and peptidases, respectively.**
- **Medium and small peptides contribute to a brothy background flavor in many cheese varieties; short, hydrophobic peptides are bitter.**
- **Amino acids contribute directly to sweet taste to cheese (Gly, Ser, Thr, Ala, Pro), sour (His, Glu, Asp) or bitter (Arg, Met, Val, Leu, Phe, Tyr, Ile, Trp).**

# Proteolysis in Cheese during Ripening



# Ripening of a Camembert





## **Microbiology of Cheese Ripening**

- Bacteria, yeasts and molds contribute to ripening process through their metabolic activity.**
- Enzymes released by these microorganisms perform proteolysis, glycolysis and lipolysis.**
- Microorganisms in cheese may gain entry in form of starter culture and some may be associated with the ingredients used in cheese making.**
- Secondary microflora do not play any active role during cheese manufacture but contribute to ripening process.**
- Factors controlling growth of microorganisms in cheese include  $a_w$ , concentration of salt, Eh, pH, ripening temperature and presence/absence of bacteriocins.**

## **Water activity:**

- **Ratio of vapor pressure of water in a material ( $p$ ) to vapor pressure of pure water ( $p_0$ ) at same temperature.**
- **Value ranges 0-1.0.**
- **Expresses water availability rather than total water present in the system.**
- **Water activity of cheese reduces during ripening process due to:**
  - ✓ **Evaporation of moisture if the cheese is not vacuum packed or paraffin coated**
  - ✓ **Hydration of proteins bound water rendering it unavailable for bacterial growth**
  - ✓ **Hydrolysis of proteins to peptides and amino acids and lipids to glycerol and fatty acids**
  - ✓ **Salt and organic acids (lactate, acetate, and propionate) dissolved in the moisture of the cheese reduce the vapor pressure**

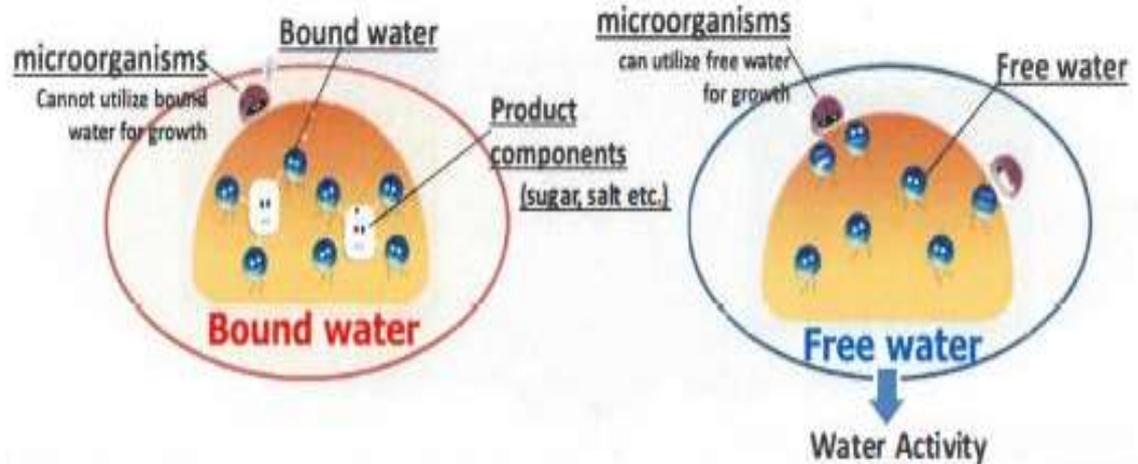
- Growth of microorganisms at low  $a_w$  is characterized by a long lag phase, slow rate of growth, and reduction in the maximum number of cells produced.
- Salt normally used in cheese making is about 2% of weight of curd. It suppresses growth of unwanted microorganism.
- Growth of unwanted microorganisms is essentially curbed by reduction in  $a_w$  as salt act as a humectant.

## Water Activity

$$a_w = \frac{P}{P_0}$$

$P$  = vapor pressure in food

$P_0$  = vapor pressure of pure water



## **Oxidation-Reduction Potential (Eh):**

- **Measure of tendency of solution to either gain or lose electrons when it is subject to change by introduction of a new species.**
- **Eh of milk is +150 mV and cheese is about -250 mV.**
- **As cheese ages, products of proteolysis and lipolysis may reduce Eh of cheese. This reduction of Eh makes cheese an anaerobic system, where facultative or obligate anaerobic microorganisms can grow causing bitter and putrid flavor.**
- **Obligate aerobes (*Pseudomonas* spp., *Brevibacterium* spp., and *Micrococcus* spp.,) will not grow within the cheese.**

## pH:

- Most bacteria require neutral pH value for optimum growth and grow poorly at pH below 5.0.
- pH of cheese curd after manufacture generally lies within the range 4.5-5.3, so pH control bacterial growth in cheese.
- Lactobacilli has pH optima below 7 and *Lactobacillus* spp. can grow at pH 4.0. Yeasts and molds can grow at pH below 3.0, although their optimal range is from 5- 7.
- *B. linens* in smear-ripened cheese cannot grow below pH 6.0.

## Temperature:

- Ripening temperature of cheese depends on two considerations: temperature should be such that the growth of undesirable spoilage causing and pathogenic bacteria can be checked and at the same time, this temperature should be conducive for various ripening reactions essential for development of typical flavor, body and texture of cheese.
- Ripening temperature for **Cheddar cheese** is 6-8°C while **Camembert and other mold-ripened cheeses** are ripened at 10-15°C.
- **Emmental cheese** is ripened initially for 2 -3 weeks at a low temperature (~ 12°C), after which the temperature is increased to 20-24°C for 2-4 weeks to promote the growth of propionic acid bacteria. Temperature then reduced again to around 4°C.
- Use of higher ripening temperature can be used for accelerated ripening of cheese.

## Condition Monitoring During Cheese Ripening

