THE EFFECTS OF UHT HEAT TREATMENT ON THE MILK NUTRIENTS

- Milk is a complete food comprising all the essential nutrients which is required to nourish the human.
- It contains lactose, protein, fat, vitamin and minerals.
- Milk is sterile at the secretion but it easily can be spoiled after the milking within 3 to 4 hours if it is stored in the room temperature.
- Milk processing is required to convert the milk into several other conditions to preserve it and increase the shelf life.

UHT treatment

- It involves several heating conditions
- Two types
  - direct heating system
  - indirect heating system
- It is normally in the range of 135-150^{o}C in combination with holding times necessary to achieve commercial sterility.

Direct heating systems

- The product is heated by direct contact with steam of potable or culinary quality which could be obtained from potable water
- The main advantage is that the product is held at the elevated temperature for a shorter period of time
- There are two methods for direct heating, they are;
  - Injection direct heating system
  - Infusion direct heating system

Injection direct heating system

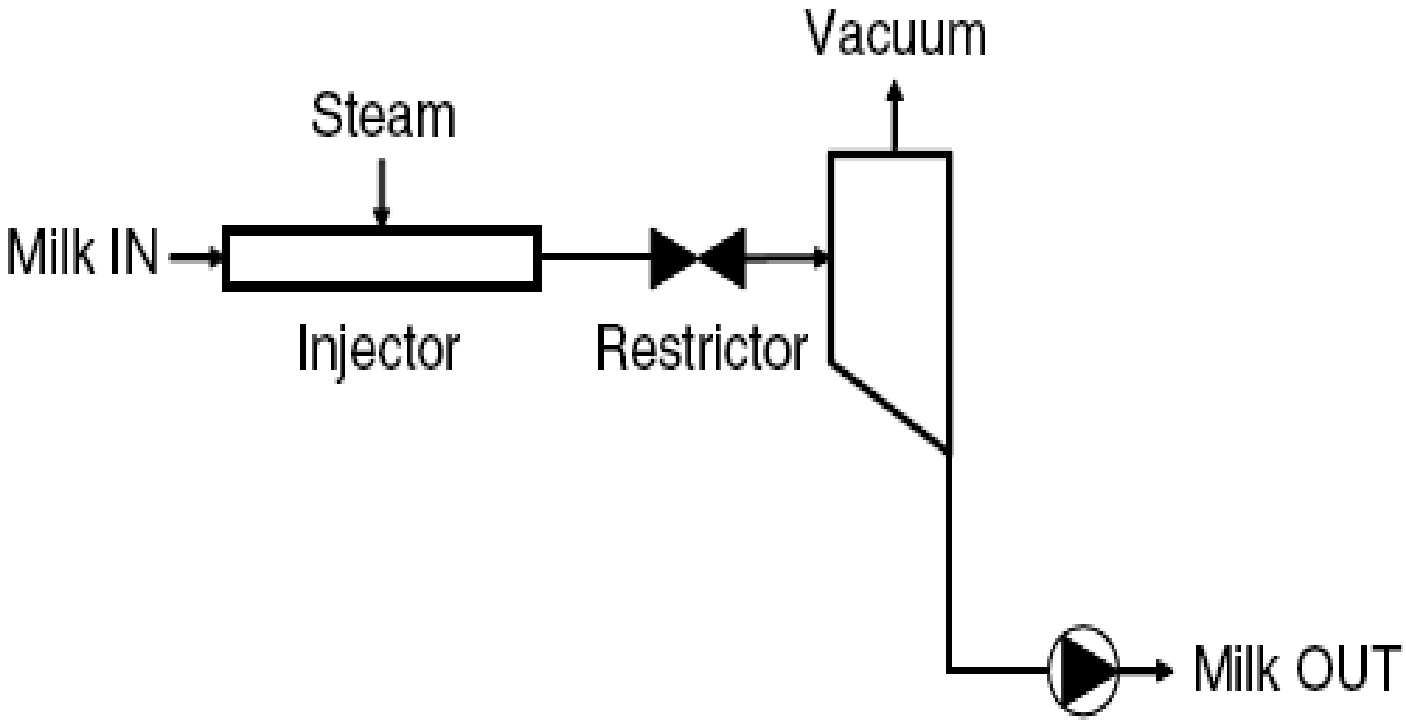

Fig 1: Schematic diagram of injection direct heating system

Infusion direct heating system

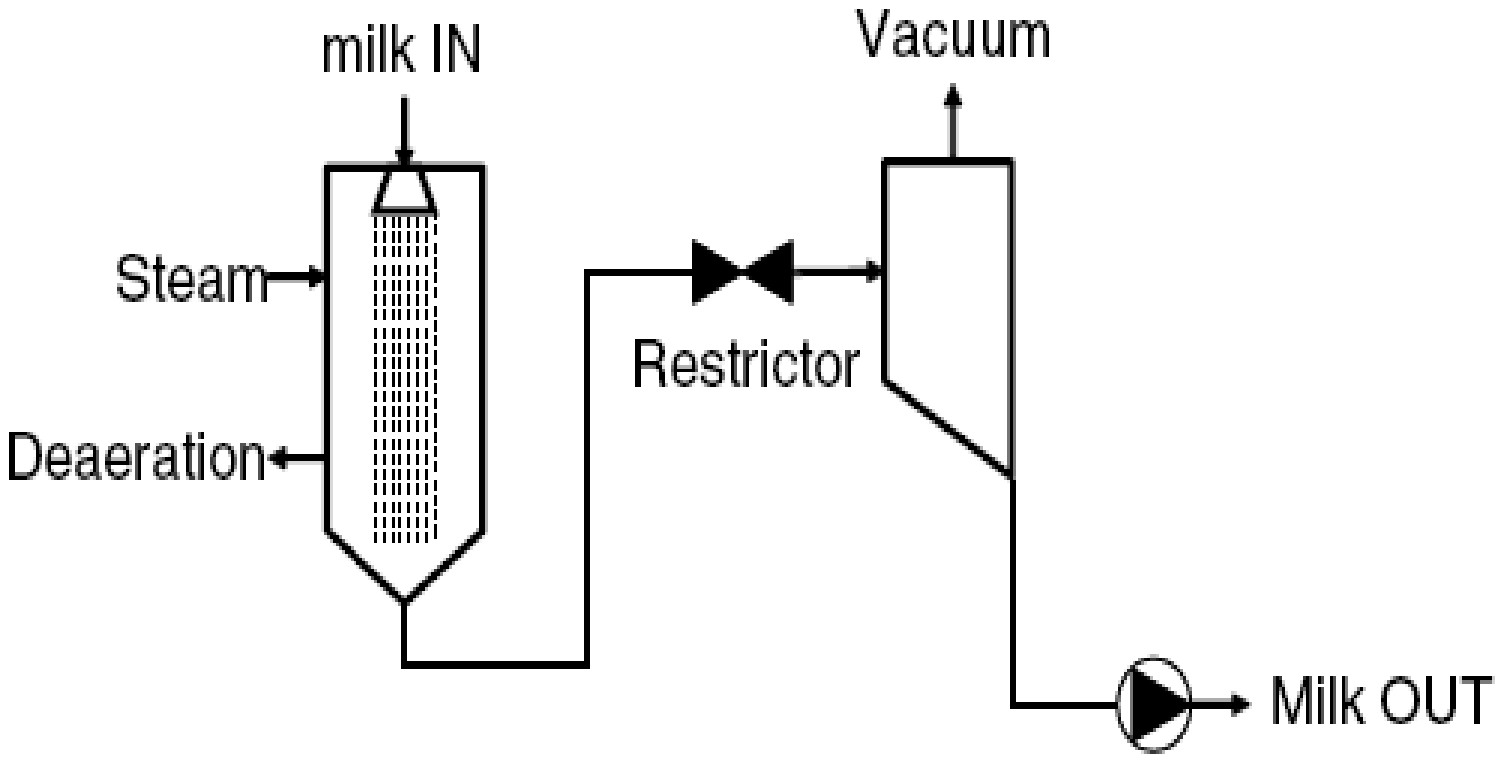

Fig 2: Schematic diagram of Infusion direct heating system

Indirect heating system

- The heating medium and product are not in direct contact, but separated by equipment contact surfaces. Several types of heat exchangers are applicable. They are;
  - Plate heat exchanger
  - Tubular heat exchanger

Plat heat exchanger

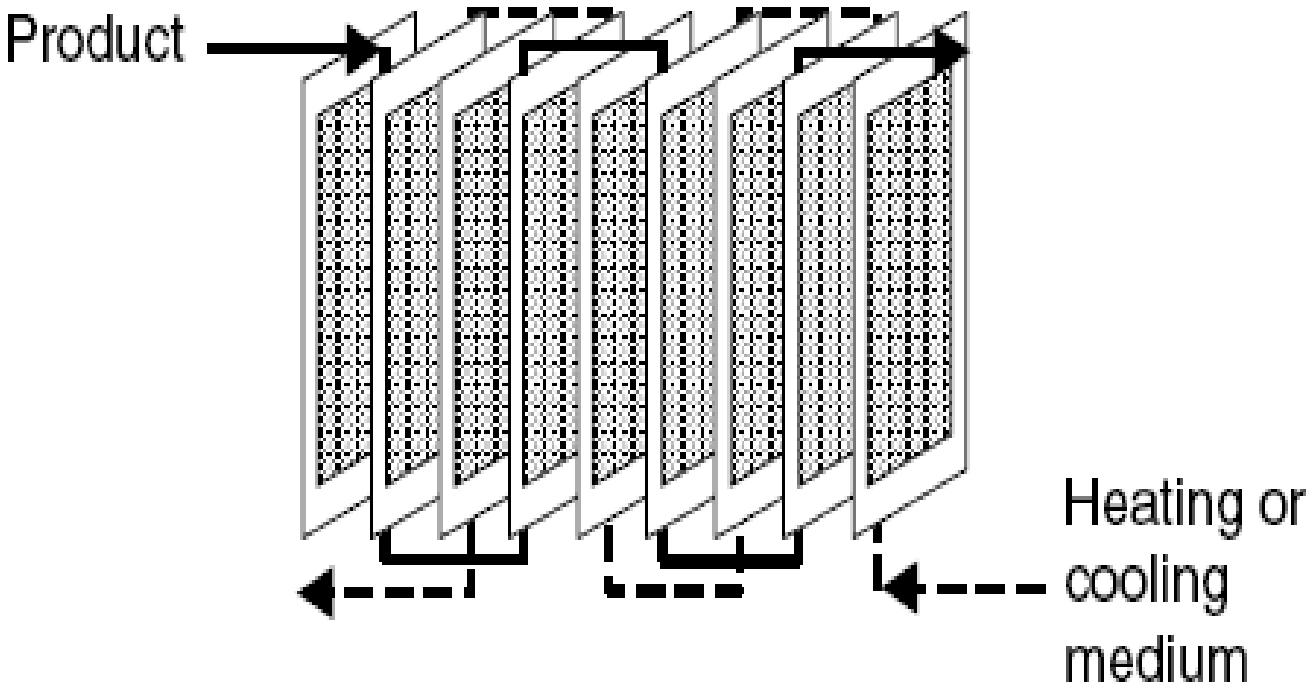

Fig 3: Schematic diagram of Plate heat exchanger

Tubular heat exchanger

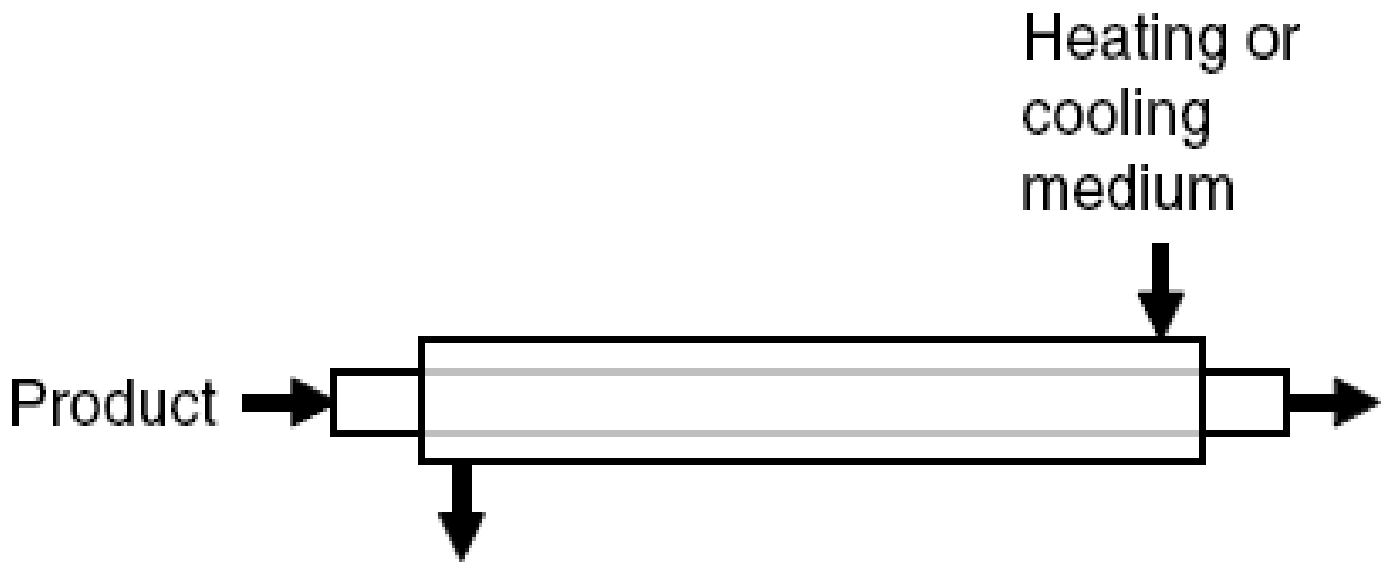

Fig 4: Schematic diagram of tubular heat exchanger

UHT treatment procedure

Raw milk

Preheating and heat regeneration

Homogenization (indirect systems only)

Holding at preheat temperature

Holding to sterilization temperature

Holding at sterilization temperature

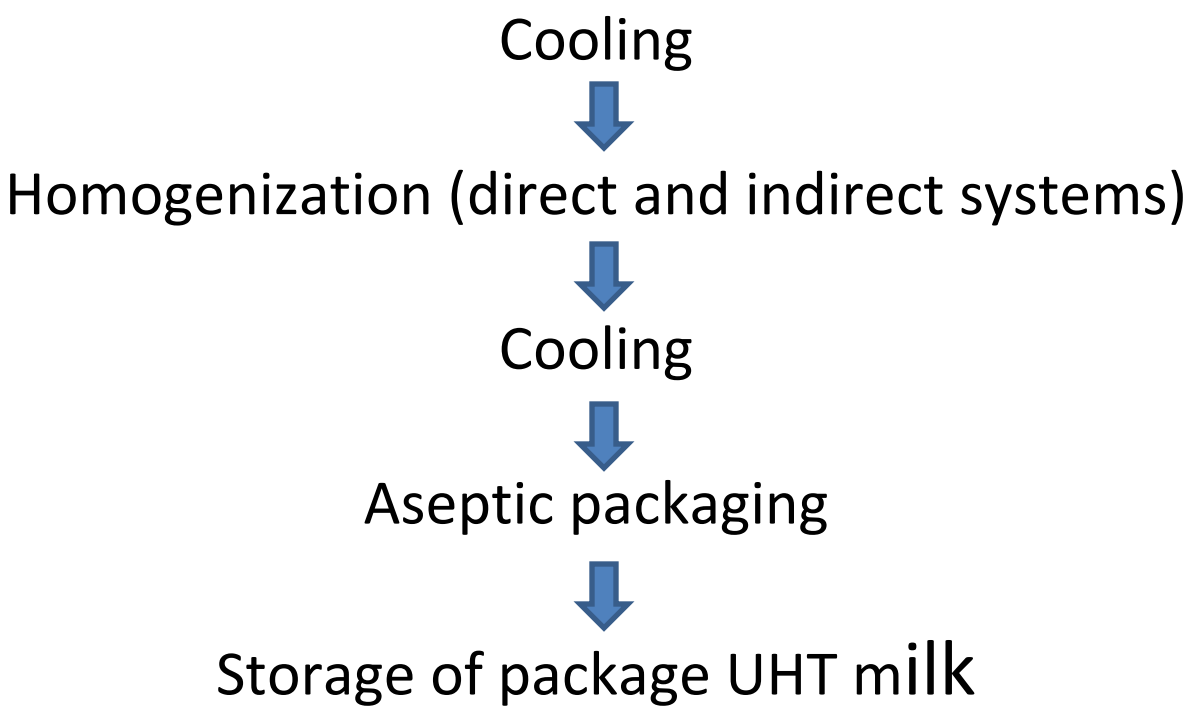

Fig 5: Flow diagram of UHT processing of milk

Time- temperature profile

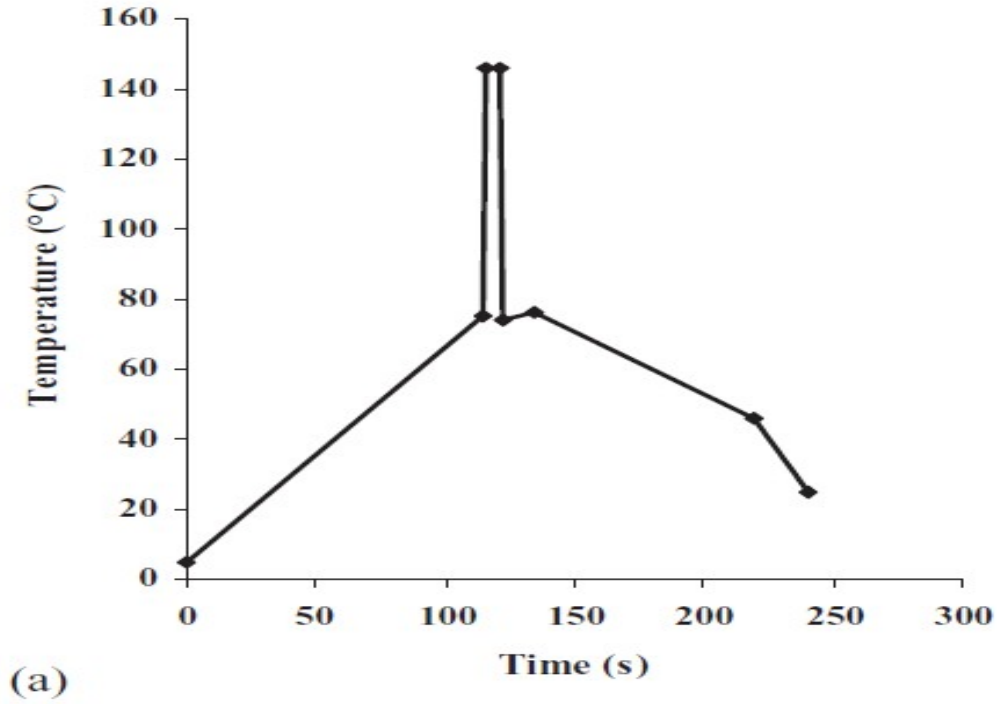

Fig 6: Time-temperature profile for direct heating system

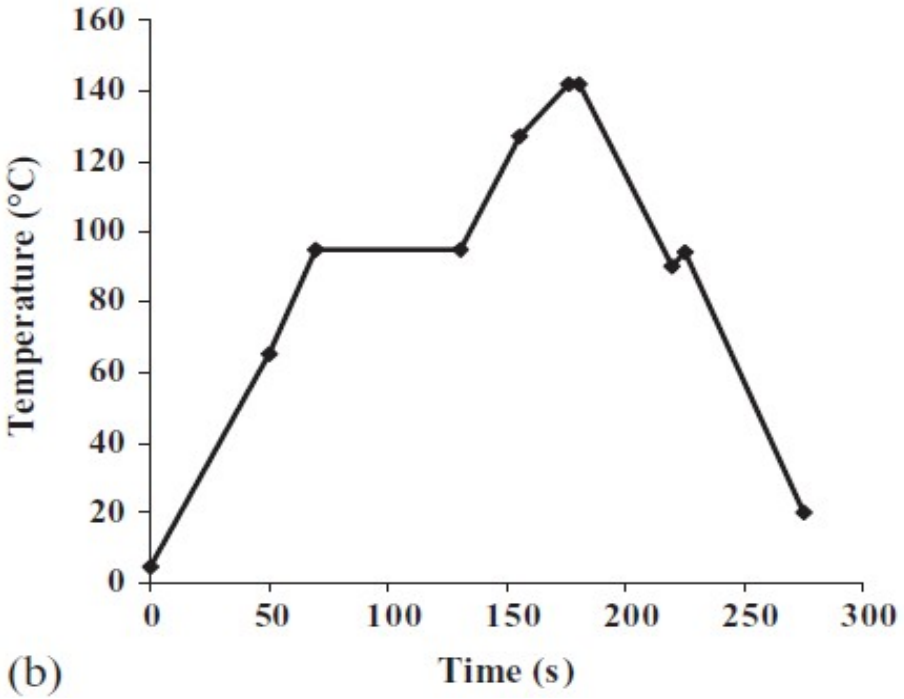

Fig 7: Time-temperature profile for indirect heating system

Effects of nutrients during UHT treatment

- Numerous changes in the
  - chemical composition
  - physical and organoleptic characteristics of milk even the heating conditions are optimized to obtain higher quality of milk in the industry
- Some, heat induced changes are reversible and others are not which means the structure and the nutritional values of nutrients will be damaged.

- The reversible heat induced changes occur during the heat processing are;
  - lactose mutarotation
  - ionic equilibrium and protein conformation alterations
  - casein association
  - fat globules agglutination
  - fat crystallization

- The irreversible heat induced changes are;
  - Whey protein denaturation
  - Whey protein-casein micelle interactions
  - Maillard reactions
  - Fat globule composition changes
  - Vitamin content changes

Lactose

- Main milk carbohydrate (4.8 to 5.2%).
- It is made of D-glucose and D-galactose linked by 1-4 beta glycosidic bond
- Other carbohydrates in milk include
  - Free monosaccharides (glucose, fructose and galactose in minute quantities)
  - Aminosugars (glucosamine and galactosamine)
  - Oligosaccharides.

- Lactose is converted to lactulsoe by isomerization through UHT treatment.
- Lactulose isomerization is catalyzed by free amino group of casein and this isomerization is strictly depends on time of heating and heating temperature and pH.
- The lactulsoe formation is little higher in the indirect heat systems with comparing the direct heating systems and UHT direct with injection system having more effect than the UHT direct with infusion system.

- Other carbohydrates especially
  - monosaccharides has less heat defect
  - No significance changes in the initial galactose content of milk during direct and indirect UHT treatment.
  - The content of monosaccharides, aminosugars are ranged from 2 to 14 mg/100ml in the just processed UHT milk.

Protein

- Milk protein can be classified in to two categories; they are
  - casein protein (major part, approx. 80%)
    - α-casein
    - β-casein
    - γ-casein
    - κ-casein
  - whey protein (approx. 20%)
    - α-lactalbumin,
    - β-lactoglobulin
    - immunoglobin.

- Several physical and chemical changes in whey protein can occur
- These changes affect the functional and sensory properties of milk.
- During the heating process, whey protein containing sulfyhydryl residues undergo following changes,
  - A protein complex between beta-lactoglobulin and kappa-casein, with consequent modification of rennet coagulation behavior and heat stability
  - Typical off flavors
  - Unusual amino acids
- The extent of denaturation of β-lactoglobulin in UHT milk can vary from as low as 35% in direct plants to close to 100% in indirect plants

- Slight increase in the size of the casein micelle due to its association with denatured whey proteins and calcium phosphate
- Depends on the time and temperature of processing and the pH of the milk.
- This lead to a chalky or astringent defect in UHT
- Milk (especially if heated by steam injection), which can be eliminated by homogenization after the high-heat treatment

- Protein and Nitrogen contents of milk, protein digestibility were not significantly modified by UHT heat treatment.
- Biological value and net protein utilization of UHT milk were lower for stored milk than directly used milk. Lysine loss during UHT is high but not significant to affect milk nutritional values.

Fat

- Milk fat globule are mostly
  - triglycerides (98%);
  - the other lipids amount to less than 2% of the total
    - diacylglycerols and monoacylglycerols - 0.5%
    - phospholipids
    - sterols
    - free fatty acids
    - fat-soluble vitamin.

- Fat protects milk components against tested heat-induced changes (lactulose formation, decreased furosine levels, and whey protein denaturation).
- UHT processing causes virtually no physical or chemical changes in the structure, properties, or nutritional value of milk fat (Da-wen sun 2006).

Vitamins

- Milk contains both water soluble and fat soluble vitamins.
- The water soluble vitamins are,
  - vitamin B
    - thiamin (vitamin B1)
    - riboflavin (vitamin B2)
    - niacin (vitamin B3)
    - panthothenic acid (vitamin B5)
    - vitamin B6 (pyridoxine)
    - vitamin B12 (cobalamin)
    - folate.
- Vitamin C

- Fat soluble vitamins are;
  - Vitamin A (beta-carotene and retinol)
  - Vitamin D
  - Vitamin E
  - Vitamin K

- 20 and 30% losses in vitamin B1 (thiamine) and vitamin B12 can occur during UHT treatment
- The levels of Vitamin C (ascorbic acid) and folic acid are markedly reduced in UHT milk containing a significant level of oxygen during UHT processing and storage.
- UHT affects the folate binding protein (FBP) at a considerable level which is significantly lower with compared to raw milk. The concentration of FBP, which might have an impact on folate absorbtion.

- The fat-soluble vitamins (A, D, and E) are largely unaffected by UHT treatment
- They are heat resistant especially beta-carotene is unaffected by UHT processing.
- But in case of retinol, it undergoes some changes

- In retinol stability sometimes are contradictory,
- depends on whether the analytic method employed involved separation of the isomers.
- Here some authors report no significance vitamin A loss from UHT processing, while others using chromatographic methods that allow separation of vitamin isomers reports significance losses in vitamin A.

- Vitamin A in the milk is found in the main form of all-trans retinol and other cis retinol isomers also present.
- If the heat is applied to the milk the predominant

  all-trans isomers ⟶ cis-isomers
- The isomerization of all-trans retinol into cis-retinol is occurring during the UHT treatment which has some sort of loss of vitamin A in the UHT milk.

Minerals

- The most common cations (positively charged ions) in milk are
  - potassium (K)
  - sodium (Na)
  - calcium (Ca)
  - magnesium (Mg)
- The most common anions are
  - chloride (Cl)
  - inorganic phosphate; citrate, sulfate, carbonate, and bicarbonate (lesser amounts)

- K, Na, and Cl are almost entirely diffusible, while Ca, Mg, inorganic phosphate, and citrate are non diffusible and associated with the casein micelles.
- Milk salts thus exist in an equilibrium between the liquid and colloidal phase: this equilibrium can be affected by processing.

- UHT processing transfers minerals from the aqueous phase to the casein micelle and reduces ionic calcium levels by 10 to 20%.
- This, in addition to the interaction of whey proteins with the casein micelle, reduces the susceptibility of UHT milk to coagulation by rennet.
- Some calcium phosphate is rendered insoluble at the high temperatures used in UHT heating and deposits on the surfaces of the heat exchanger (fouling).

Other effects

- Protein- sugar interaction
  - mainly casein-bound lysine residues and lactose are interacts and form several chemical compounds which influence the nutritional quality of milk
  - considerable loss of biologically available lysine
- Flavor compound production
  - Cooked or heated flavor (processing)
    - Volatile sulfur compounds produced mainly from denatured lactoglobulin
  - Stale flavor (storage)
    - Aliphatic aldehydes

Conclusion

- The protein especially whey protein has the higher loss, lactose and vitamins have some marginal loss, the fat and the minerals have no damages are observed.