Microbiology of Milk

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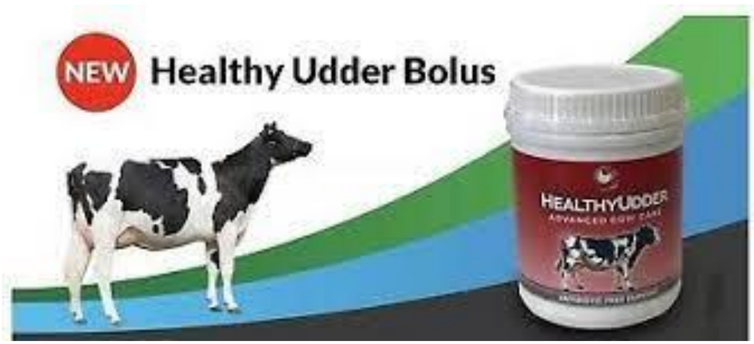
Microbiology and Deterioration of Milk and Milk Products

Introduction

In general, cows are milked twice a day on farms worldwide.


NEW
Healthy Udder Bolus
HEALTHYUDDER
ADVANCED COW CARE

- Milk constitutes an **excellent medium for the growth of microorganisms**.

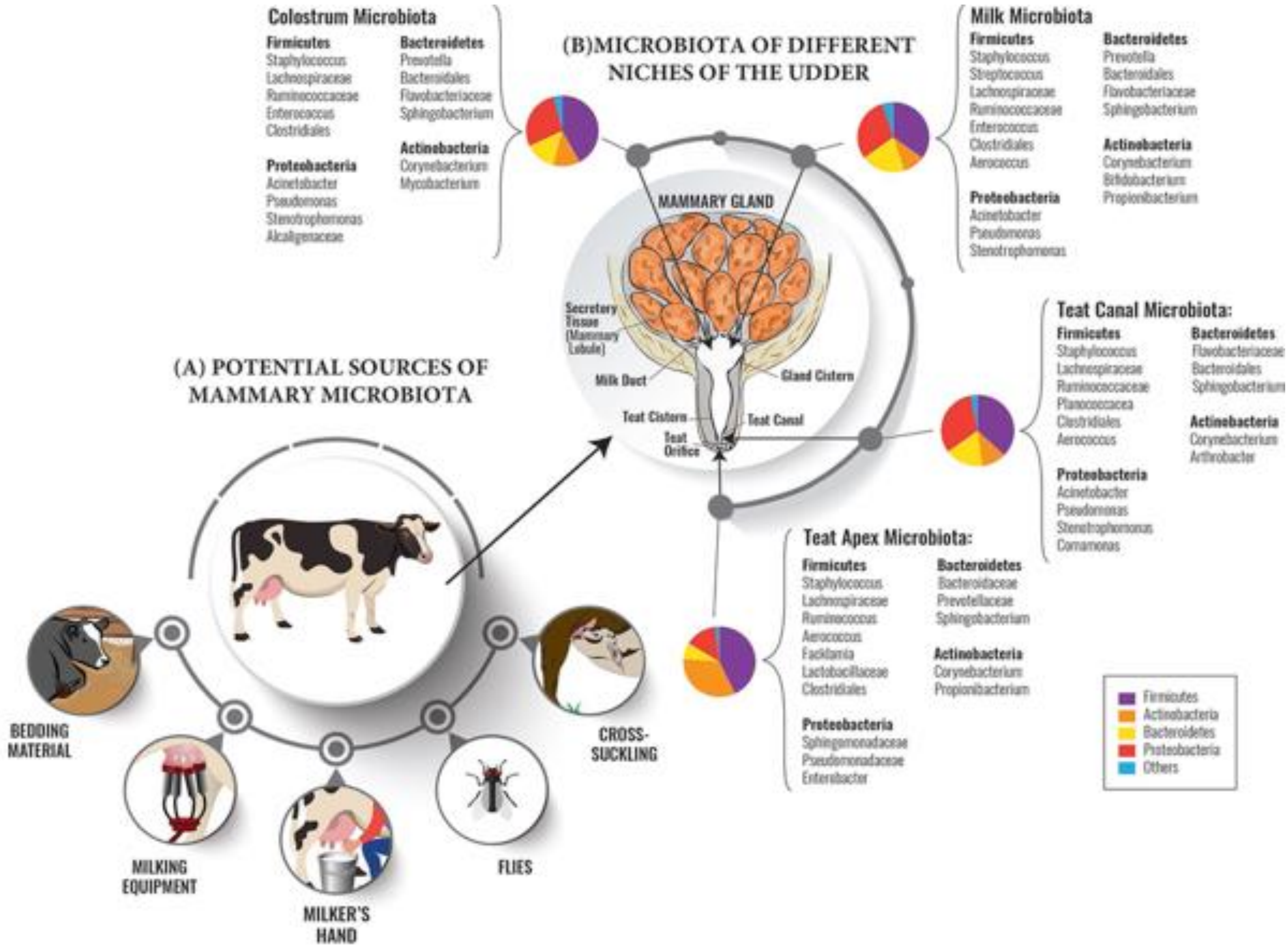
- **Freshly drawn milk** from healthy animals contains a **small number of harmless micro-organisms**, however, during milking process and storage the contamination takes place, the extent of which depends upon the hygienic measures taken before, during and after milking process and storage conditions observed thereafter.

- Nearly all the changes that take place in the **flavor and appearance of the milk** after it is drawn form the cow, are the result of the **activities of microorganisms** ,therefore, it is very essential to control these microorganisms.

Significance of Microorganisms in Milk

- **Microbial content** serves as an **indicator** of production conditions and sanitary quality of milk.
- Prevention of spoilage.
- Prevention of milk borne illnesses.
- Production of dairy products with desired characteristics imparted via m.o. introduction.

Microorganisms in Milk



(A) POTENTIAL SOURCES OF MAMMARY MICROBIOTA
BEDDING MATERIAL
MILKING EQUIPMENT
MILKER'S HAND
FLIES
CROSS-SUCKLING
(B)MICROBIOTA OF DIFFERENT NICHES OF THE UDDER
MAMMARY GLAND
Secretory Tissue (Mammary Lobule)
Milk Duct
Gland Cistern
Teat Cistern
Teat Canal
Teat Orifice
Colostrum Microbiota
Firmicutes
Staphylococcus
Lachnospiraceae
Ruminococcaceae
Enterococcus
Clostridiales
Bacteroidetes
Prevotella
Bacteroidales
Flavobacteriaceae
Sphingobacterium
Proteobacteria
Acinetobacter
Pseudomonas
Stenotrophomonas
Alcaligenaceae
Actinobacteria
Corynebacterium
Mycobacterium
Milk Microbiota
Firmicutes
Staphylococcus
Streptococcus
Lachnospiraceae
Ruminococcaceae
Enterococcus
Clostridiales
Aerococcus
Bacteroidetes
Prevotella
Bacteroidales
Flavobacteriaceae
Sphingobacterium
Actinobacteria
Corynebacterium
Bifidobacterium
Propionibacterium
Proteobacteria
Acinetobacter
Pseudomonas
Stenotrophomonas
Teat Canal Microbiota:
Firmicutes
Staphylococcus
Lachnospiraceae
Ruminococcaceae
Planococcacea
Clostridiales
Aerococcus
Bacteroidetes
Flavobacteriaceae
Bacteroidales
Sphingobacterium
Actinobacteria
Corynebacterium
Arthrobacter
Proteobacteria
Acinetobacter
Pseudomonas
Stenotrophomonas
Comamonas
Teat Apex Microbiota:
Firmicutes
Staphylococcus
Lachnospiracese
Ruminococcus
Aerococcus
Facklamia
Lactobacillaceae
Clostridiales
Bacteroidetes
Bacteroidaceae
Prevotellaceae
Sphingobacterium
Actinobacteria
Corynebacterium
Propionibacterium
Proteobacteria
Sphingomonadaceae
Pseudomonadaceae
Enterobacter
Firmicutes
Actinobacteria
Bacteroidetes
Proteobacteria
Others

- The types of microorganisms found in milk vary considerably
- Bacteria, yeasts, moulds and bacteriophages are commonly encountered.
- Viruses and protozoa are seldom observed in milk, except as occasional contaminants.

*Bacteria

Most common and most numerous of microorganisms found in milk and milk products

.

Contents

Microbiology of Liquid Milk

B Özer and H Yaman, Ankara University, Ankara, Turkey; Abant Izzet Baysal University, Bolu, Turkey

Table 1 The main groups of aerobic mesophilic microorganisms in raw milk

Spore-formers	*Micrococci*	*Gram-positive rods*	*Streptococci*	*Gram-negative rods*
Bacillus spp.	*Micrococcus*	*Microbacterium*	*Enterococcus*	*Pseudomonas*
	Staphylococcus	*Corynebacterium*	*Streptococcus*	*Acinetobacter*
		Arthrobacter	*S. agalactiae*	*Flavobacterium*
		Kurthia	*S. dysgalactiae*	*Enterobacter*
			S. uberis	*Klebsiella*
				Aerobacter
				Escherichia
				Serratia
				Alcaligenes

- They belong to four main groups:

1. Gram +ive cocci
2. Gram +ive non-spore forming rods
3. Gram +ive spore-forming rods
4. Gram -ive non-spore forming rods.

Normally present in milk and they are also used as starter culture for the production of cultured dairy products. They ferment lactose and yield lactic acid.

Non pathogens in milk

- **Air borne contaminants** : Pseudomonas, Flavobacterium, Alcaligenes ,Some coliforms, micrococcus, fungi
- **Psychrotrophs** :more detrimental to milk

They are able to grow at 5°c and less and make up a large number of the microbes in milk, they are natural soil inhabitants and wide spread in environment esp. water.

- **Spoilage** of refrigerated milk consists usually of bitter, rancid, fruity flavours
- Spoilage of milk at room temp. consists usually of souring

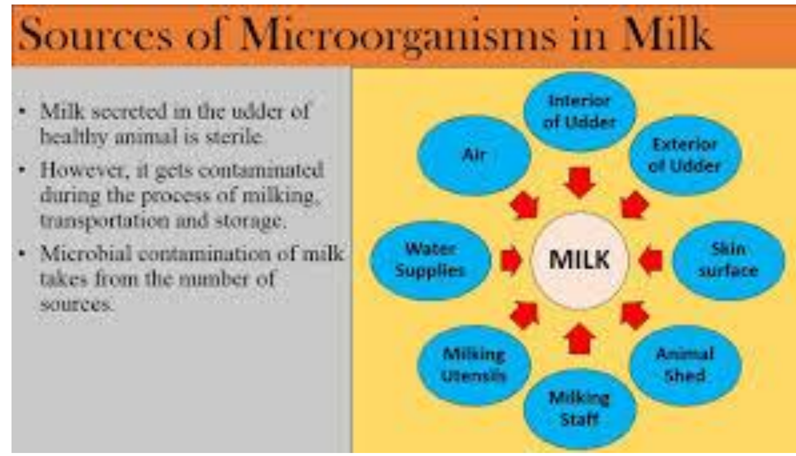
Rancidity is the complete or incomplete oxidation or hydrolysis of fats and oils when exposed to air, light, or moisture or by bacterial action, resulting in unpleasant taste and odor.

Sources of Pathogens in milk

- Animal itself : *Mycobacterium bovis, Brucella species, Coxiella burneti ,Campylobacter* sp.
- Humans : *Salmonella, Shigella*
- Environment : *Bacillus anthracis*, *Clostridium perfringens, Clostridium botulinum*

Table 2 Pathogenic microorganisms associated with raw milk and the diseases they cause

Organisms	*Diseases*
Enterobacteriaceae	
Escherichia coli, including O157:H7	Gastroenteritis, hemolytic uremic syndrome
Salmonella	Gastroenteritis, typhoid fever
Yersinia enterocolitica (psychrotrophic)	Gastroenteritis
Other Gram-negative bacteria	
Aeromonas hydrophila (psychrotrophic)	Gastroenteritis
Brucella spp.	Brucellosis
Campylobacter jejuni	Gastroenteritis
Pseudomonas aeruginosa	Gastroenteritis
Gram-positive spore-formers	
Bacillus cereus	Gastroenteritis
Bacillus anthracis	Anthrax
Clostridium perfringens	Gastroenteritis
Clostridium botulinum (Type E is psychrotrophic)	Botulism
Gram-positive cocci	
Staphylococcus aureus	Emetic intoxication
Streptococcus agalactiae	Sore throat
Streptococcus pyogenes	Scarlet fever/sore throat
Streptococcus zooepidemicus	Pharyngitis, nephritic sequelae
Miscellaneous Gram-positive bacteria	
Corynebacterium spp.	Diphtheria
Listeria monocytogenes	Listeriosis
Mycobacterium bovis	Tuberculosis
Mycobacterium tuberculosis	Tuberculosis
Mycobacterium paratuberculosis	Johne's disease
Rickettsia	
Coxiella burnetii	Q fever



Coliforms

- Facultative anaerobes
- Optimum growth @ 37^0c
- Indicator organism and are closely associated the presence of pathogens but not necessary pathogens themselves.
- They ferment lactose with production of acid and gas cause rapid spoilage of milk
- They are killed by pasteurization
- Their presence is an indication of contamination of milk.

Yeast

- Most frequently encountered in raw cream during hot weather produce acid and CO_2. They are potential contaminants throughout the year.

Moulds

- Their growth is visible as a fuzzy or fluffy growth on the surface of milk and milk products.
- They may be black, green, grey, blue or white.
- They discolor the product and often produce repulsive undesirable off odors
- Essential in production of certain varieties of cheese.

Bacteriophages

- Particularly obnoxious in starter cultures used for the production of cultured dairy products.
- Phages kill bacterial culture and entire fermentation process fails (slow or dead vat).

Factors affecting growth of Microorganisms in Milk

1. Food supply (H_2O, energy,C,N Vit. &Mineral source)
2. Moisture
3. Oxygen supply (Obligate aerobes, facultative, micoaerophillic, Aerotolerant anaerobes, obligate anaerobes)
4. Acidity and pH (Acidophilic)
5. Preservatives
6. Light (phototrophic)
7. Concentration (osmophillic yeasts)
8. Temperature (psychrotrophs- 20-30^{o}C , Mesophiles-30-40^{o}C, Thermophiles-55-65^{o}C
9. Antimicrobial constituents

Table 3 Generation time (h) of some groups of bacteria in raw milk

Temperature (° C)	*Lactic acid bacteria*	*Pseudomonads*	*Coliforms*	*Heat-resistant Streptococci*	*Aerobic spore-formers*
5	>20	4	8	>20	18
15	2.1	1.9	1.7	3.5	1.9
30	0.5	0.7	0.45	0.5	0.45

Products of Microbial Growth in Milk

-Enzymes

- Decomposition products of protein, fat & CHO etc.
- Pigments , Toxins etc (mycotoxins & bacterial toxin)

Result of microbial growth in milk (Spoilage)

- Principal cause are Psychrotrophs
- Most of these are destroyed by pasteurization
- Some may survive e.g. *Pseudomonas fluorescens* , *Pseudomonas fragi*
- Other species and strains that survive pasteurization and grow at Refrigeration temp., Produce heat stable proteolytic & lipolytic enzymes and cause spoilage *:* -*Bacillus* - *Clostridium* - *Cornebacterium* -*Arthrobacter* - *Lactobacillus* - *Microbacterium* - *Micococcus*

  - *Streptococcus*

Deteriorative changes

- Souring- Lactose fermentation
- Souring & gassiness- coliforms→ acid & gas
- Aroma production- starter culture → diacetyl
- Proteolysis- unpleasant odors- undesirable. controlled→ desirable –cheese production.
- Ropiness- Milk drawn into long threads *(Alkaligenes viscolactis)*
- Sweet curdling- due to prod^n of rennin like enzyme which curdles without souring
- Stormy fermentation- Rapid fermentation by *Clostridium perfringens*
- Color changes *Pseudomonas syncyanea* (blue); *Pseudomonas synxantha* (yellow); *Serratia marcescens* (red)

Stages of milk decay

Rancid

(“on the turn”)-Milk consumable

Curdling

Separation of curd and whey – milk still consumable

Coagulation

period of aromatic decay with mould growth –milk beyond use

Dry

dehydration ensues- hard and chalky –milk beyond use

Pathogenic Microorganisms in Milk

- Food borne illnesses occur as a result of :

~Ingestion of raw milk

~Improper pasteurization

~Poor handling / storage leading to PP contamination

- Measures to decrease the threat :

~Hygienic production practices

~Proper handling and storage

~Pasteurization

Microbial Pathogens

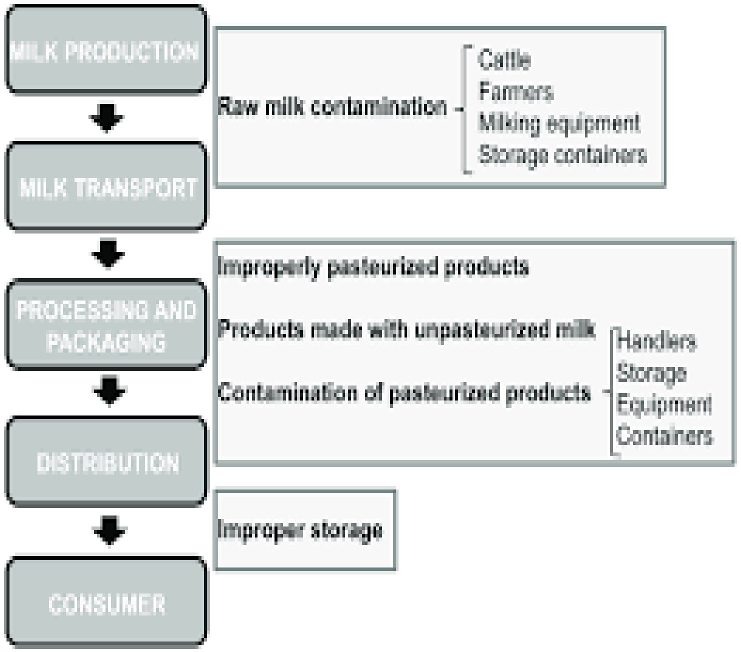
- *Bacillus cereus*
- *Listeria monocytogens*
- *Yersinea entrocolitica*
- *Salmonella spp.*
- *E.coli O 157:H_7*
- *Compylobacter jejuni*
- *Coxeilla burnetii*
- Moulds (*Aspergillus, Fusarium, Penicillium*) grow in milk and milk products & produce potentially hazardous mycotoxins.

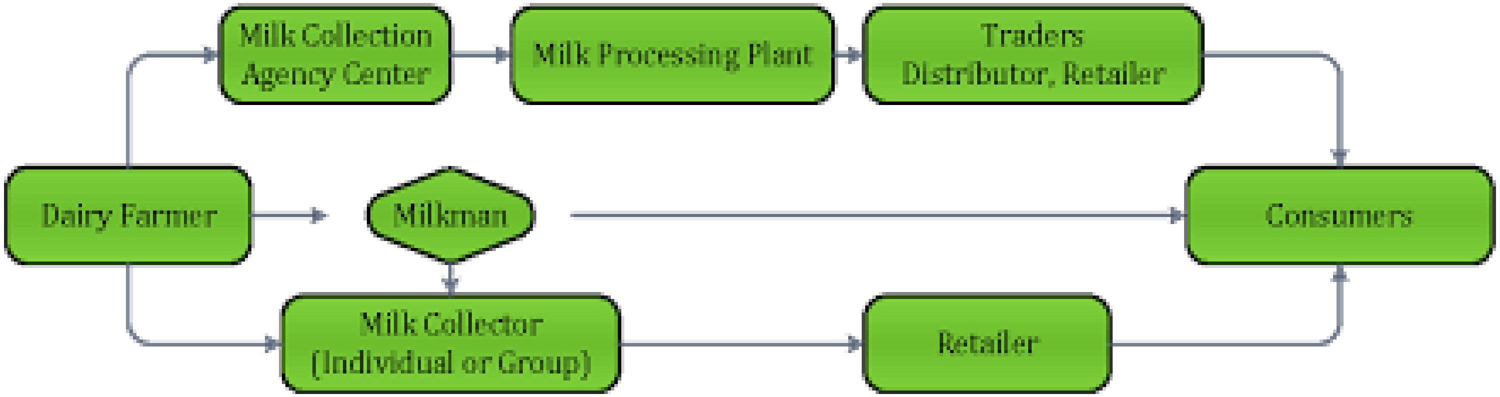
- Thus, the prevalence of pathogenic and spoilage microorganisms in milk and dairy products is influenced by a high number of factors and their combinations.

- These factors may include health status of the dairy herd, hygiene level in the dairy farm environment, milking and prestorage conditions, available storage facilities and technologies, farm management practices, geographic location and season.

- In addition to microbial hazards, milk and dairy products can also contain chemical hazards and contaminants mainly introduced through the environment, animal feedstus, animal husbandry and industry practices

- Thus, safety and production are intrinsically linked in the dairy food chain; from production through handling and processing to consumption.





- Food-safety hazard generally refers to any biological, chemical or physical agent in a food, or condition of food with the potential to cause adverse health consequences for consumers.

- Such hazards may be introduced into the dairy chain at any time during primary production, milking, formulation and processing, packaging and labelling, transportation, storage, preparation, and serving.

- From raw milk production through processing to the consumer, milk is exposed to several hazards, which ultimately influence the safety and quality of the final product.
- Some of these hazards may stem from animal husbandry practices, through their feeding, milking and processing.

Table 1. Main categories of food safety hazards associated with milk and dairy products (adopted from the Food and Agricultural Organization (FAO), [13]).

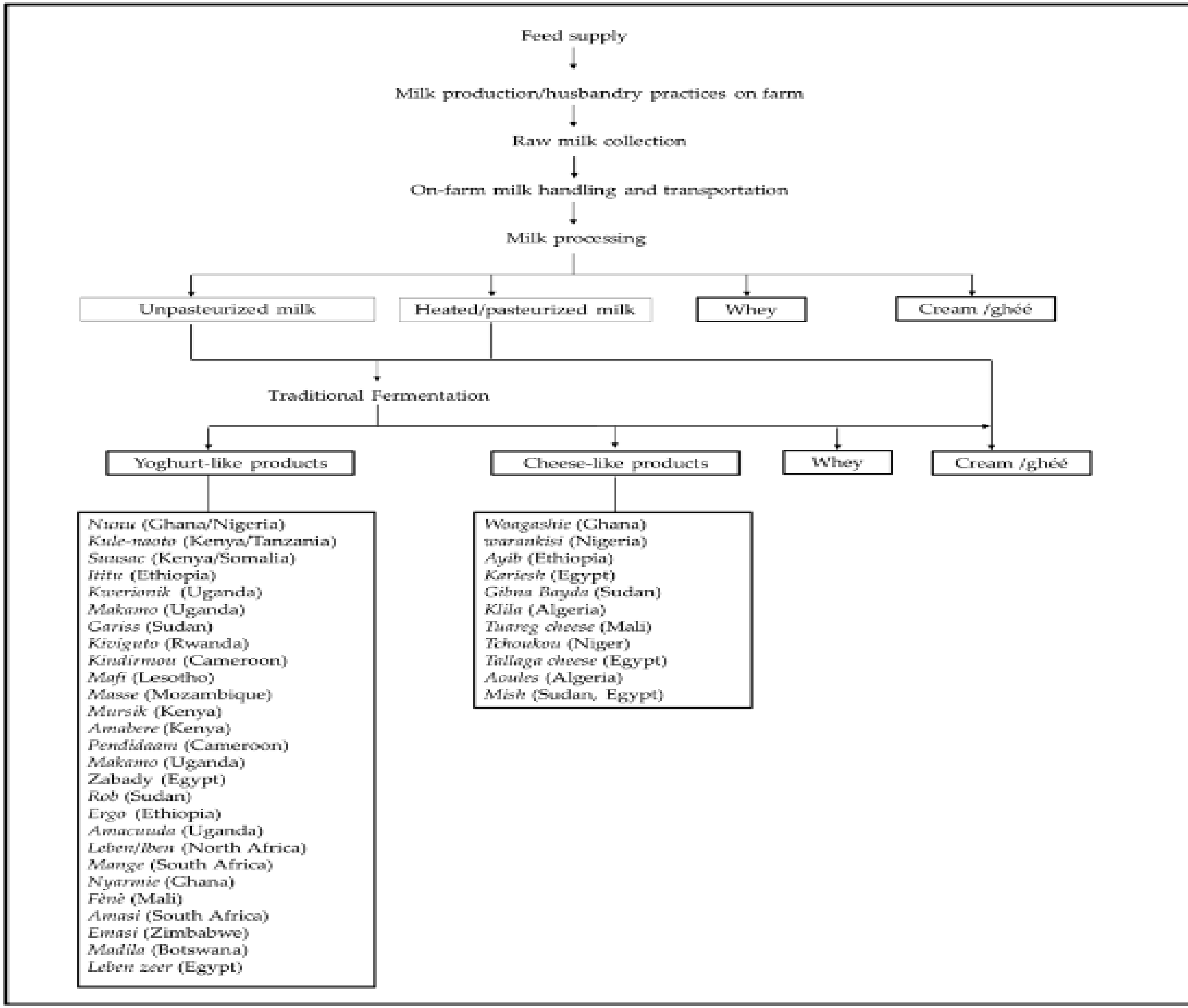
Biological Hazards		Chemical Hazards		Physical Hazards	
i.	Pathogenic bacteria (including toxins produced by bacteria)	i.	Naturally occurring toxins	i.	Metal fragments
ii.	Toxigenic moulds/fungi	ii.	Direct and indirect food additives	ii.	Bone fragments
iii.	Parasites	iii.	Pesticide residues	iii.	Glass pieces
iv.	Viruses	iv.	Veterinary drug residues	iv.	Insects or their parts
v.	Other biological hazards	v.	Heavy metals	v.	Jewellery
		vi.	Environmental contaminants	vi.	Stones/soil/dust
		vii.	Chemicals from packaging material	vii.	Hair/fur

microorganisms MDPI

Review

Microbial Safety of Milk Production and Fermented Dairy Products in Africa

James Owusu-Kwarteng [1,*], Fortune Akabanda [2], Dominic Agyei [3] and Lene Jespersen [4]


Feed supply
Milk production/husbandry practices on farm
Raw milk collection
On-farm milk handling and transportation
Milk processing
Unpasteurized milk
Heated/pasteurized milk
Whey
Cream /ghéé
Traditional Fermentation
Yoghurt-like products
Cheese-like products
Whey
Cream /ghéé
Nunu (Ghana/Nigeria)
Kule-naoto (Kenya/Tanzania)
Suusac (Kenya/Somalia)
Ititu (Ethiopia)
Kwerionik (Uganda)
Makamo (Uganda)
Gariss (Sudan)
Kivuguto (Rwanda)
Kindirmou (Cameroon)
Mafi (Lesotho)
Masse (Mozambique)
Mursik (Kenya)
Amabere (Kenya)
Pendidaam (Cameroon)
Makamo (Uganda)
Zabady (Egypt)
Rob (Sudan)
Ergo (Ethiopia)
Amacunda (Uganda)
Leben/lben (North Africa)
Mange (South Africa)
Nyarmie (Ghana)
Fènè (Mali)
Amasi (South Africa)
Emasi (Zimbabwe)
Madila (Botswana)
Leben zeer (Egypt)
Wagashie (Ghana)
warankisi (Nigeria)
Ayib (Ethiopia)
Kariesh (Egypt)
Gibna Bayda (Sudan)
Klila (Algeria)
Tuareg cheese (Mali)
Tchoukou (Niger)
Tallaga cheese (Egypt)
Aoules (Algeria)
Mish (Sudan, Egypt)

- Generally, pathogenic microorganisms can contaminate raw milk in two ways. First, endogenous contamination occurs when milk is contaminated by a direct transfer of pathogens from the blood (systemic infection) of an infected animal into the milk, or via an infection in the udder.
- The second means by which fresh milk can be contaminated, known as exogenous contamination, occurs where milk is contaminated during or after collection by animal faeces, the exterior of the udder and teats, the skin, and other environmental sources

Table 2. Major microbiological risk factors and their implications for safety in the dairy chain in Africa.

Step in Dairy Chain	Important Risk Factors	Implications for Milk Safety
Primary production	• Diseases (mastitis) • Housing, bedding and husbandry • Feed and water quality • Waste management	• Increased shedding of pathogens directly into milk from diseased animals (including asymptomatic carriers). • Poor housing and husbandry practices increase the risk of udder contamination due to high stocking, concentration of waste, stress and soiled bedding, leading to contamination of milking environment and raw milk. • Increased risk of milk contamination can result from using poor quality water for stock drinking, teat washing and cleaning. • Contaminated or poorly prepared feed may increase faecal shedding of pathogens into milk and milking environment.
Milk collection	• Milking practices • Equipment cleaning • Personnel hygiene	• Poor milking practices, including dirty, chapped or cracked teats, insufficient cleaning and maintenance of milking equipment, and poor personnel hygiene can lead to direct contamination of raw milk with pathogens.
Raw milk storage	• Availability and efficiency of cold storage facilities	• Inappropriate temperature control of raw milk, coupled with the usually high temperature in the region and erratic power supply, can lead to accelerated growth of pathogens in milk during storage.
Packaging	• Packaging Equipment and material	• Poor packaging, inappropriate packaging materials and poor hygiene can contribute to cross contamination of milk or open up milk to contamination from the environment.
Transportation and distribution	• Transportation mode • Road network between milk collection centres and market centres • Maintenance of cold chain	• Transporting of raw milk between farms and market centres by foot, bicycles, motorbikes or other means without a proper cold chain enables growth of pathogens. • Poor road network systems increase the time for transportation and distribution of raw milk, and coupled with poor cold chain facilities, allows the rapid growth of pathogens in raw milk.

Table 2. *Cont.*

Step in Dairy Chain	Important Risk Factors	Implications for Milk Safety
Traditional milk processing	• Pasteurization/thermal treatment • Fermentation practices • Personnel hygiene and sanitation of processing environment.	• Inadequate pasteurization temperatures may not be able to eliminate pathogens in already contaminated milk, and may even encourage the faster growth of pathogens. • Spontaneous fermentations (without properly defined starter cultures), coupled with poor time/temperature controls can expose fermented products to pathogenic microorganisms. • Poor sanitation of processing environments and personal hygiene by milk processors can lead to a direct contamination of processed milk products with pathogenic microorganisms.
Consumer practices	• Storage temperature at home storage • Adherence to handling instructions and good personal hygiene	• Poor refrigeration during home storage of both raw and processed milk can accelerate the proliferation of pathogenic microorganisms. • Lack of proper hygiene and nonadherence to handling instructions can lead to contamination and proliferation of pathogenic microorganisms.

microorganisms

MDPI

Review

Microbial Safety of Milk Production and Fermented Dairy Products in Africa

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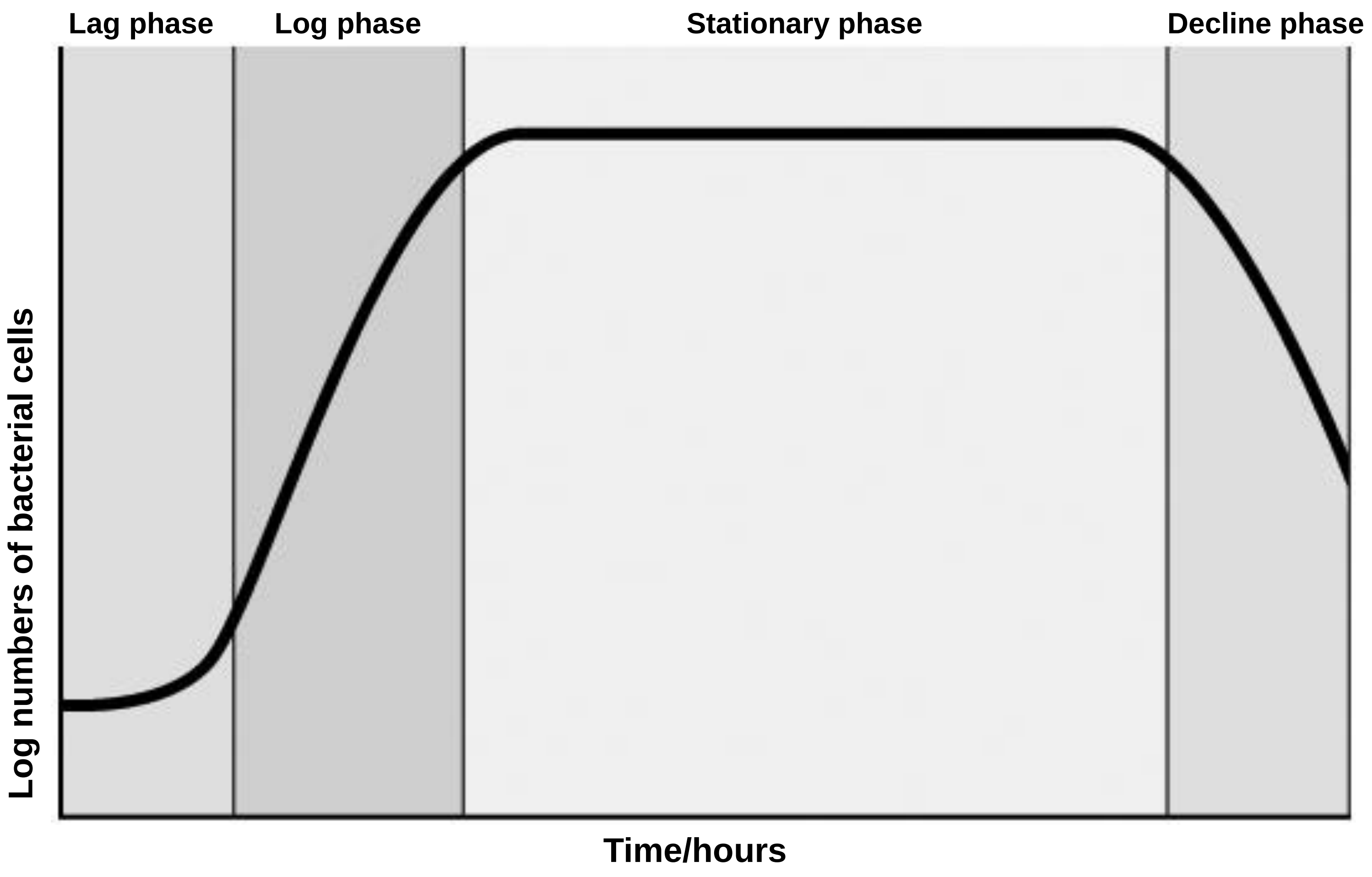
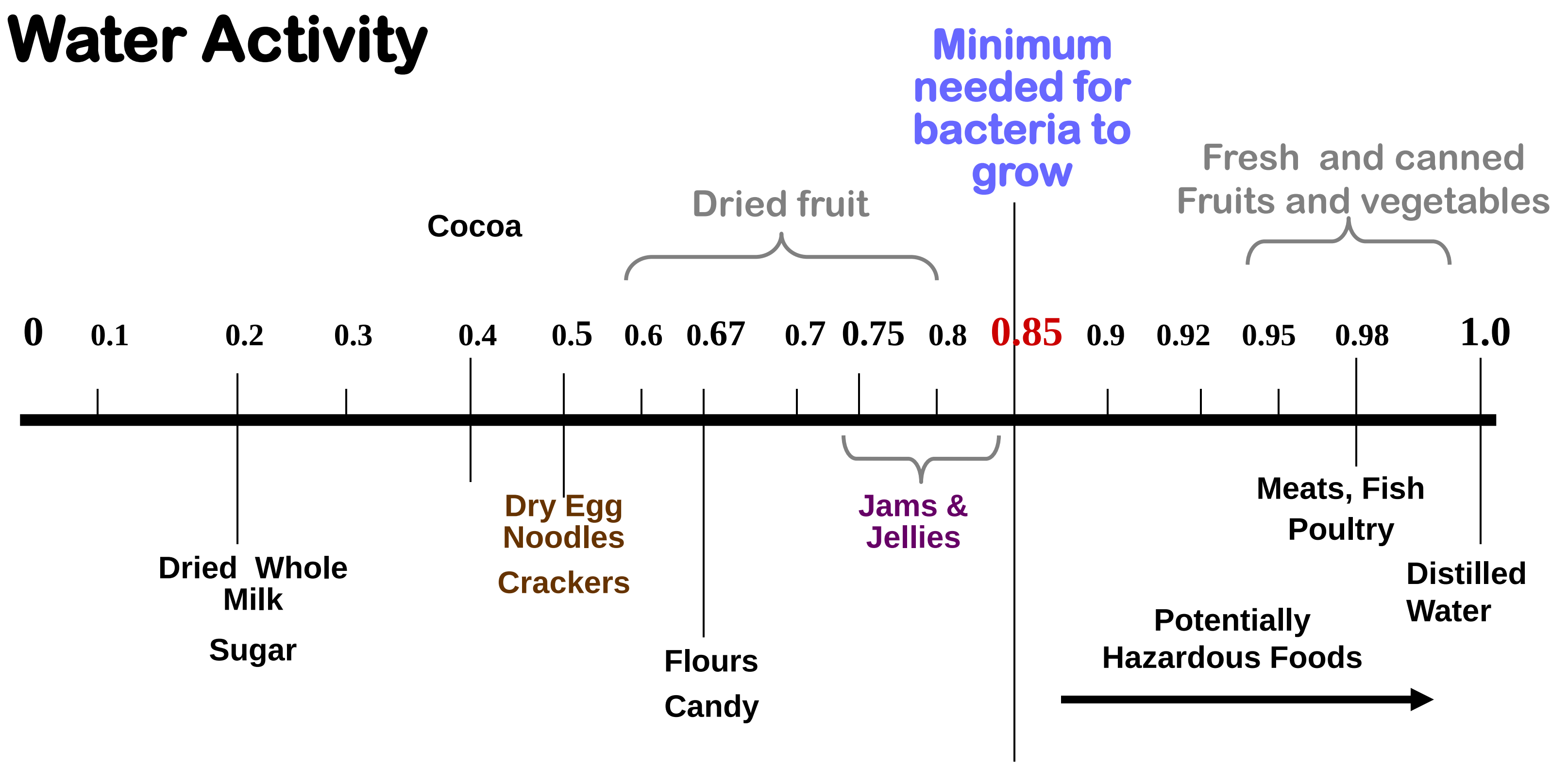
Bacterial growth curve



Moisture

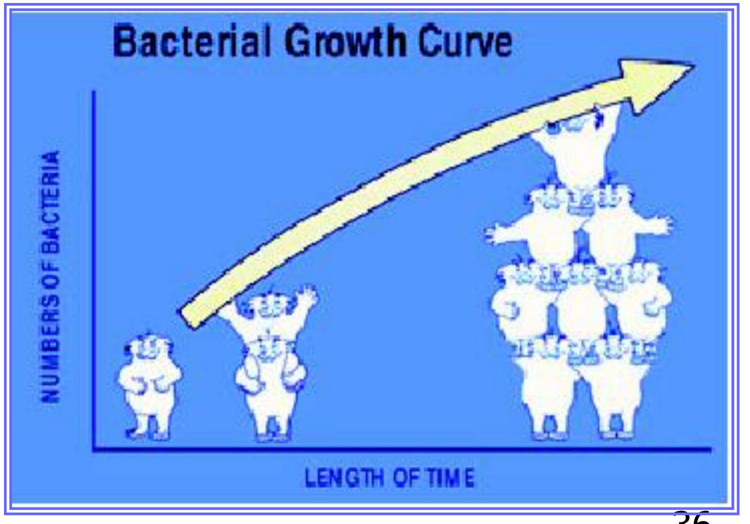

Water Activity
Minimum needed for bacteria to grow
Fresh and canned Fruits and vegetables
Dried fruit
Cocoa
0
0.1
0.2
0.3
0.4
0.5
0.6
0.67
0.7
0.75
0.8
0.85
0.9
0.92
0.95
0.98
1.0
Dry Egg Noodles
Crackers
Jams & Jellies
Meats, Fish
Poultry
Distilled Water
Dried Whole Milk
Sugar
Flours
Candy
Potentially Hazardous Foods

35

How do bacteria grow?

- If the right conditions exist (FAT TOM), bacteria will grow very quickly – doubling every 20 minutes or faster.
- One bacteria can multiply to more than 30,000 in 5 hours or

millions in just 8 hours



The danger zone

danger zone

57°C
(135°F)

37°C
(98.6°F)

5°C
(41°F)

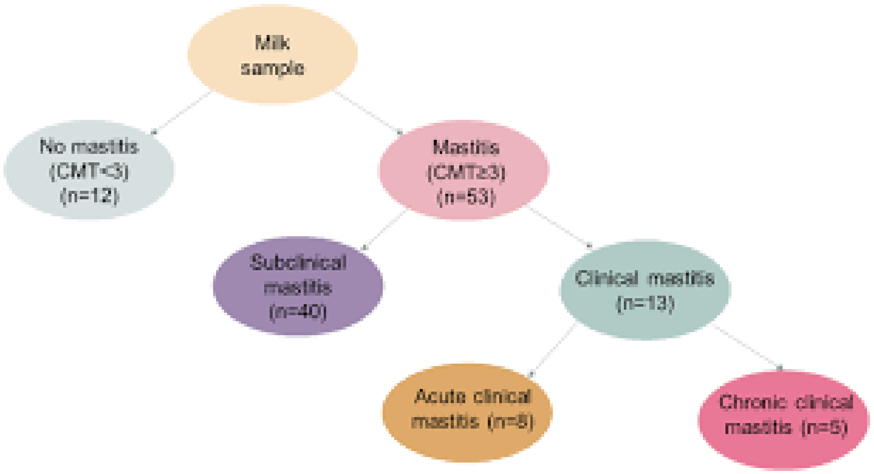
-18°C
(0°F)

Control and Practical Application

1. Heat - pasteurization , sterilization etc.
2. Ionizing Radiations- UV., gamma rays
3. High frequency sound waves- super & ultrasonic
4. Electricity - by the heat generated.
5. Pressure - 600 x › atmospheric pressure
6. Chemicals Acids ,alkalis, halogens H_20_2 etc.

The period of storage and the temperature are determinative factors with respect to the microbiological quality of raw milk, as well as the type and number of bacteria present. Unless proper hygienic and storage conditions are provided, the spoilage bacteria rapidly multiply in the milk, and at 25–30 °C, streptococci and coliforms – both of which increase the acidity of the milk – become predominant. Until inhibited by developed acidity, Gram-negative rods and micrococci (including streptococci) also multiply at moderate temperatures. Some measures that should be taken to prevent contamination and the growth of pathogens and nonpathogens in milk are as follows:

- General hygiene
- Disinfection of the udder, utensils, and equipment in contact with milk
- Cooling below 10 °C immediately after milking
- Separation of abnormal milks (unusually smell or color)
- The 'cold chain' should not be broken between milking and processing
- If necessary, thermization should be applied



Pasteurization of milk

- LTLT : Low temp. Long time 63°C 30 minutes
- HTST: High temp. Short time72°C 15 seconds
- UHT : Ultra high temp.,130-135 °C 1 second

Pasteurization:

- Kills and removes all pathogens(100%)
- Kills most non pathogens (99%)
- Surviving organisms are spore formers, thermoduric and thermophilic organisms

Pasteurization of milk

- Common thermoduric organisms:

  Bacillus, Micrococci, Lactococci, Arthrobacter

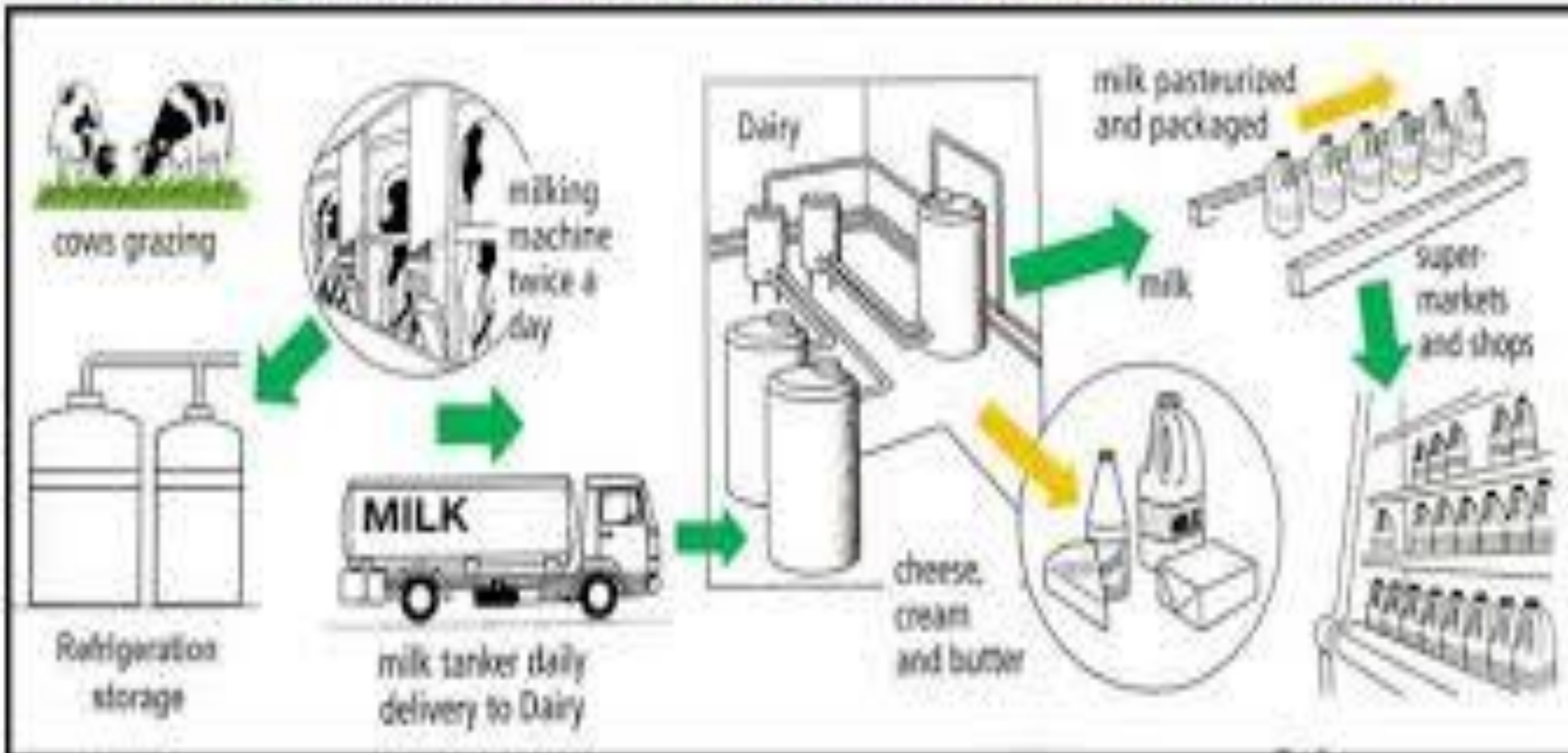
  Microbacteria, Corynebacteria

- Pasteurization provide a product with average shelf life 7-10 days(LTLT-HTST)
- Types and numbers of bacteria in milk depend on the microbial load before pasteurization

Pasteurization of milk

- No of non pathogens in raw milk is 500,000 to 3,000,000 organisms/ml of milk
- While No of non pathogens in pasteurized milk is 2,000 to 20,000 organisms /ml
- Different methods to count non pathogens in milk such as:
- **Viable count (pour plate method)**
- **Dye reduction test**
- **Direct (clump) microscopic count**

The diagram below shows the process of milk production



Viable count method

- Pour plate method
- Deliver 1ml of milk to 9ml of sterile saline tube(10-1), mix and transfer 1ml diluted milk from tube 1 to tube 2 (10-2).
- Deliver 1ml of milk to an empty Petri dish ,1ml of diluted milk 10-1,10-2 to empty Petri dishes .
- Pour 9ml of molten nutrient agar to each Petri dish, mix well
- Leave to solidify, then incubate at 37 c 48 hrs.
- Count No of colonies and multiply by dilution factor to determine No of viable non pathogens on milk
- A plate containing more than 300 colonies should not counted, plate with more dilution is counted instead.

Viable count method

Advantages

- Can see cell morphology
- Count viable cell only
- Can be used to different types of samples (milk, milk products

Disadvantages

- Take long time
- Lots of tubes , tedious.

Dye reduction test

- A quick test for determination of microbial load of milk
- Use Methylene blue or resazurin dyes
- Add 1ml of dye to 10ml of milk, incubate 1 hr at 36c
- If there is change in color , it means high bact. Load .It is not good quality milk, shorten expiration date.
- If no change in color (still blue), low bact. Load , good quality milk , expand expiration period
- A long history of use in the dairy industry, especially to measure microbial quality from raw milk

Dye reduction test

- Advantages
  1. Simple, rapid, and inexpensive
  2. Only viable cells actively reduce the dyes

- Disadvantages
  1. Not all organisms reduce the dyes equally
  2. Not applicable to food specimens that contain reductive enzymes

Direct microscopic count

- **Method**
- Deliver 0.01 ml of milk on slide ,air dry
- Stain with LW (Levowitz- Weber)stain for 10 min.
- Count bacterial clumps with the microscope
- **Reading results:**
- Bacterial clump: dark blue
- Protein, Leucocytes and somatic cells :light blue background
- Fat globules : colorless
- Dirt: brown

* clump : is one cell or group of cells of same type separated by a distance from other clumps or cells

Direct Microscopic Count

Advantages

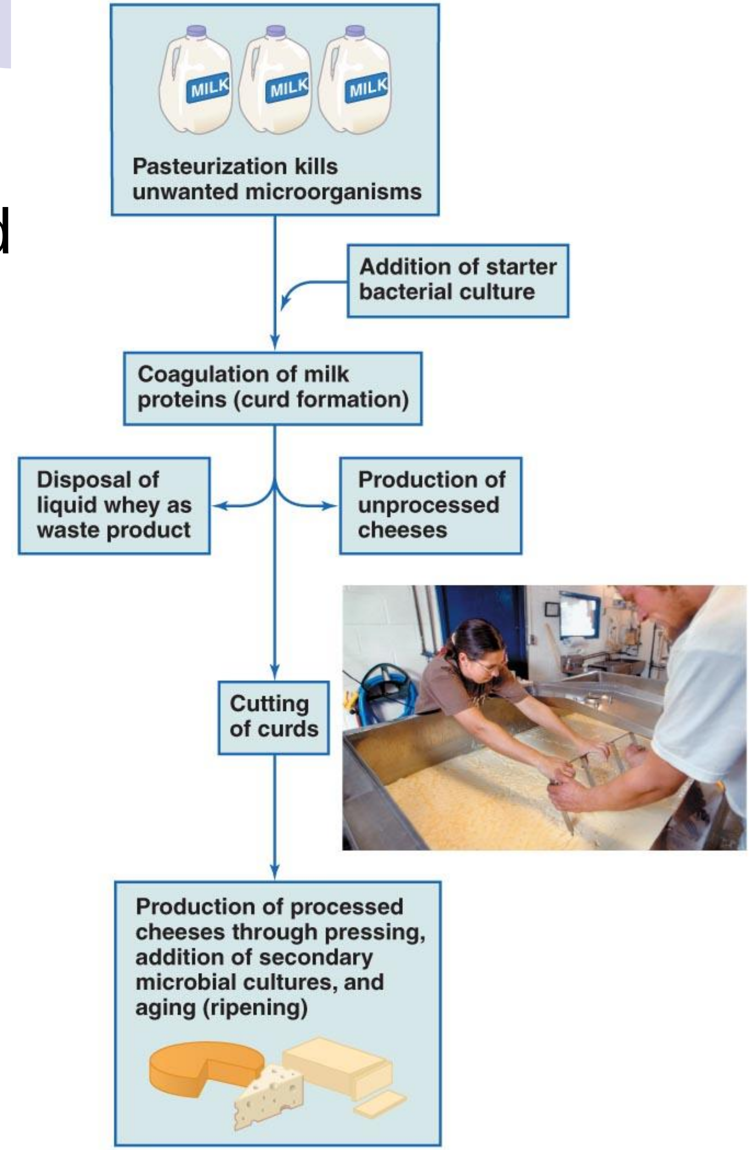
1. It is rapid and simple
2. Cell morphology can be determined
3. Can se whole picture of milk

Disadvantages

1. Results depends on each analyst
2. Both viable and nonviable are counted
3. Some bact. may not take the stain well

Microbes in Cheese Production

- Cheese
  - Curd (**casein** protein) separated from liquid **whey**
  - Aided by action of *Lactococcus* and **rennin** enzyme
  - Ripened or un-ripened
  - Physical and microbial ripening



- Classified by degree of hardness
- Hard cheeses
  - Ripened by lactic acid bacteria in interior
  - The longer the incubation the higher the acidity and sharper the flavor
  - *Propionibacterium* – swiss cheese
- Softer cheeses are ripened by aerobic bacterium and molds on surface
  - *Penicillium* – blue cheese

- Other fermented dairy products:
  - Buttermilk, sour cream, yogurt and fermented milk beverages
  - *Lactococcus lactis*, *Streptococcus thermophilus* and *Lactobacillus bulgaricus*

Diary products safety issues:

- **Outbreaks** have been associated with cheeses
- *Salmonella* serovar Zanzibar in goat milk cheese
- *Listeria monocytogenes* in Mexican-style cheese
- *Salmonella* and *Staphylococcus aureus* die off during cheese aging due to antagonistic activity by starters, salt and acid
- No outbreaks associated with yogurt

Table 25.1 Some Fermented Foods and the Microorganisms Used in Their Production

Food	Starting Material	Representative Culture Microorganisms
Fermented Vegetables		
Sauerkraut/kimchi	Cabbage	Various lactic acid bacteria
Pickle	Cucumbers, peppers, beets	Various lactic acid bacteria
Soy sauce	Soybeans and wheat	*Aspergillus oryzae* or *Aspergillus soyae* and *Lactobacillus* spp.
Miso	Rice and soybeans or rice and other grains	*Aspergillus oryzae* and *Lactobacillus* spp. and *Torulopsis etchellsii*
Fermented Meat Products		
Dry salami	Pork, beef, chicken	Various lactic acid bacteria
Fish sauce/paste	Ground fish	Various naturally occurring bacteria
Fermented Dairy Products		
Milks		
Buttermilk	Pasteurized skim milk	*Lactococcus lactis cremoris* and *Leuconostoc citrovorum*
Yogurt	Pasteurized skim milk	*Streptococcus thermophilus* and *Lactobacillus bulgaricus*
Cheeses		
Cottage cheese	Pasteurized milk	*Lactococcus cremoris* and *Lactococcus lactis*
Hard cheese (cheddar)	Milk curd	Starter culture as in cottage cheese without further additions
Soft cheese (Camembert)[a]	Milk curd	Starter culture as in cottage cheese plus *Penicillium camemberti*
Mold-ripened (Roquefort)	Milk curd	Starter culture as in cottage cheese plus *Penicillium roqueforti*
Animal Feed		
Silage	Corn, grains, vegetation	Various naturally occurring bacteria
Alcoholic Fermentations		
Wine	Grapes	*Saccharomyces cerevisiae*
Distilled spirits	Fruits, vegetables, grains	*Saccharomyces cerevisiae*
Beer	Barley	*Saccharomyces cerevisiae* or *S. carlsbergensis*
Sake	Cooked rice	*Aspergillus oryzae* and *Saccharomyces* spp.
Vinegar	Fruits, vegetables, grains	*Saccharomyces cerevisiae* and *Acetobacter* or *Gluconobacter*
Bread	Flour, salt, etc.	*Saccharomyces cerevisiae*

[a]In addition to being a soft cheese, Camembert is also a mold-ripened cheese.

Organic compounds contain mainly carbon, oxygen and hydrogen.

Inorganic compounds contain mainly other atoms.

Basic physical-chemical properties of cows' milk

Cows' milk consists of about 87 % water and 13 % dry substance. The dry substance is suspended or dissolved in the water. Depending on the type of solids, there are different distribution systems of them in the water phase.

Table 2.1
Physical-chemical status of cows' milk.

	Average composition %	Emulsion type oil/water	Collodial solution/ suspension	True solution
Moisture	87,0			
Fat	4,0	X		
Proteins	3,5		X	
Lactose	4,7			X
Ash	0,8			X

Definitions

Emulsion: a suspension of droplets of one liquid in another. Milk is an emulsion of oil in water (o/w), butter an emulsion of water in oil (w/o). The finely divided liquid is known as the dispersed phase and the other as the continuous phase.

Collodial solution: when matter exists in a state of division intermediate to true solution (*e.g.* sugar in water) and suspension (*e.g.* chalk in water) it is said to be in colloidal solution or colloidal suspension. The typical characteristics of a colloid are:

- Small particle size
- Electrical charge and
- Affinity of the particles for water molecules

***Fig* 2.5** *When milk and cream turn to butter, there is a phase inversion from an oil-in-water emulsion to a water-in-oil emulsion.*

In milk the whey proteins are in colloidal solution and the casein in colloidal suspension.

Substances such as salts destabilise colloidal systems by changing the water binding and thereby reducing protein solubility, and factors such as heat, causing unfolding of the whey proteins and increased interaction between the proteins, or alcohol which may act by dehydrating the particles.

Table 2.2
Relative sizes of particles in milk.

Size (mm)	Type of particles
10^{-2} to 10^{-3}	Fat globules
10^{-4} to 10^{-5}	Casein-calcium phosphates
10^{-5} to 10^{-6}	Whey proteins
10^{-6} to 10^{-7}	Lactose, salts and other substances in true solutions

Ref. *A Dictionary of Dairying* by J G Davis

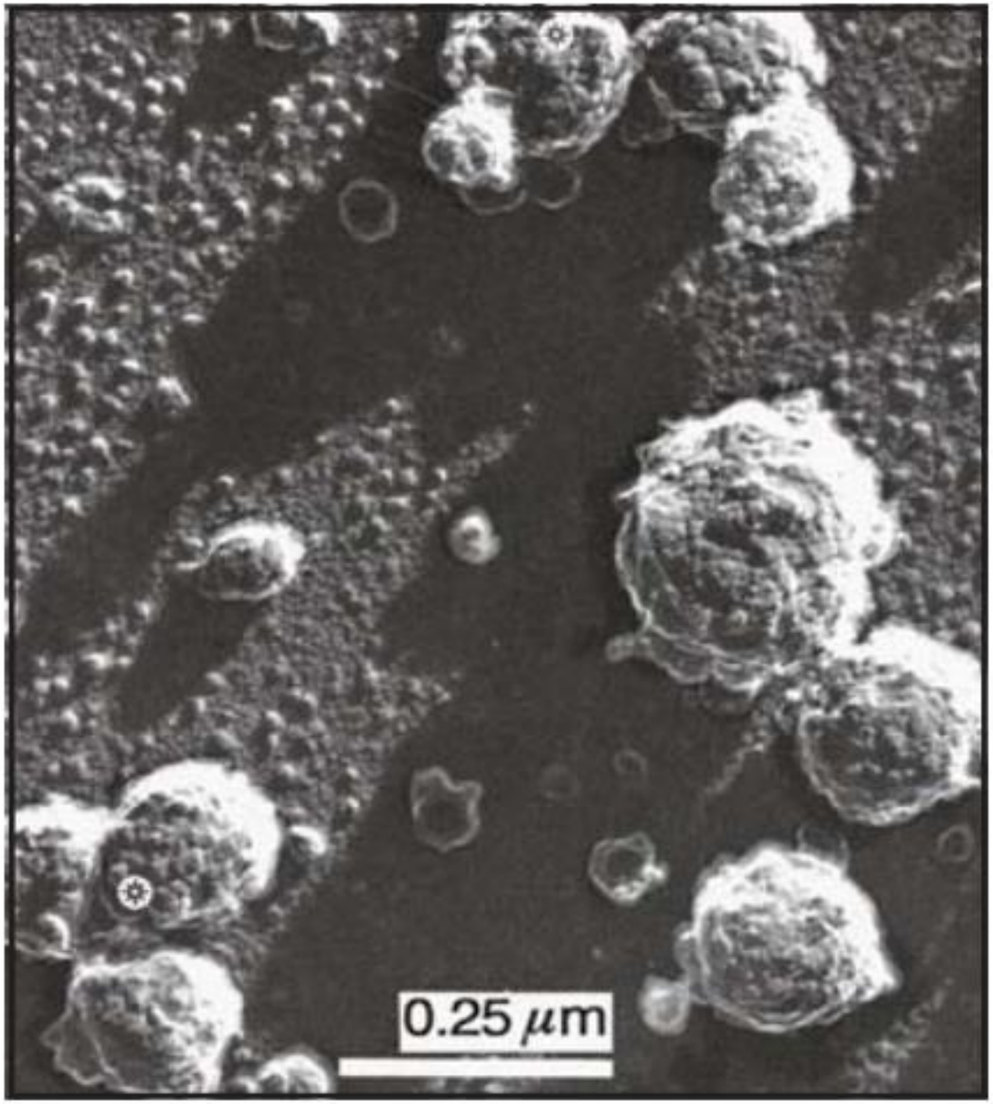


Fig 2.6 *Milk proteins can be made visible by an electron microscope.*

Ref. Miloslav Kaláb, Food structure, 1993.

Composition of cows' milk

The quantities of the various main constituents of milk can vary considerably between cows of different breeds and between individual cows of the same breed. Therefore only limit values can be stated for the variations. The numbers in Table 2.3 are simply examples.

Besides total solids, the term solids-non-fat (SNF) is used in discussing the composition of milk. SNF is the total solids content less the fat content. The mean SNF content according to Table 2:3 is consequently 13,0 – 3,9 = 9,1 %. The pH of normal milk generally lies between 6,5 and 6,7, with 6,6 as the most common value. This value is true for pH measurement of milk of approximately 25 °C.

Table 2.3

Quantitative composition of milk

Main constituent	Limits of variation	Mean value
Water	85,5 – 89,5	87,5
Total solids	10,5 – 14,5	13,0
Fat	2,5 – 6,0	3,9
Proteins	2,9 – 5,0	3,4
Lactose	3,6 – 5,5	4,8
Minerals	0,6 – 0,9	0,8

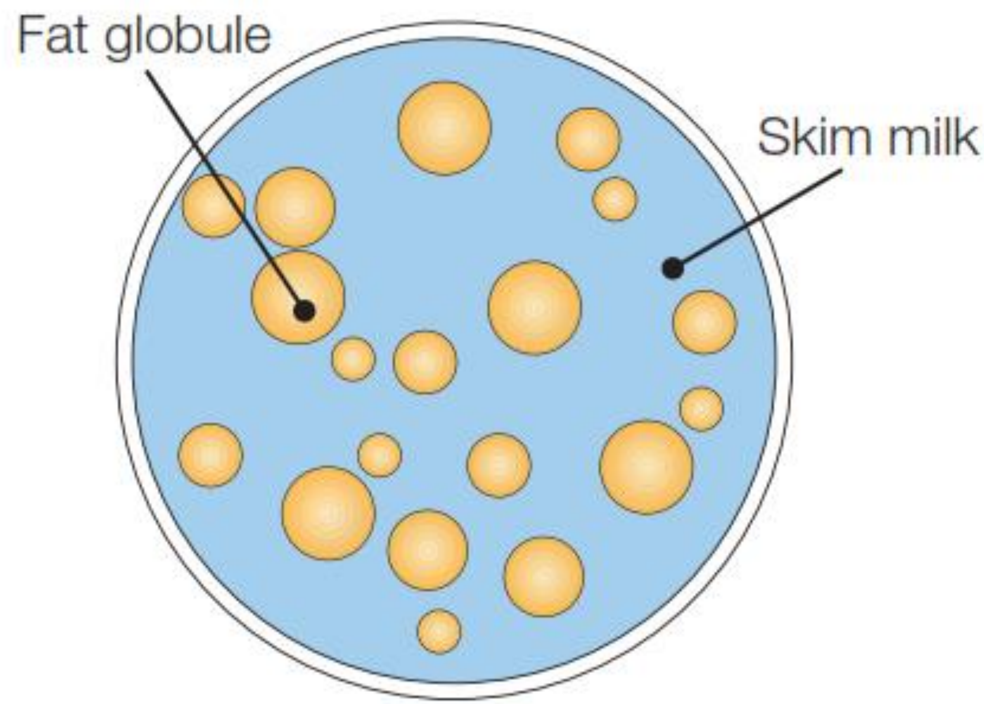


Fig 2.15 *A look into milk.*

Milk fat

Milk and cream are examples of *fat-in-water* (or oil-in-water) emulsions. The milk fat exists as small globules or droplets dispersed in the milk serum, Figure 2.15. Their diameters range from 0,1 to 20 µm (1 µm = 0,001 mm). The average size is 3 – 4 µm and there are some 15 billion globules per ml.

The emulsion is stabilised by a very thin membrane only 5 – 10 nm thick (1 nm = 10^{-9} m) which surrounds the globules and has a complicated composition.

Milk fat consists of triglycerides (the dominating components), di- and monoglycerides, fatty acids, sterols, carotenoids (giving the yellow colour of the fat) and vitamins (A, D, E, and K). Trace elements, are minor components. The composition of a milk fat globule is outlined in Figure 2.16.

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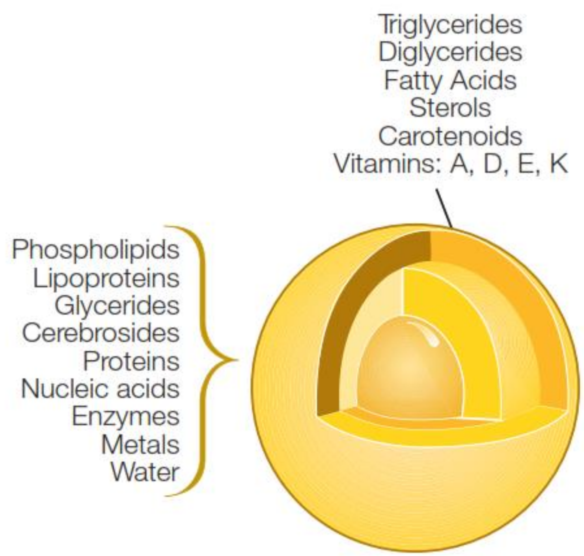


Fig 2.16 *The composition of milk fat.*
Size 0,1 – 20 μm. Average size 3 – 4 μm.

The membrane consists of phospholipids, lipoproteins, cerebrosides, proteins, nucleic acids, enzymes, trace elements (metals) and bound water. It should be noted that the composition and thickness of the membrane are not constant, because components are constantly being exchanged with the surrounding milk serum.

As the fat globules are not only the largest particles in the milk but also the lightest (density at 15,5 °C = 0,93 g/cm^3), they tend to rise to the surface when milk is left to stand in a vessel for a while, Figure 2.17.

The rate of rise follows *Stokes' Law*, but the small size of the fat globules

The rate of rise follows *Stokes' Law*, but the small size of the fat globules makes creaming a slow process. Cream separation can, however, be accelerated by aggregation of fat globules under the influence of a protein called *agglutinin.* These aggregates rise much faster than individual fat globules. The aggregates are easily broken up by heating or mechanical treatment. Agglutinin is denatured at time-temperature combinations such as 65 °C/10 min or 75 °C/2 min and the possibility of aggregation disappears.

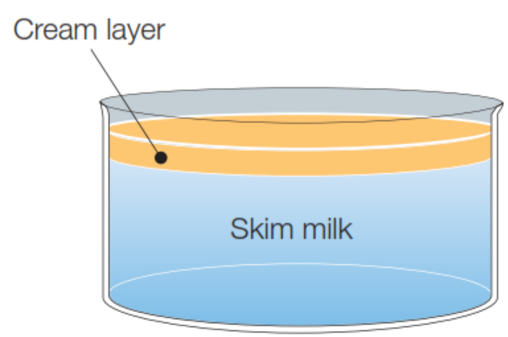


Fig 2.17 *If milk is left to stand for a while in a vessel, the fat will rise and form a layer of cream on the surface.*

Chemical structure of milk fat

Milk fat is liquid when milk leaves the udder at 37 °C. This means that the fat globules can easily change their shape when exposed to moderate mechanical treatment – pumping and flowing in pipes for instance – without being released from their membranes.

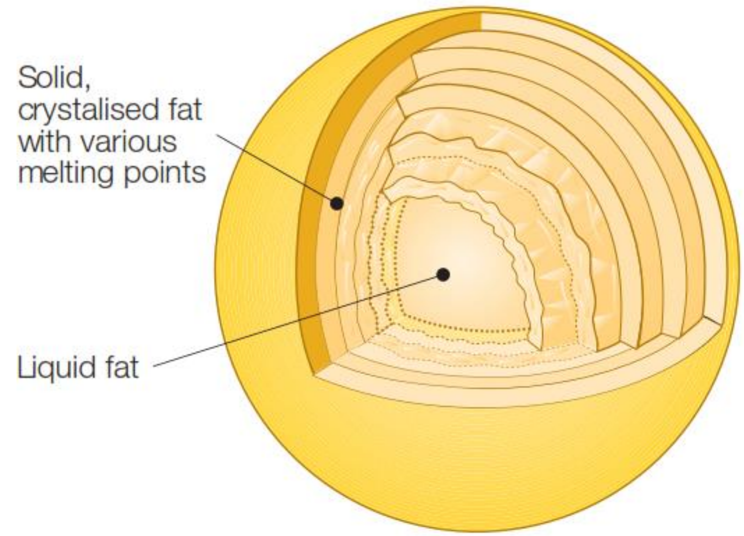


Fig 2.18 *Sectional view of a fat globule.*

All fats belong to a group of chemical substances called esters, which are compounds of alcohols and acids. Milk fat is a mixture of different fatty-acid esters called triglycerides, which are composed of an alcohol called glycerol and various fatty acids. Fatty acids make up about 90 % of milk fat.

Classes of milk proteins

Milk contains hundreds of types of protein, most of them in very small amounts. The proteins can be classified in various ways according to their

Table 2.5

Concentration of proteins in milk

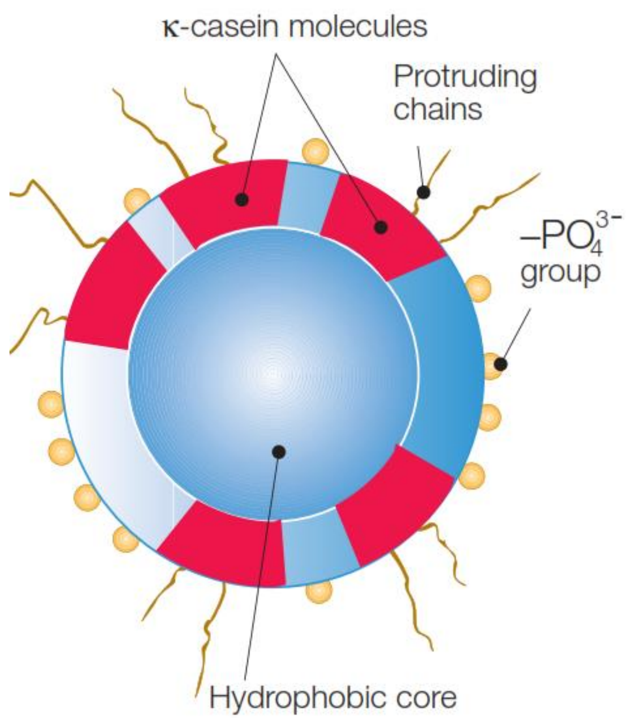
	Conc. in milk g/kg	**% of total protein w/w**
Casein		
α_{s1}-casein*)	10,0	30,6
α_{s2}-casein*)	2,6	8,0
β-casein**)	10,1	30,8
κ-casein	3,3	10,1
Total Casein	26,0	79,5
Whey Proteins		
α-lactalbumin	1,2	3,7
β-lactoglobulin	3,2	9,8
Blood Serum Albumin	0,4	1,2
Immunoglobulins	0,7	2,1
Miscellaneous (including Proteose-Peptone)	0,8	2,4
Total Whey Proteins	6,3	19,3
Fat Globule Membrane Proteins	0,4	1,2
Total Protein	32,7	100

*) Henceforth called α_s-casein
**) Including γ-casein

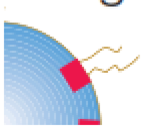
Ref: Walstra & Jennis

Casein

Casein is a group name for the dominant class of proteins in milk. The caseins easily form polymers containing several identical or different types of molecules. Due to the abundance of ionisable groups and hydrophobic and hydrophilic sites in the casein molecule, the molecular polymers formed by the caseins are very special. The polymers are built up of hundreds and thousands of individual molecules and form a colloidal solution, which is what gives skim milk its whitish-blue tinge. These molecular complexes are known as casein micelles. Such micelles may be as large as 0,4 microns, and can only be seen under an electron microscope.



Casein micelles



Casein micelles are fairly dense aggregates of sub-micelles with small regions of calcium phosphate, which links the sub-micelles together, giving the micelles an open, porous structure. Removal of calcium phosphate (CCP – colloidal calcium phosphate), *e.g.* by

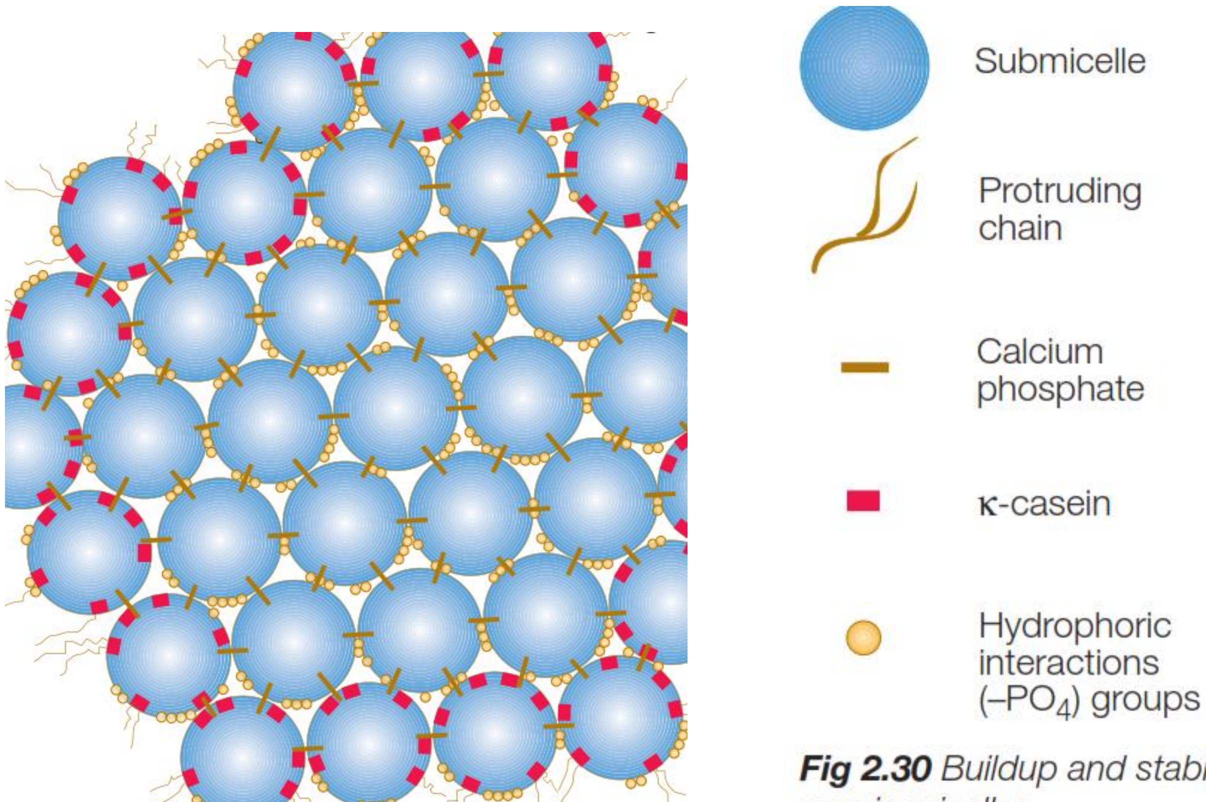


Fig 2.30 *Buildup and stabilisation of casein micelles.*

Ref: A digest of models by Slattery and Evard (1973), Schmidt (1982) and Walstra (1990) according to Rollema (1992). Rollema H.S. (1992) Casein Association and Micelle Formation p 63-111. Elsevier Science Publications Ltd.

Chapter 5

Collection and reception of milk

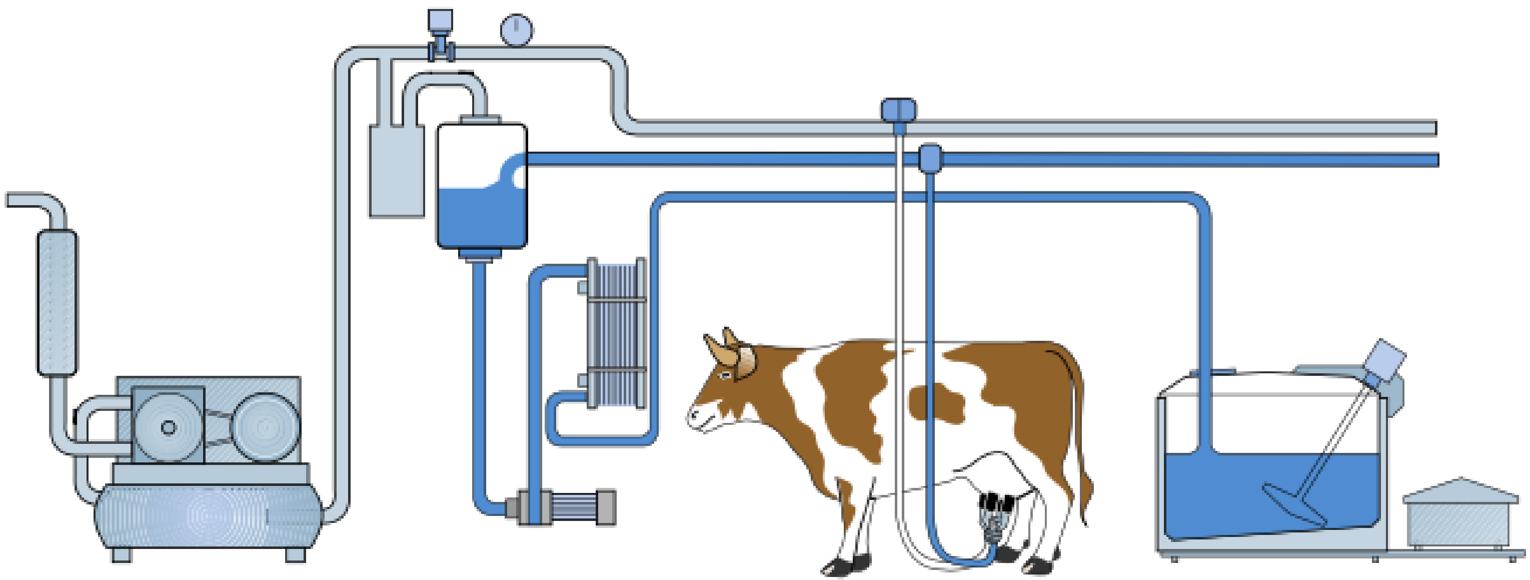


Fig. 5.1 *The milk run in a closed system from cow to cooling tank*

Today the trend is towards progressively larger dairy units. The demand is for increased production without reduction in the quality of the finished product. Milk must be brought from farther away and this means that daily collection is generally out of the question. Nowadays collection usually takes place every other day, but the interval can often be three days and sometimes even four.

Keeping the milk cool

The milk should be chilled to below + 4°C immediately after milking and be kept at this temperature all the way to the dairy.

If the cold chain is broken somewhere along the way, e.g. during transportation, the micro-organisms in the milk will start to multiply. This will result in the development of various metabolic products and enzymes. Subsequent chilling will arrest this development, but the damage has already been done. The bacteria count is higher and the milk contains substances that will affect the quality of the end product.

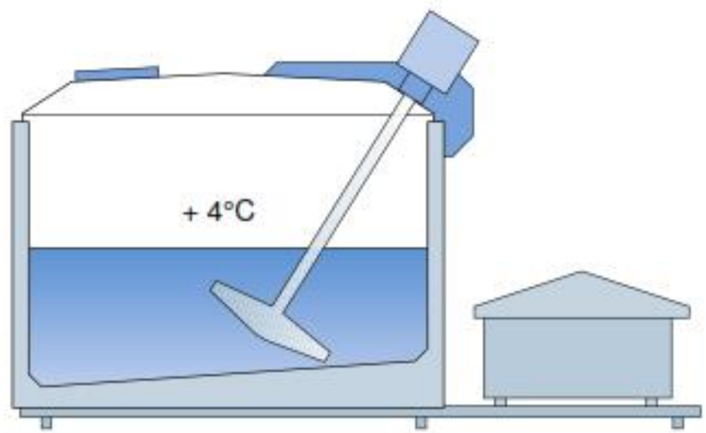


Fig. 5.2 *Bulk cooling tank with agitator and chilling unit*

Design of farm dairy premises

The first steps in preserving the quality of milk must be taken at the farm. Milking conditions must be as hygienic as possible; the milking system designed to avoid aeration, the cooling equipment correctly dimensioned.

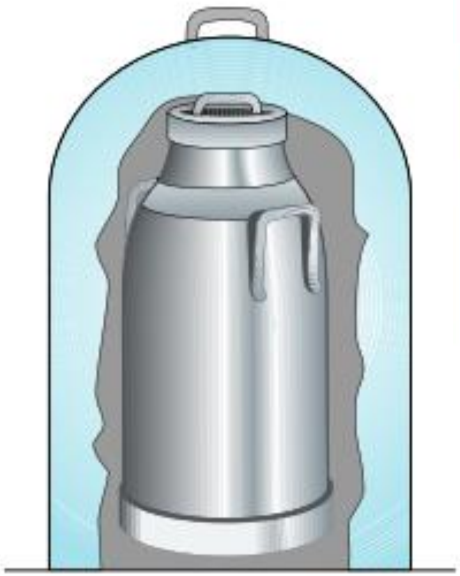
To meet the hygienic requirements, dairy farms have special rooms for refrigerated storage. Bulk cooling tanks are also becoming more common. These tanks, figure 5.2, with a capacity of 250 to 10 000 litres, are fitted with an agitator and cooling equipment to meet certain stipulations – for example that all the milk in the tank should be chilled to below +4°C within 2 hours of milking.

Delivery to the dairy

The raw milk arrives at the dairy in churns or in insulated road tankers, the latter being used only in combination with bulk cooling tanks at the farm. The requirements are the same for both methods – the milk must be kept well chilled and free from air and treated as gently as possible. For example, churns and tanks should be well filled in order to prevent the milk from sloshing around in the container.

Churn collection

Milk is transported in churns of various sizes, the most common being of 30 or 50 litres capacity. The churns are taken from the farm to the roadside. This should be done just before the arrival of the collecting lorry. The churns



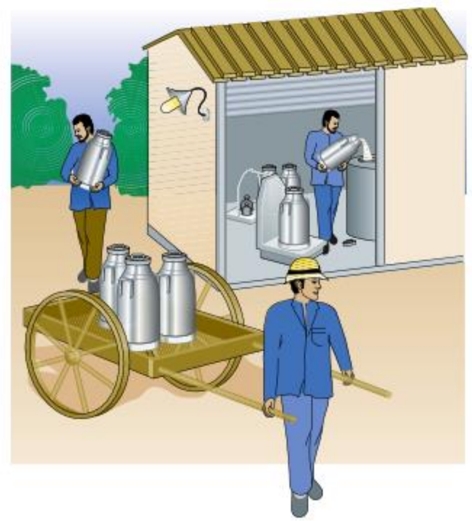


Fig. 5.3 *An insulating cover protects the milk from heat and cold.*

should be protected from the sun by a tarpaulin or a shelter, figure 5.4, or even better by a loose insulating cover of polystyrene, figure 5.3.

Bulk collection

When milk is collected by tanker it must be possible to drive all the way to the farm dairy room. The loading hose from the tanker is connected to the outlet valve on the farm cooling tank. The tanker is usually fitted with a flow meter and pump so that the volume is automatically recorded. Otherwise the volume is measured by recording the level difference which, for the size of the tank in question, represents a certain volume. In many cases the tanker is equipped with an air eliminator.

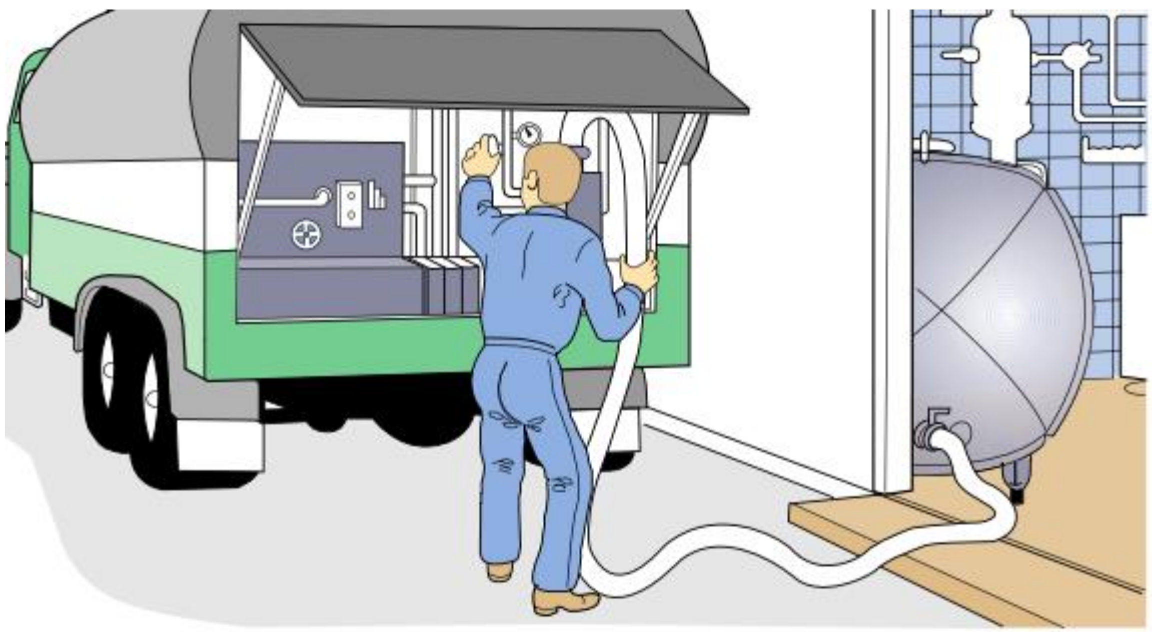


Fig. 5.6 *Bulk collection at the farm*

Testing milk for quality

Milk from sick animals and milk which contains antibiotics or sediment must not be accepted by the dairy. Even traces of antibiotics in milk can render it unsuitable for the manufacture of products which are acidified by the addition of bacteria cultures, e.g. yoghurt and cheese.

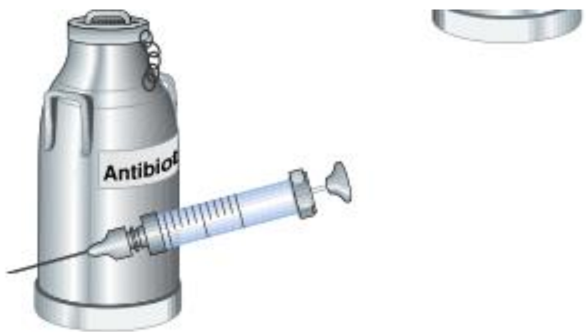


Fig. 5.7 *Milk from animals treated with antibiotics must be kept separate from other milk*

Taste and smell

In the case of bulk collection, the driver takes a sample of the milk at the farm for testing at the dairy. Churn collected milk is sampled at the churn reception department. Milk that deviates in taste and smell from normal milk receives a lower quality rating. This affects the payment to the producer. Milk with significant deviations in taste and smell should be rejected by the dairy.

Cleaning checks

The inside surfaces of farm tanks and churns are carefully inspected. Any milk residue is evidence of inefficient cleaning and will result in a deduction in accordance with a quality payment scheme.

Hygiene or Resazurin tests

The bacteria content of the milk is a measure of its hygienic quality. The Resazurin Tests are used frequently. Resazurin is a blue dye which becomes colourless when it is chemically reduced by the removal of oxygen. When it is added to the milk sample, the metabolic activity of the bacteria present has the effect of changing the colour of the dye at a rate which bears a direct relationship to the number of bacteria in the sample.

Two hygiene tests use this principle. One is a quick-screening test, which may form the basis for the rejection of a bad churn supply. If the sample starts to change shade immediately, the consignment is considered unfit for human consumption.

The other test is a routine test and involves storage of the sample in a refrigerator overnight, before a Resazurin solution is added. The sample is then incubated in a water bath and held at 37.5 °C for two hours.

Fig. 5.8 *Analysing milk samples.*

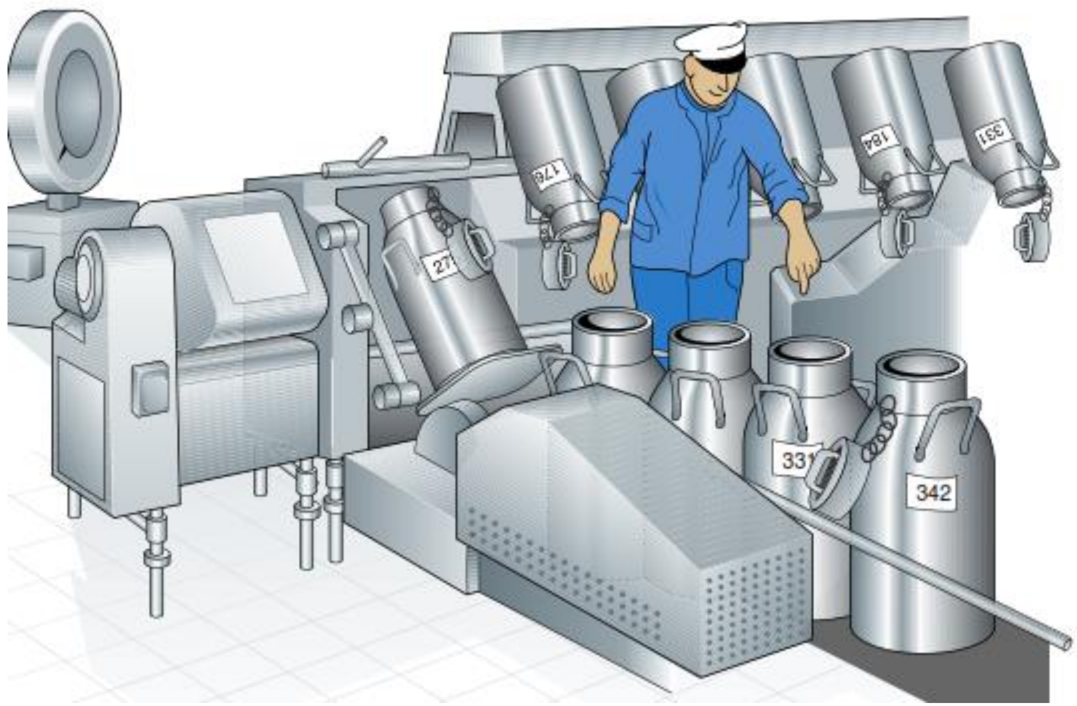
The common tests carried out on milk supplies are:

- taste and smell
- cleaning
- sediment
- hygiene
- somatic cell count
- bacteria count
- protein content
- fat content
- freezing point

Milk reception

Dairies have special reception departments to handle the milk brought in from the farms. The first thing done at reception is to determine the quantity of the milk. The quantity is recorded and entered into the weighing system that the dairy uses to weigh the intake and compare it with the output.

The quantity of the intake can be measured by volume or by weight.



Tanker reception

Tankers arriving at the dairy drive straight into a reception hall, often large enough to accommodate several vehicles.

The milk is measured either by volume or by weight.

Measuring by volume

This method uses a flowmeter. It registers the air in the milk as well as the milk, so the results are not always reliable. It is important to prevent air from entering with the milk. Measuring can be improved by fitting an air eliminator before the flowmeter, figure 5.11.

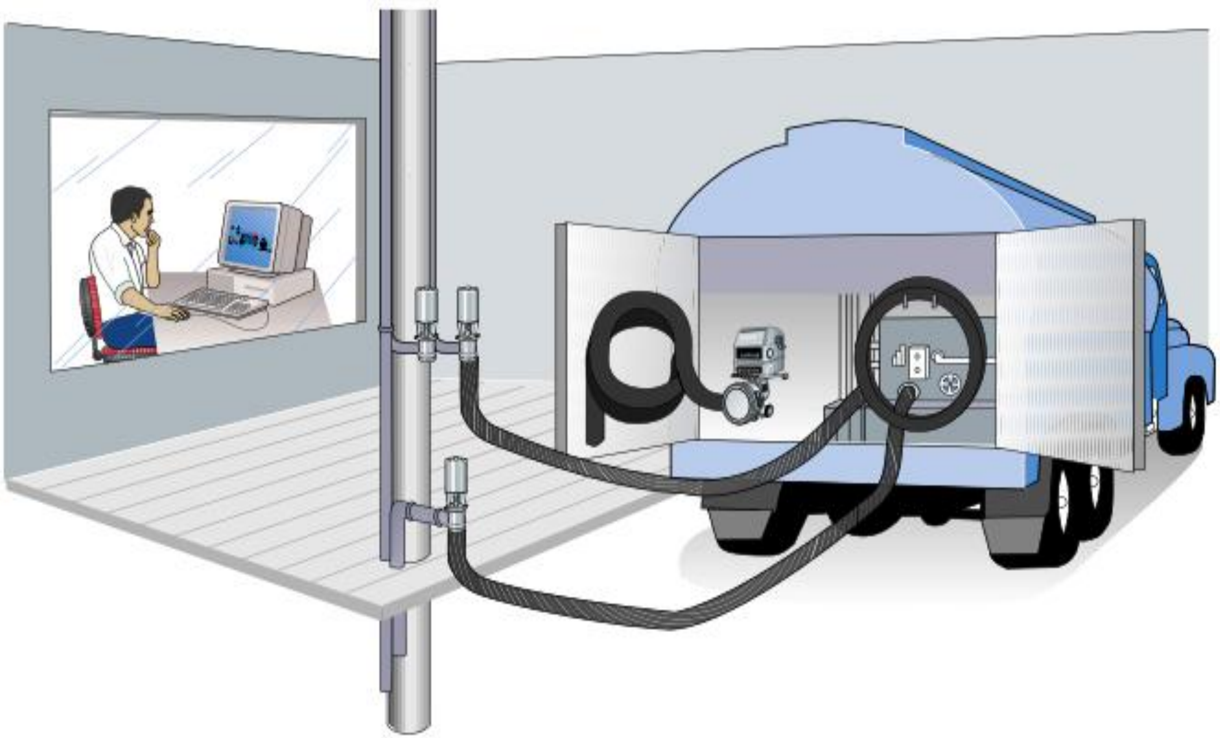


Fig. 5.10 *Measuring milk intake in a tanker reception hall*

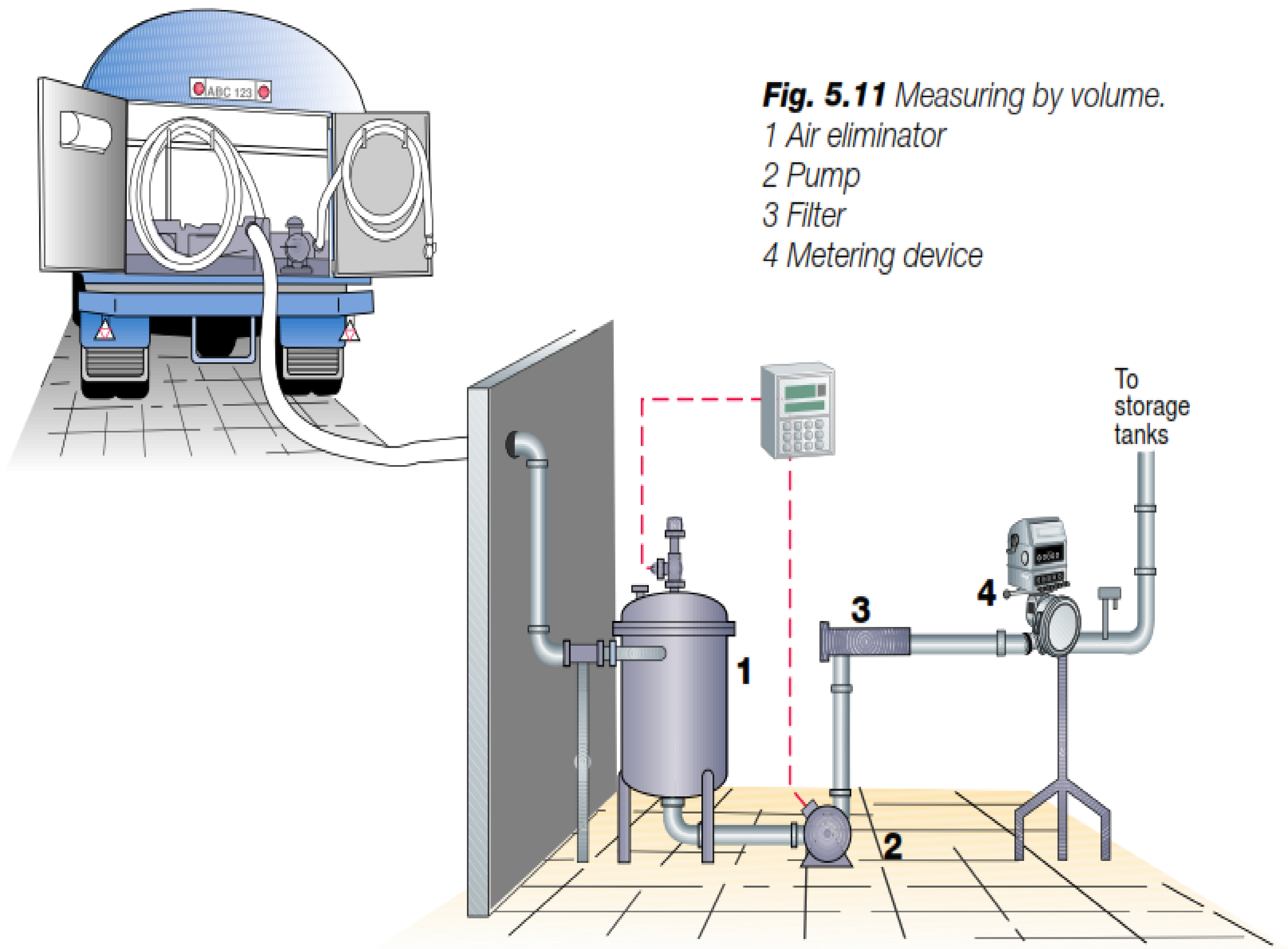


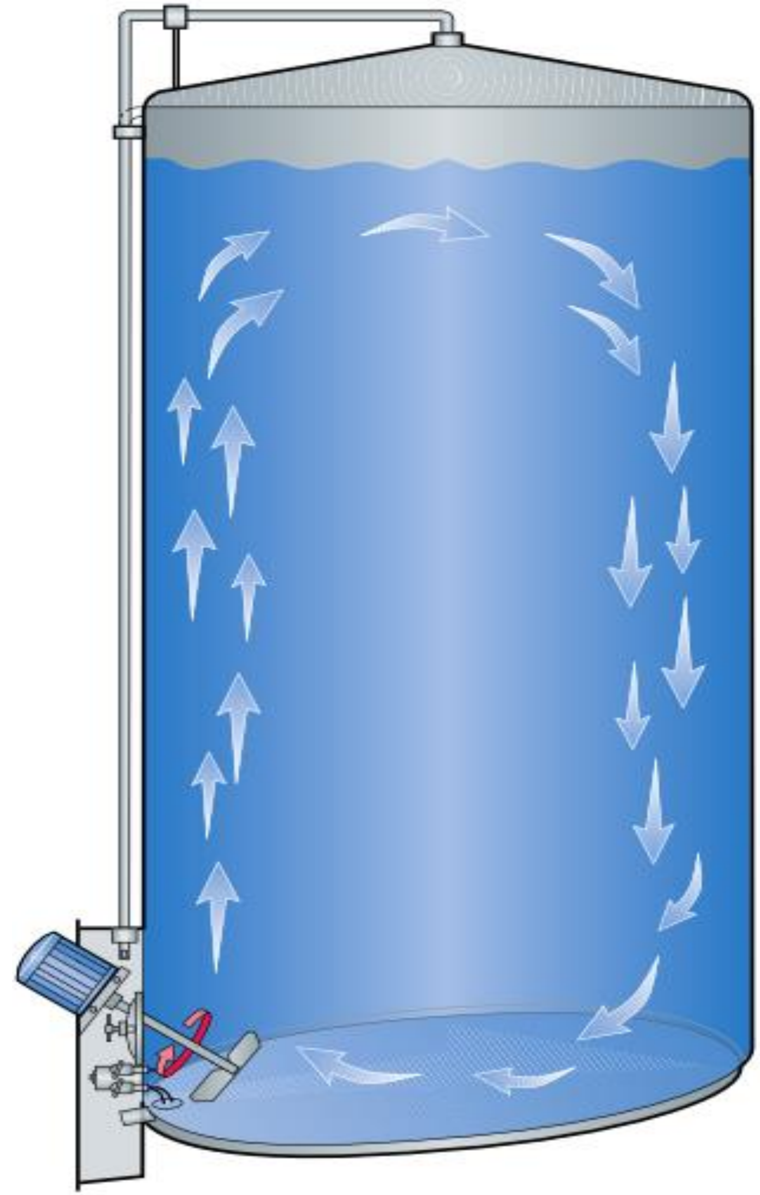
Fig. 5.11 *Measuring by volume.*
1 Air eliminator
2 Pump
3 Filter
4 Metering device

Chilling the incoming milk

Normally a temperature increase to slightly above + 4 °C is unavoidable during transportation. The milk is therefore usually cooled to below + 4 °C in a plate heat exchanger before being stored in a silo tank to await processing.

Raw milk storage

The untreated raw milk – whole milk – is stored in large vertical tanks – silo tanks – which have capacities from about 25 000 litres up to 150 000 litres. Normally, capacities range from 50 000 to 100 000 litres. Smaller silo tanks are often located indoors while the larger tanks are placed *outdoors* to reduce building costs. Outdoor silo tanks are of double-wall construction, with insulation between the walls. The inner tank is of stainless steel, polished on the inside, and the outer wall is usually of welded sheet metal.



Agitation in silo tanks

These large tanks must have some form of agitation arrangement to prevent cream separation by gravity. The agitation must be very smooth. Too violent agitation causes aeration of the milk and fat globule disintegration. This exposes the fat to attack from the lipase enzymes in the milk. Gentle agitation is therefore a basic rule in the treatment of milk. The tank in the illustration 5.14 has a propeller agitator, often used with good results in silo tanks. In very high tanks it may be necessary to fit two agitators at different levels to obtain the required effect.

Outdoor silo tanks have a panel for ancillary equipment. The panels on the tanks all face inwards towards a covered central control station.

Centrifugal separators and milk fat standardisation

Sedimentation by gravity

Historically speaking the centrifugal separator is a recent invention. Up to a hundred years ago the technique used for separating one substance from another was the natural process of sedimentation by gravity.

Sedimentation takes place all the time. Clay particles moving in puddles will soon settle, leaving the water clear. Clouds of sand stirred up by waves or by the feet of bathers do the same. Oil that escapes into the sea is lighter than water, rises and forms oil slicks on the surface.

Sedimentation by gravity was also the original technique used in dairying to separate fat from milk. Milk fresh from the cow was left in a vessel. After some time the fat globules aggregated and floated to the surface where they formed a layer of cream on top of the milk. This could then be skimmed off by hand.

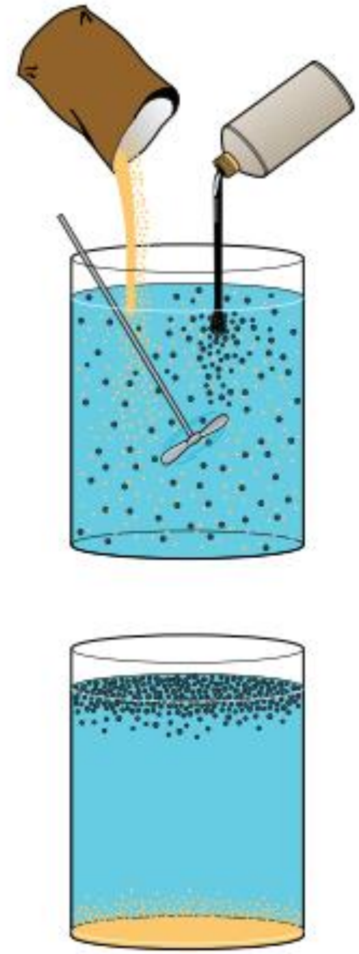


Fig. 6.2.3 *Sand and oil sink and float respectively after admixture into water.*

Requirements for sedimentation

The liquid to be treated must be a dispersion – a mixture of two or more phases, one of which is continuous. In milk it is the milk serum, or skimmilk, that is the continuous phase. Fat is dispersed in the skimmilk in the form of globules with variable diameters up to some 15 μm. Milk also contains a third phase, consisting of dispersed solid particles such as udder cells, pulverised straw and hair, etc.

The phases to be separated must not be soluble in each other. Substances in solution cannot be separated by means of sedimentation.

Dissolved lactose cannot be separated by means of centrifugation. It can, however, be crystallised. The lactose crystals can then be separated by sedimentation.

The phases to be separated must also have different densities. The phases in milk satisfy this requirement; the solid impurities have a higher density than skimmilk, and the fat globules have a lower density.

Separation by centrifugal force

Sedimentation velocity

A field of centrifugal force is generated if a vessel is filled with liquid and spun, as shown in figure 6.2.13. This creates a centrifugal acceleration *a*. The centrifugal acceleration is not constant like the gravity *g* in a stationary vessel. The centrifugal acceleration increases with distance from the axis of rotation (radius r) and with the speed of rotation, expressed as angular velocity ω, figure 6.2.14.

Fig. 6.2.13 *Centrifugal force is generated in a rotating vessel .*

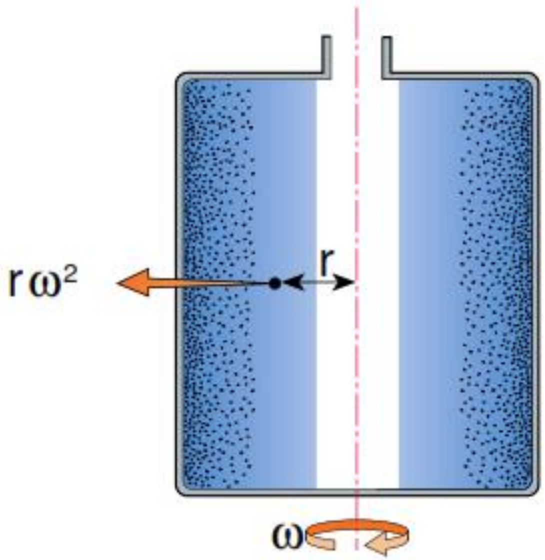


Fig. 6.2.14 *A simple separator*

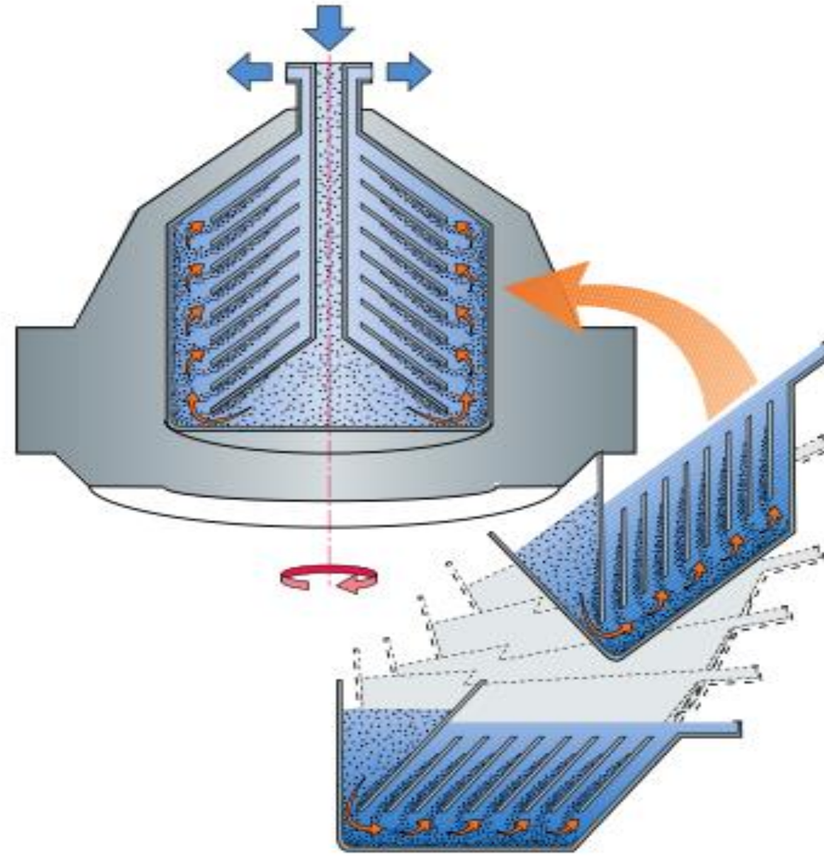


Fig. 6.2.15 *The baffled vessel can be turned 90° and rotated, creating a centrifuge bowl for continuous separation of solid particles from a liquid.*

Continuous centrifugal separation of milk

Clarification

In a centrifugal clarifier, the milk is introduced into the separation channels at the outer edge of the disc stack, flows radially inwards through the channels towards the axis of rotation and leaves through the outlet at the top as illustrated in figure 6.2.18. On the way through the disc stack the solid impurities are separated and thrown back along the undersides of the discs to the periphery of the clarifier bowl. There they are collected in the sediment space. As the milk passes along the full radial width of the discs, the time of passage also allows very small particles to be separated. The most typical difference between a centrifugal clarifier and a separator is the design of the disk stack – clarifier without distribution holes – and the number of outlets – clarifier one and separator two.

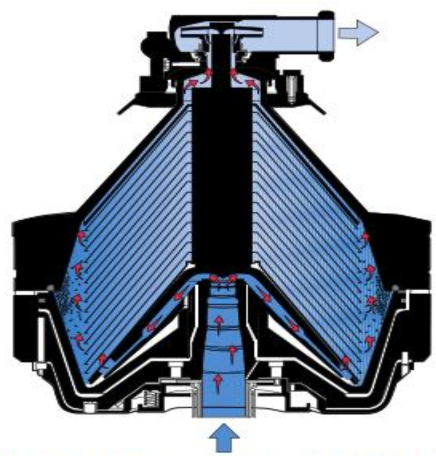


Fig. 6.2.18 *In a centrifugal clarifier bowl the milk enters the disc stack at the periphery and flows inwards through the channels.*

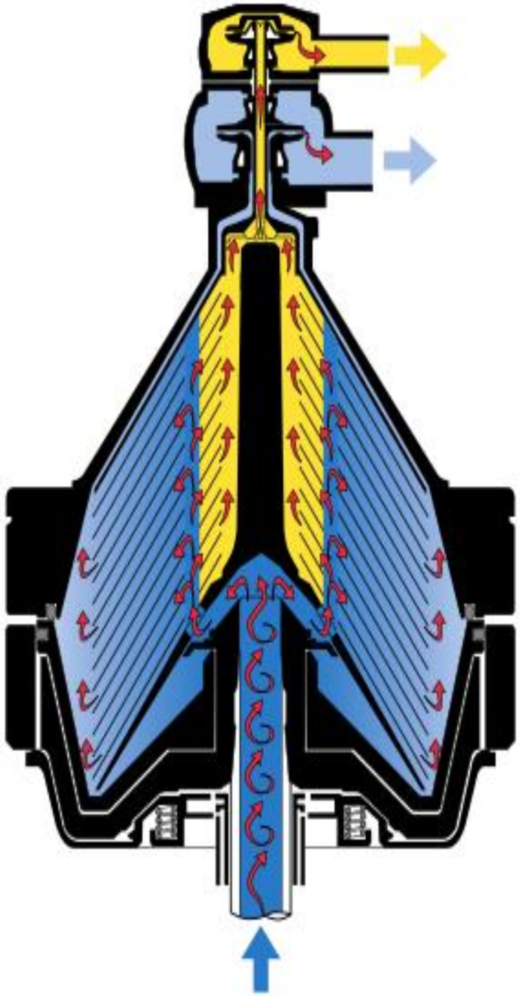


Fig. 6.2.19 *In a centrifugal separator bowl the milk enters the disc stack through the distribution holes.*

The size of fat globules varies during the cow's lactation period, i.e. from parturition to going dry. Large globules tend to predominate just after parturition, while the number of small globules increases towards the end of the lactation period.

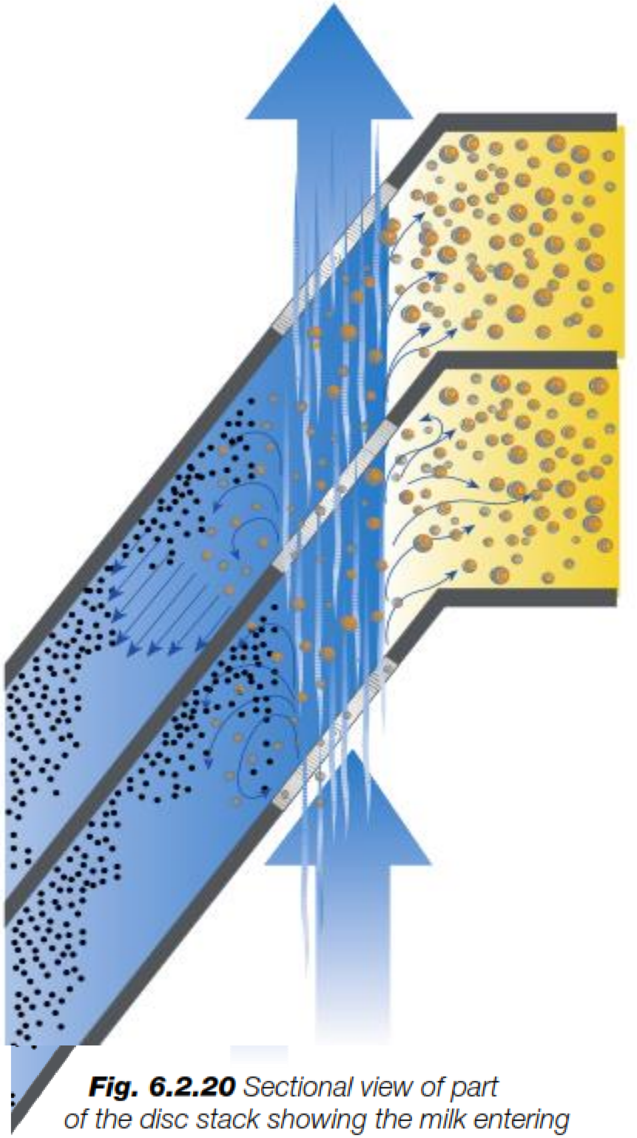


Fig. 6.2.20 *Sectional view of part of the disc stack showing the milk entering through the distribution holes and separation of fat globules from the skimmilk.*

1 Air column
2 Outer cream level
3 Inner cream level
4 Level of required cream fat content

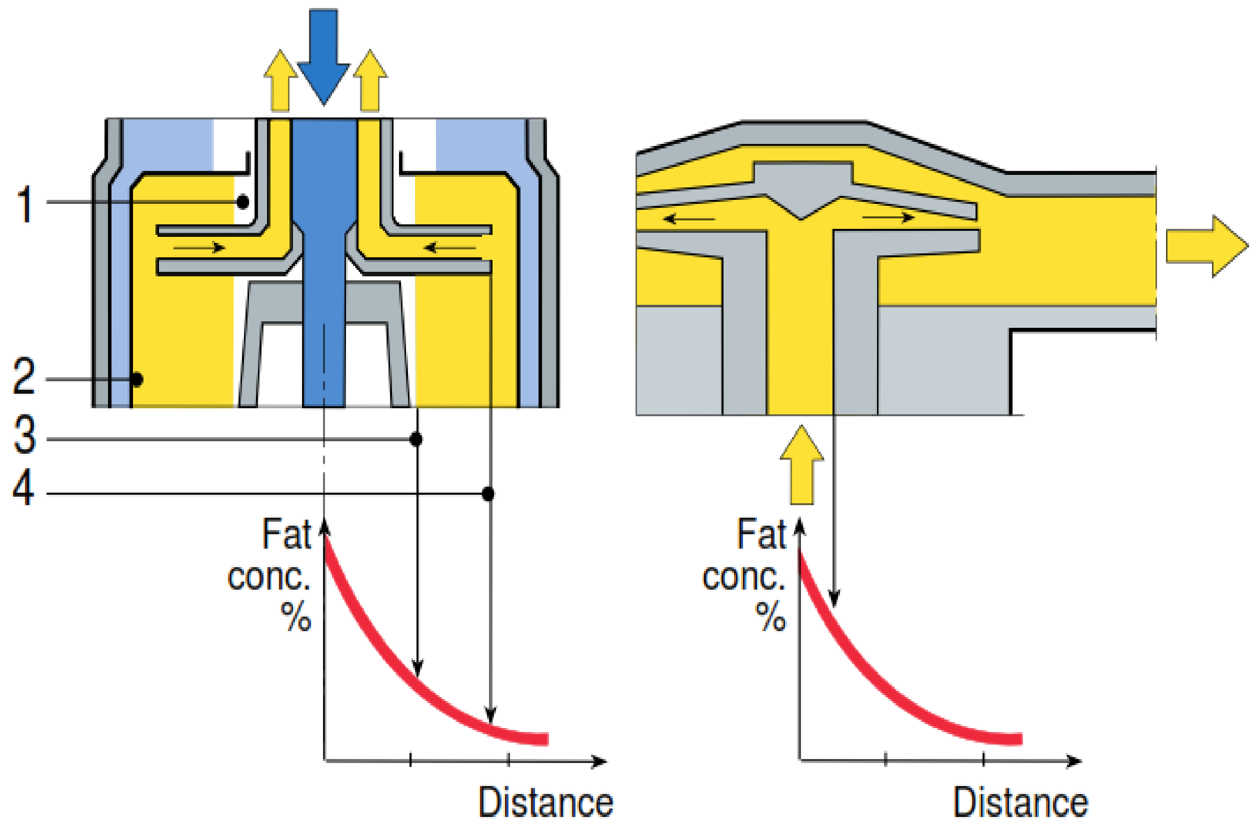


Fig. 6.2.29 *The cream outlet of a paring disc and a hermetic separator and corresponding cream fat concentrations at different distances.*

Dairy Products and Processing

- Definitions and standards
- Processing steps
- Shelf-life
- Fermented dairy products

Definitions

- Raw milk: The lacteal secretion , practically free from colostrum, obtained by the complete milking of one or more healthy cows (PMO).

- "Consumer Milk" products:
  - Homogenized milk: ≥3.25% fat
  - Reduced fat milk: 2% fat
  - Low fat milk: 1% fat
  - Fat-free milk: skim milk, <0.5% fat

  (all with 8.25% solids-non-fat)

- Other "milk products": lactose reduced milks, heavy cream, cultured milks, yogurt, cottage cheese.

Shelf-life:

- Time for which a product can be stored without the quality falling below a certain acceptable minimum level
- Consumer milk: 14 days, under refrigeration (Muir, 1996)

Pasteurized Milk Ordinance (PMO)

- produced by Public Health Service/Food and Drug Administration

- sanitary regulations for milk and milk products

- specifies sanitation measures throughout production, handling, pasteurization, and distribution of milk

(http://vm.cfsan.fda.gov/~ear/p-nci.htm#pmo96)

Fluid Milk Processing

Raw milk storage

↓

Cleaning and decreaming (Separator)

↓

Homogenization

↓

Fat standardization

↓

Heat Treatment

↓

Chilling (Heat exchanger)

↓

Intermediate storage

↓

Filling/Packing

Raw Milk Quality and Storage

- Chemical, bacteriological, and temperature standards for Grade A raw milk for pasteurization, ultrapasteurization or aseptic processing (PMO)
  - Temperature: 45ºF or less within 2 h after milking
  - Bacterial counts: <100,000 cfu/ml for individual farm milk and <300,000/ml as commingled milk prior to pasteurization
  - Somatic Cell Counts: <750,000/ml
  - Antibiotic presence: negative
- Storage time at plant max. 72h
- Longer holding times allow growth of psychrophilic bacteria which can secrete heat-resistant proteases and lipases

Bacteria that limit milk shelf-life

- lipolytic and proteolytic psychrotrophs
  - heat resistant enzymes
  - ex. *Pseudomonas fluorescens*

- psychrotrophic spore formers (thermoducrics)
  - heat resistant spores
  - ex. *Bacillus cereus*

Thermization (Lewis and Heppell, 2000)

- 57-68°C for 15 seconds
- only effective if cooled to 4°C after treatment
- applied to raw milk that needs to be stored for several days prior to use
- purpose: reduce gram-negative psychrotrophic spoilage organisms (enzyme production)

Clarification and Clearing

- Clarification: removal of small particles
  - straw, hair etc. from milk; 2 lb/2,642 gal
  - based on density

- “Bactofugation”: Centrifugal separation of microorganisms from milk:
  - Bacteria and particularly spores have higher density than milk
  - Two-stage centrifugation can reduce spore loads up to >99%
  - Optimal temperature for clarification is 55-60ºC

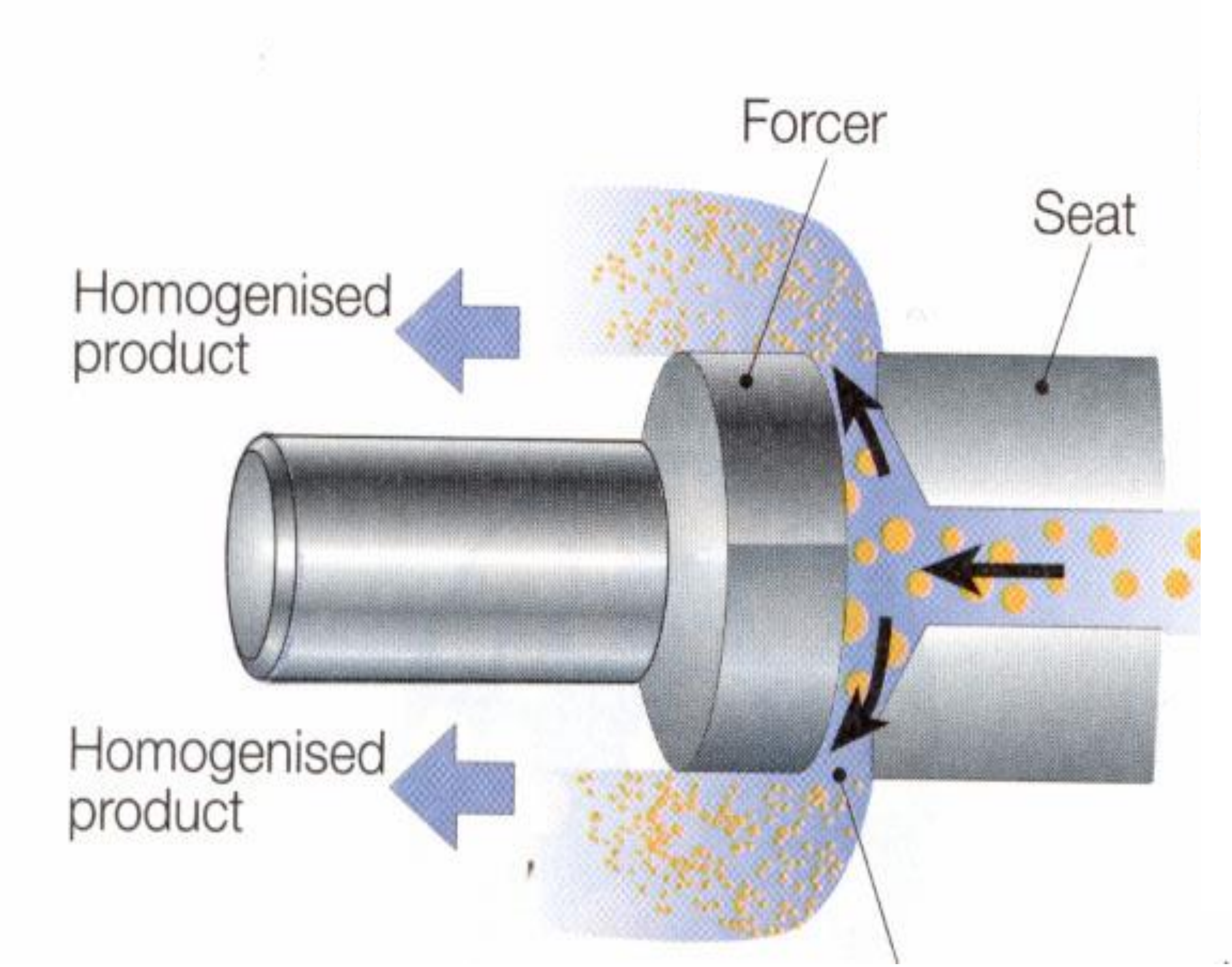
- Microfiltration
  - Microfilter membranes of 1.4 μm or less can lead to reduction of bacteria
  - and spores up to 99.5-99.99%.

Milk Fat Standardization/Decreaming

- Separation of skim milk (about 0.05% fat) and cream (35-40% fat)
- Based on the fact that cream has lower density than skim milk
- Centrifugal separators are generally used today
- Standardization of fat content: Adjustment of fat content of milk or a milk product by addition of cream or skim milk to obtain a given fat content

Homogenization

- Definition: Treatment of milk or a milk product to insure breakup of fat globules such that no visible cream separation occurs after 48 h at 40ºF (4.4ºC)
- Effects of homogenization:
  - No cream line formation due to smaller fat globules
  - Whiter color
  - More full-bodied flavor, better mouthfeel
- Process requirements:
  - Homogenization most efficient when fat phase is in a liquid state
  - Cream >12% fat cannot be homogenized at normal pressure, high pressure homogenization process is necessary
- Homogenization is a mechanical process where milk is forced through a small passage at high velocity



From the “Dairy Processing Handbook” 1995. Tetra Pak

Pasteurization

- Purpose: Inactivation of bacterial pathogens (target organisms *Coxiella burnettii*)

  - assurance of longer shelf life (inactivation of most spoilage organisms and of many enzymes)
- Pasteurization
  - Heat treatment of 72ºC (161°F) for 15 sec (HTST) or 63ºC (145°F) for 30 min (or equivalent)
  - does not kill all vegetative bacterial cells or spores (*Bacillus* spp. and *Clostridium* spp.)
  - Pasteurization temperature is continuously recorded

Efficacy of Pasteurization

- prior to pasteurization (1938) :
  milkborne outbreaks constituted **25%** all disease outbreaks

- Today: milk products associated with **< 1%**

Heat Treatment (Con′t)

- Standards for Grade A pasteurized milk and milk products (PMO)
  - Temperature: Cooled to 45ºF or less
  - Bacterial counts: <20,000 cfu/ml
  - Coliform Counts: <10/ml
  - Phosphatase: < 1µg/ml
  - Antibiotic presence: negative

Heat Treatment (Con't)

- Ultra pasteurization: Thermal processing at 138ºC (280ºF) for at least 2 seconds

  - UP milk: ultrapasteurized and "non-aseptically" packaged, refrigerated storage

  - UHT milk: ultrapasteurized and aseptically packaged, storage at room temperature; avoid recontamination

- Standards for Grade A aseptically processed milk (UHT)

  - Temperature: none

  - Bacterial counts: no growth

  - Antibiotic presence: negative

Vitamin Fortification

- Preferably after separation
- Has to occur before pasteurization
- Can be continuous (using a metering pump) or batch addition

Filling/Packaging

- Functions of packaging:
  - Enable efficient food distribution
  - Maintain product hygiene
  - Protect nutrients and flavor
  - Reduce food spoilage
  - Convey product information
- Different containers:
  - Glass bottles (translucent vs. dark): can be reusable or recyclable
  - Plastic containers
  - Cartons
  - Plastic bags

Shelf Life of Heat Treated Fluid Milk

- Shelf life depends on:
  - Raw milk quality (bacterial and chemical quality)
  - Processing conditions
  - Post-processing storage
- Loss of taste and vitamins by light exposure:
  - Light-impermeable containers
- Extended Shelf life (ESL) milk
  - No single, specific definition of ESL
  - Pasteurized milk with a shelf life beyond the current typical shelf life of these products (10 - 14 days)
  - Generally involves measures to eliminate or minimize "post-pasteurization" contamination

Fermented Dairy products

- Fermented foods:
  - Food products produced by biological transformation (by bacteria or fungi)
  - Carbohydrate breakdown as a major characteristics (lactose → lactate)

- Preservation: production of acids and alcohol (by "beneficial" bacteria) to inhibit spoilage bacteria and pathogens

Cheese:

- product made from the curd of the milk of cows (or other animals)

- casein coagulated by rennin and acid

- subsequent heating, salting, pressing, aging

Classification of Cheeses (Potter, 1995)

- Soft
  - unripened: cottage cheese, cream cheese
  - ripened: Brie, Camembert
- Semisoft
  - Munster, Limburger, Blue
- Hard
  - cheddar, swiss
- Very hard (grating)
  - Parmesan, Asiago
- whey cheeses (ricotta)
- processed cheese

Cheddar Cheese Making Process

pasteurized milk
↓
Setting the milk
↓
Cutting the curd
↓
Cooking the curd
↓
Draining the whey
↓
Milling and salting
↓
Pressing
↓
Ripening

Cheddar cheese making process

- starting ingredient: pasteurized whole milk
- setting the milk
    - while stirring heat to 31°C
    - add lactic-acid producing starter cultures
    - (add natural color)
    - add rennin to coagulate caseins and form curds
    - stop stirring and let set
- Cut the curd
    - increase surface area
    - release the whey

- Cooking (38°C for 30 minutes)
    - removes more whey
    - increases growth and acid production of cultures

Cheddar cheese making (cont.)

- Draining whey and matting the curd
  - remove excess whey
  - form curds into a slab
  - cheddaring: cutting curd slab into blocks to allow excess whey to drain, and allow acidity to increase

- Milling and salting
  - cut curds into small pieces
  - 2.5% salt is added: drains whey, inhibits spoilage organisms and adds flavor

- Pressing to remove more whey
  - moisture content will affect bacterial growth and texture

- Ripening: bacteria develop flavor and texture over time

Ripening: flavor and texture development

- Primary proteolysis
  - 60 days; residual chymosin
  - caseins broken down into medium molec. wt. peptides

- secondary proteolysis
  - starter cultures break down peptides to lower molec. wts.

- Temperature: 5-7°C

- pH: 5.0 - 4.7
  - inhibits growth of spoilage organisms
  - inhibits enzyme activity

Cheese flavor development

- A complex, dynamic process
- Nature of the flavor evolves
- Proteolysis essential for full flavor development
  - Proteolytic enzymes
    - Allow LAB to utilize proteins present in milk to obtain essential amino acids necessary for growth
  - Generates peptides and amino acids
    - Impart flavor directly or serve as flavor precursors

Whey

- 100 lb of milk => 10 lb cheese + **90 lb whey**
  (NYS produces 3.6 billion lb/year)

- low solids, high lactose

- highly perishable (contains starter organisms)

- Acid whey: drained from cheese curd acidified to 4.6 by
  cultures (or acid); ex. Cottage cheese

- sweet whey: drained from curd formed by rennet coagulation
  ex. Cheddar

Whey Products

- concentrated and spray dried

- whey powder

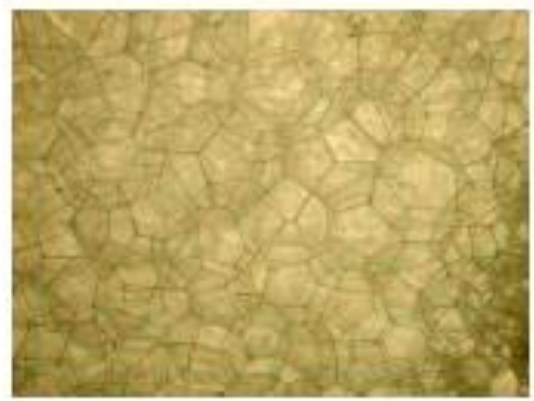
- whey protein concentrates
  - different % purity
  - food ingredient

- lactose
  - food ingredient
  - fermented into alchohol

- whey cheeses

Milk Foam

Foam – a network of protein and or fat and sugar creating a cage around pockets of air.



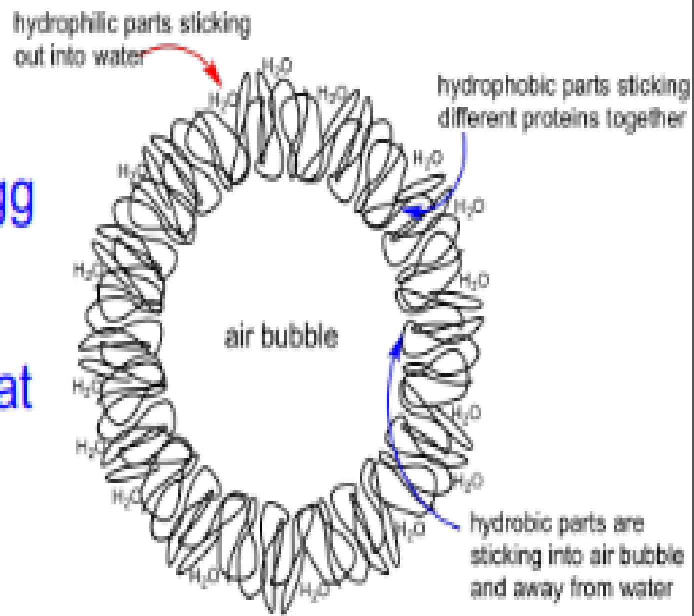
Foam

Espresso foams - milk foams made of coagulated whey proteins forming the cage around the bubbles in the steam

- Less protein than other foams and are thus unstable

Meringue foam – egg white protein and sugar foam

Whipped Cream – fat globule cages



Creams and Butter

Cream - Separated fat from raw milk

- what's left behind? Skimmed milk!

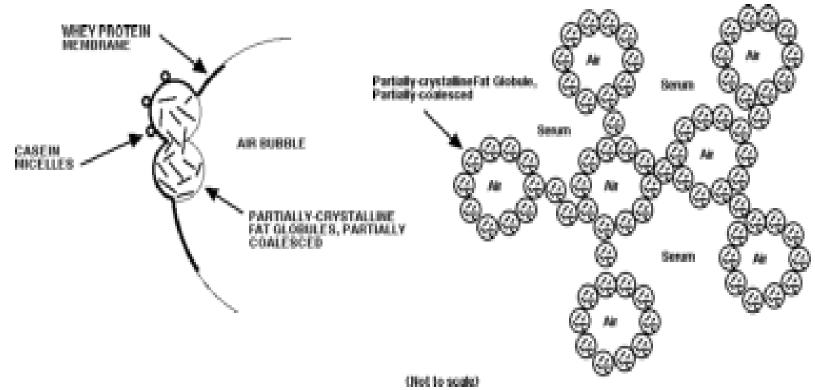
- Light and heavy whipping cream is about the fat content
- Creams used in cooking serve to keeping denatured proteins (like caseins) from binding to each other and clotting (aka curdling)
  - This happens because the globule membranes remain intact during cooking and bind to the proteins as they denature while cooking
  - Try cooking high fat vs low fat yogurt or cream with or without an emulsifier

Whip it good...

Whipping cream – keep it cool and don't over do your whipping!

- These foams are a thick stable cage of fat globules
- Formed when mechanically shearing the heavy cream – why heavy and not light?
- Whipping breaks the fat into smaller pieces which the membranes can't fully cover
- This results in partial connected (crystalline) globes of fat with proteins wrapped around air bubbles

Up close look at whipped cream



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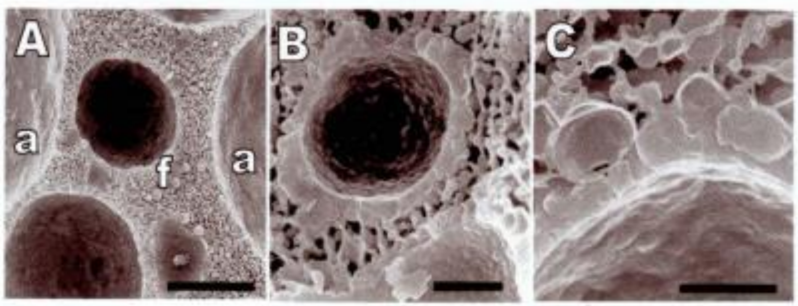
The Science of Cooking

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

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The Science of Cooking

Whip it good…

Whipping cream – keep it cool and don't over do your whipping!

- Warm fat – oozes together and pools into one big blob – no air, no foam
- Over whipped fat (while cold) forms too many contacting fat globs and the cream turns into … butter

Butter

What is butter?

- Churned Cream resulting in a hardened fat with ***most*** of the water expelled
- 21 lbs of fresh cow's milk are needed to make one pound of butter
- An avg American consumes >4 lbs each year!
- 80% of mass must be milkfat (not other fat or solids)

Fats in Butter

Fat Composition in Butter

Fatty acid	Structure	% total fatty acid in butter
oleic acid	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$	31.9
myristic acid	$CH_3(CH_2)_{12}COOH$	19.8
palmitic acid	$CH_3(CH_2)_{14}COOH$	15.2
stearic acid	$CH_3(CH_2)_{16}COOH$	14.9
lauric acid	$CH_3(CH_2)_{10}COOH$	5.8
butyric acid	$CH_3CH_2CH_2COOH$	2.9
caproic acid	$CH_3(CH_2)_4COOH$	1.9
capric acid	$CH_3(CH_2)_8COOH$	1.6
caprylic acid	$CH_3(CH_2)_6COOH$	0.8
linoleic acid	$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$	0.2
linolenic acid	$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7COOH$	0.1

The Science of Cooking

Making Butter

Prepare the cream – heavy cream of whole milk

- Concentrate by heating cream or using whole un-homogenized milk
  - Let stand 6-12 hrs (cultured or not…)
  - Skim off cream.
- Alternatively start with heavy cream
  - The work is already done!

The Science of Cooking

Making Butter

Churn!

- The high fat content is still stable in the fat globules
- Butter crystals or grains form to help break fat
- Churning simply provides mechanical breakage of the membranes of the fat globules
- Eventually the fat pools at room temps
- Buttermilk – old fashioned kind
- Add protein for and a bit of acid for modern buttermilk
- Solid is ready to use or finish
- Contains water fat and some lactose
- Yellow color comes from dye or carotene in diet of cow

Kinds of Butter

Salted Butter

- Add salt to final butter or soak in 2% salt water (brine)
- Salt reduces spoilage as the bacteria can not grow in high salt conditions

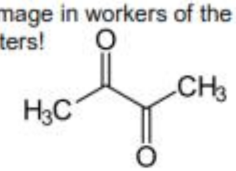
Sweet Cream Butter

- No salt, butter formed after milk liquid is removed

Kinds of Butter

Cultured Butter

- Cream is cultured with bacteria and acidified
- Give the butter a different, sour taste
- One by-product is diacetyl – once used for artificial "butter taste"
  - I can't believe, microwave popcorn, even provided a butterscotch or slippery taste to alcohol…
  - Inhibits enzymes (arginine binding in superoxide dismutase) which are important for protecting cells from oxidative damage
  - Caused damage in workers of the compound and heavy microwave popcorn eaters!



What is ice cream?

- Ice cream is a frozen dairy product that comes in a wide range of flavours and colours. It’s used as a dessert, and to accompany things like pie and cake. This frozen product is enjoyed all over the world, but more so in America.

ICE CREAM CHEMISTRY

Ice Cream - Defined

- **Product that meets the Standard of Identity according to the Code of Federal Regulations**
  - Minimum of 10% fat
  - Maximum of 100% overrun

Overrun(%) = Volume ice cream/Volume mix

  - So 100% overrun means the volume of mix is doubled by addition of air
    - Cheaper ice creams tend to have close to 100% while super-premium brands are closer to 40%

Ice Cream at a Structural Level - A Multi-Phase Product

- **Ice crystals**
  - Provide cooling effect and hardness
- **Air cells**
  - Reduce density
- **Partially-coalesced fat globule network**
  - Affects melt-down rate and hardness of ice cream

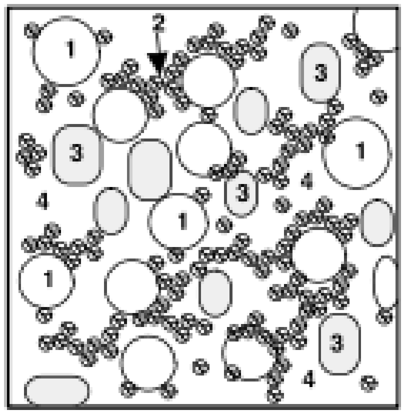
- **Proteins and hydrocolloids**
  - Network in serum phase
- **Serum phase**
  - Dissolved sugars, minerals, proteins, etc.
  - Some liquid even at very low temperature

1 Air cells

2 Fat globules

3 Ice crystals

4 Continuous phase



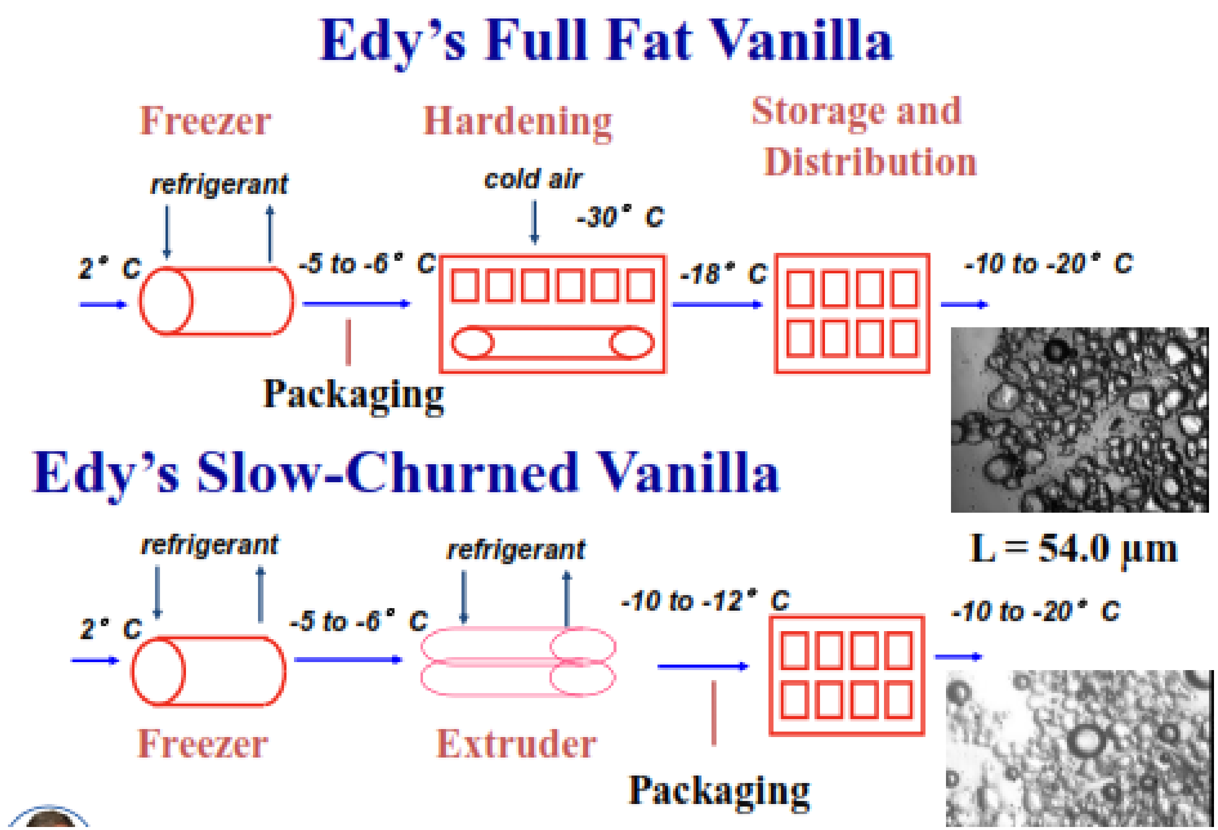
Goff & Hartel, 2013

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

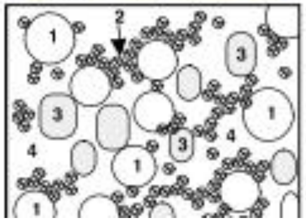
What's the difference between Edy's/Dreyer's regular and Slow-Churned?

- Slow-churned has half the fat but tastes just as creamy
- Slow-churned costs more
- They have different formulations and different manufacturing processes
- All of the above


Edy's Full Fat Vanilla
Freezer
Hardening
Storage and Distribution
refrigerant
cold air
-30° C
2° C
-5 to -6° C
-18° C
-10 to -20° C
Packaging
Edy's Slow-Churned Vanilla
L = 54.0 µm
refrigerant
refrigerant
-10 to -12° C
2° C
-5 to -6° C
-10 to -20° C
Freezer
Extruder
Packaging

Factors that Influence Meltdown

- **Heat transfer**
  - Overrun, number and size of air bubbles
  - Outside temperature, convective factors
- **Ice content**
  - Thermal diffusivity – insulation effect
- **Viscosity of serum phase**
  - Diluted by melted ice
- **Gravity**
  - Ability of serum phase to flow
- **Fat globule clusters**
  - Number and size

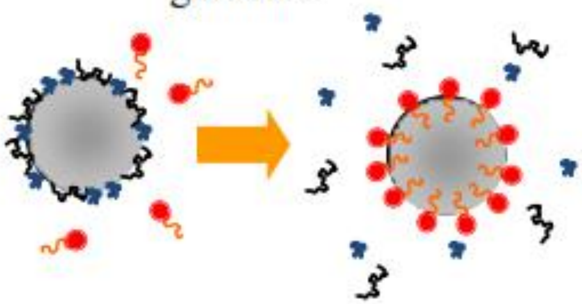


Ice Cream Melting

Not all ice creams are created equal – or melt in the same way

Fat Globules in Ice Cream Mix

- **Emulsion droplets in mix**
  - Coated with protein/emulsifier surface after homogenization
  - Emulsifier replaces protein during ageing
  - Partially crystalline milk fat network within globules



Courtesy: J McClements

Ice cream mix fat globules
(Doug Goff, University of Guelph)

Why was ice cream developed and who developed it?

- Ice cream was developed to be a refreshing, cooling treat, that was favoured among royalty for sometime before entering the home.
- Ice cream is thought to have been developed from flavoured ices and water ices. The Romans and Chinese are the earliest reports of people enjoying these ices. In the 13th century, an Italian explorer named Marco Polo was said to have returned from China with recipes for water ices, which are like snow cones. This may have been when ice cream development started.
- Ice cream was made at homes until American Jacob Fussell established the first ice cream plant in Baltimore, 1851.

Ice cream history

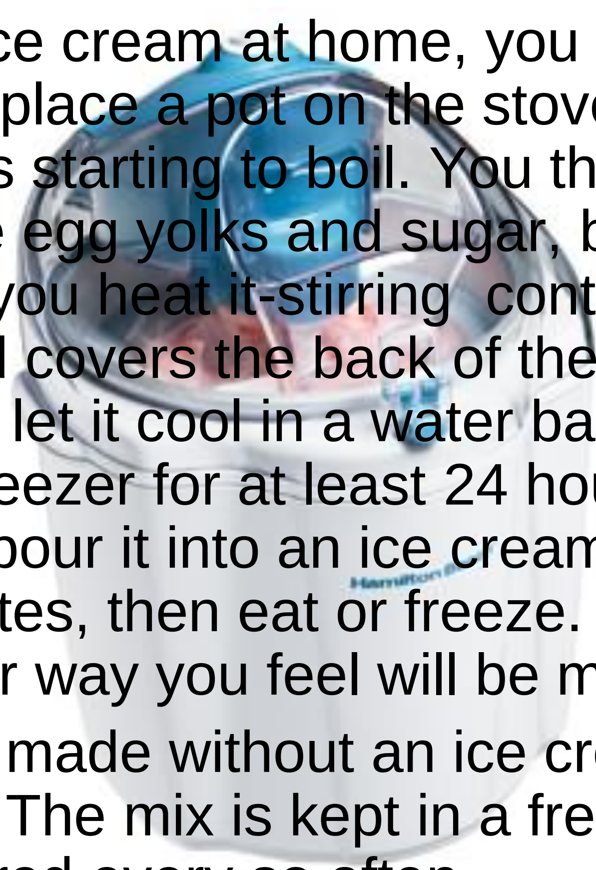
- Ice cream origins can be traced back to the 4th century B.C, to the Romans. The Romans had recipes for shaven ice concoctions, and in the 13th century, Marco Polo came back from China with recipes for water ices. It's thought this may have been when ice creams started developing.
- Ice cream was brought to America in the 1700's and was quite a luxury. It was all made at home until Jacob Fussell opened the first ice cream plant in 1851.

How is ice cream made in a factory?

- Ice cream is a hit whether homemade or factory made. In factories, the ice cream mix-which consists of milk products, sugar and flavourings is put into a huge vat. It's then pasteurized which means it's sterilized so it can keep for longer, before being homogenised, which breaks down the fat particles and helps make the ice cream smooth. The mix then goes into a cooler, then a storage tank where it's frozen for 3-4 hours. Flavourings and colours are then added, and then the mix is frozen again.

How is ice cream made at home?

- If you’re making ice cream at home, you combine egg yolks and sugar. Then, place a pot on the stove containing milk and leave this until it is starting to boil. You then remove it from the stove and add the egg yolks and sugar, before returning it to the stove, where you heat it-stirring continuously-until the mixture sticks and covers the back of the spoon. Place this mixture in a bowl, let it cool in a water bath, add cream and the place in the freezer for at least 24 hours. Once removed from the freezer, pour it into an ice cream churner/maker for about 20-30 minutes, then eat or freeze. Flavours can be added in whatever way you feel will be most successful.
- Ice cream can be made without an ice cream maker, but it does take longer. The mix is kept in a freezer, but has to be taken out and stirred every so often.



What is ice creams nutritional value?

- In basic vanilla ice cream, its nutritional value is: (per serving of ½ a cup, or 72 grams) It has a total of 145 calories.
- Fat total: 7.9g/12%
- Saturated fat: 4.9g/ 24%
- Polyunsaturated fat: 0.3g
- Monounsaturated fat: 2.1g
- Cholesterol: 32mg/11%
- Sodium: 58mg/2%
- Carbohydrates total: 17.0g/6%
- Dietary fibre: 0.5/2%
- Sugars: 15.3g
- Protein: 2.5g

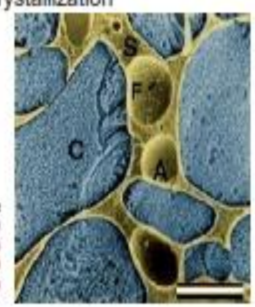
I scream

Ice Cream is a result of chemical technology

- Ice Cream is a mixture of ice (water and partially solid milk fat), liquid (cream and sugared water) and air pockets (1/2 of the volume).
- Differences are in the fat and protein which create a creaminess, the amount of crystals of fat and water and the protein emulsifiers which stabilize the membranes of the fat and decrease crystallization

Left - Microscope images of ice cream
Fat droplets (orange)
Proteins (black)
-notice the level of fat crystals shown in the lines in the lower image

Right- Electron M-scope images
Air Bubbles (A)
Ice Crystals (C)
Fat Globulets (F)
Un-frozen water, fat and sugar (S)



I scream

Ice Cream is a result of chemical technology

- More crystals (fat or water) lead to less smooth and more "crunchy" ice
- Whipping, emulsifiers and sugar all influence the crystals as they freeze
- To "ice the cream" all one has to do is create an environment colder than the freezing point of the water in milk
  - So the challenge is to create a lower temp than sugar water (less than 0ºC)
  - BUT the temp of ice warmer (0ºC) than the temp needed to freeze the cream
  - 13th Century Arabs knew how to create a colder than ice temp using salt

Freezing point depression

- A solution of water and solute (some other compound) will have a lower freezing point than pure water
- This is a result of ions interfering with the ability of water to form a latice (cage) of bonded molecules – ICE ICE BABY!

The Science of Cooking

Taste of Ice Cream

Federal standards (21 CFR § 135.110) require ice cream to contain a minimum of 10% milk fat and 20% milk solids. Some premium ice creams contain 16% milk fat. -Ice cream contains not less than 1.6 pounds of total solids to the gallon, and weighs not less than 4.5 pounds to the gallon.

Overrun is a measure of the volume of air whipped into the ice cream mix. Overrun does not have to be declared on the label.

- Quality ice creams have lower overruns than those of reduced quality.
- Generally the more overrun, the lower the cost of the ice cream

Ice crystals form when some of ice cream's water separates from fat and eventually develops into larger ice crystals. The result is a grainy-textured ice cream. As long as water remains trapped in an emulsion with fat in ice cream, the original ice crystals do not get larger.

- To protect ice cream from developing large ice crystals, do not melt and refreeze ice cream, and do not store ice cream well below 0ºF for a prolonged period.

Lactic Acid Bacteria

- Major group of Fermentative organisms.

- This group is comprised of 11 genera of gram-positive bacteria:
  - *Carnobacterium, Oenococcus, Enterococcus, Pediococcus, Lactococcus, Streptococcus, Lactobacillus, Vagococcus, Lactosphaera, Weissells and Lecconostoc*

- Related to this group are genera such as *Aerococcus*, *Microbacterium*, and *Propionbacterium*.

Lactic Acid Bacteria

- While this is a loosely defined group with no precise boundaries all members share the property of producing lactic acid from hexoses.

- As fermenting organisms, they lack functional heme-linked electron transport systems or cytochromes, they do not have a functional Krebs cycle.

- Energy is obtained by substrate-level phosphorylation while oxidising carbohydrates.

Lactic Acid Bacteria

- The lactic acid bacteria can be divided into two groups based on the end products of glucose metabolism.
- Those that produce lactic acid as the major or sole product of glucose fermentation are designated **homofermentative.**
- Those that produce equal amounts of lactic acid, ethanol and CO_2 are termed **heterofermentative.**
- The homolactics are able to extract about twice as much energy from a given quantity of glucose as the heterolactics.

L Acid Bacter

- All members of *Pediococcus, Lactococcus, Streptococcus, Vagococcus,* along with some lactobacilli are **homofermenters.**

- *Carnobacterium, Oenococcus, Enterococcus, Lactosphaera, Weissells and Lecconostoc* and some Lactobacilli are **heterofermenters**

- The heterolactics are more important than the homolactics in producing flavour and aroma components such as acetylaldehyde and diacetyl.

Lactic Acid Bacteria Growth

- The lactic acid bacteria are mesophiles:
  - they generally grow over a temperature range of about 10 to 40^{o}C,
  - an optimum between 25 and 35^{o}C.
  - Some can grow below 5 and as high as 45 ^{o}C.

- Most can grow in the pH range from 4 to 8. Though some as low as 3.2 and as high as 9.6.

Starter Cultures

- Traditionally the fermenting organisms came from the natural microflora or a portion of the previous fermentation.

- In many cases the natural microflora is either inefficient, uncontrollable, and unpredictable, or is destroyed during preparation of the sample prior to fermentation (eg pasteurisation).

- A starter culture can provide particular characteristics in a more controlled and predictable fermentation.

Starter Cultures

- Lactic starters always include bacteria that convert sugars to lactic acid, usually:
  - *Lactococcus lactis* subsp. *lactis*,
  - *Lactococcus lactis* subsp. *cremoris* or
  - *Lactococcccus lactis* subsp. lactis biovar diacetylactis.
- Where flavour and aroma compounds such as diacetyl are desired the lactic acid starter will include heterofermentative organisms such as:
  - *Leuconostoc citrovorum* or
  - *Leuconostoc dextranicum*.

Starter Cultures

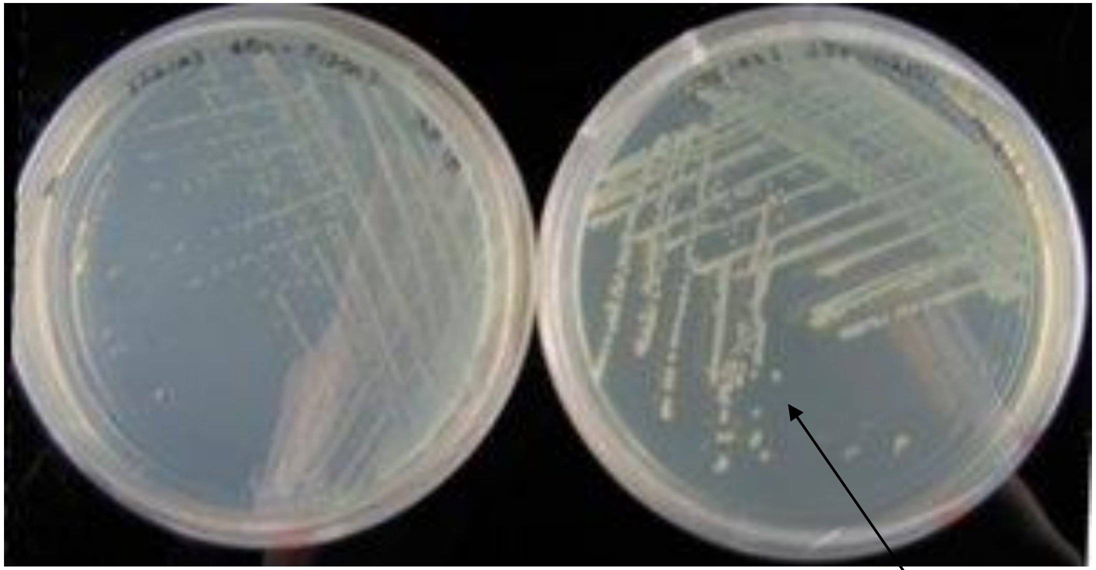
- The primary function of lactic starters is the production of lactic acid from sugars

- Other functions of starter cultures may include the following:
  - flavour, aroma, and alcohol production
  - proteolytic and lipolytic activities
  - inhibition of undesirable organisms

Added starter CULTURE will

- Convert most of the sugars to lactic acid
- Increase the lactic acid concentration to 0.8 to 1.2 % (Titratable acidity)
- Drop the pH to between 4.3 to 4.5

- Food scientists frequently use the ability of bacterial cells to grow and form colonies on solid media to:
  - isolate bacteria from foods,
  - to determine what types and
  - how many bacteria are present.
- Streak plates

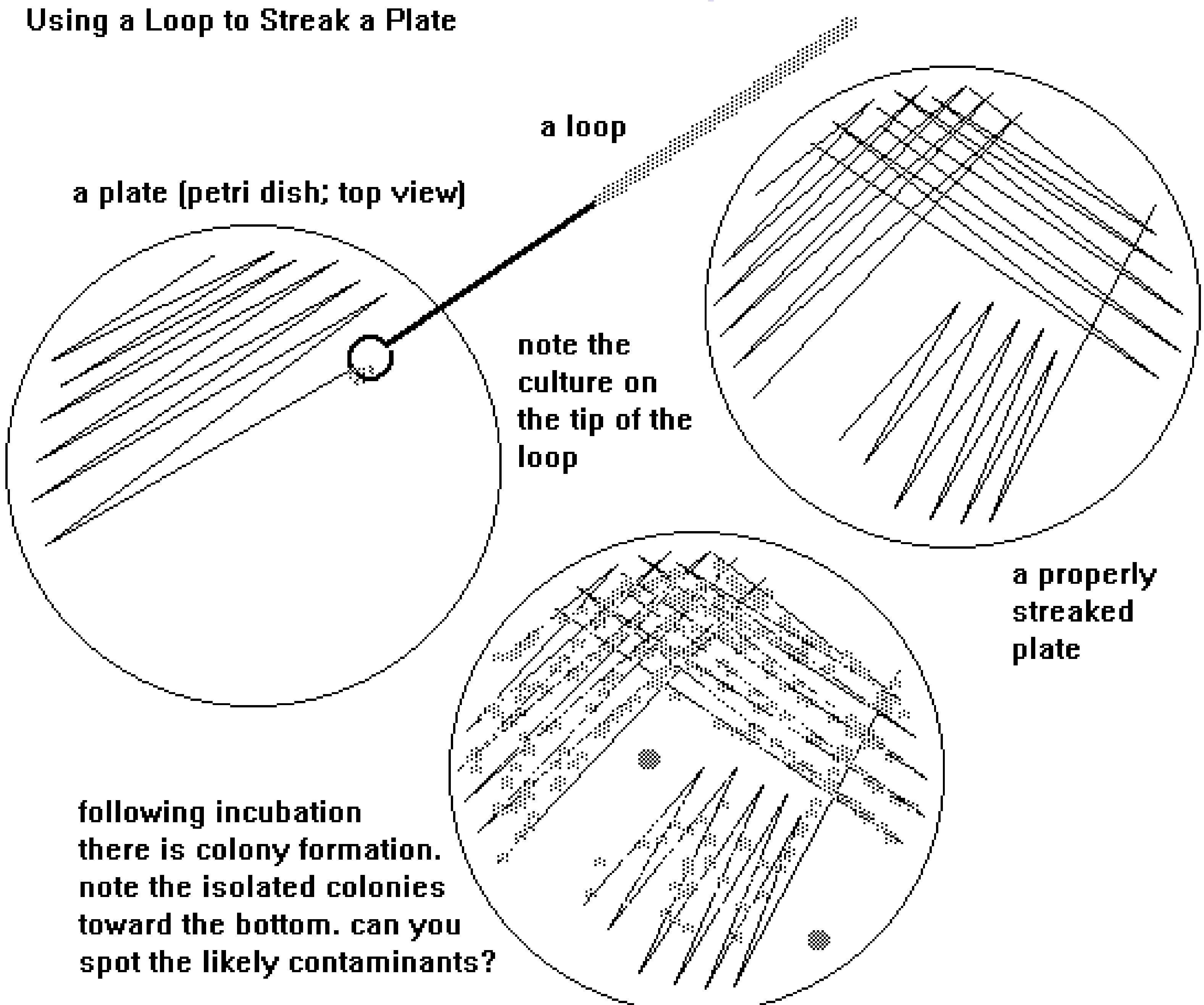


A single bacterial colony

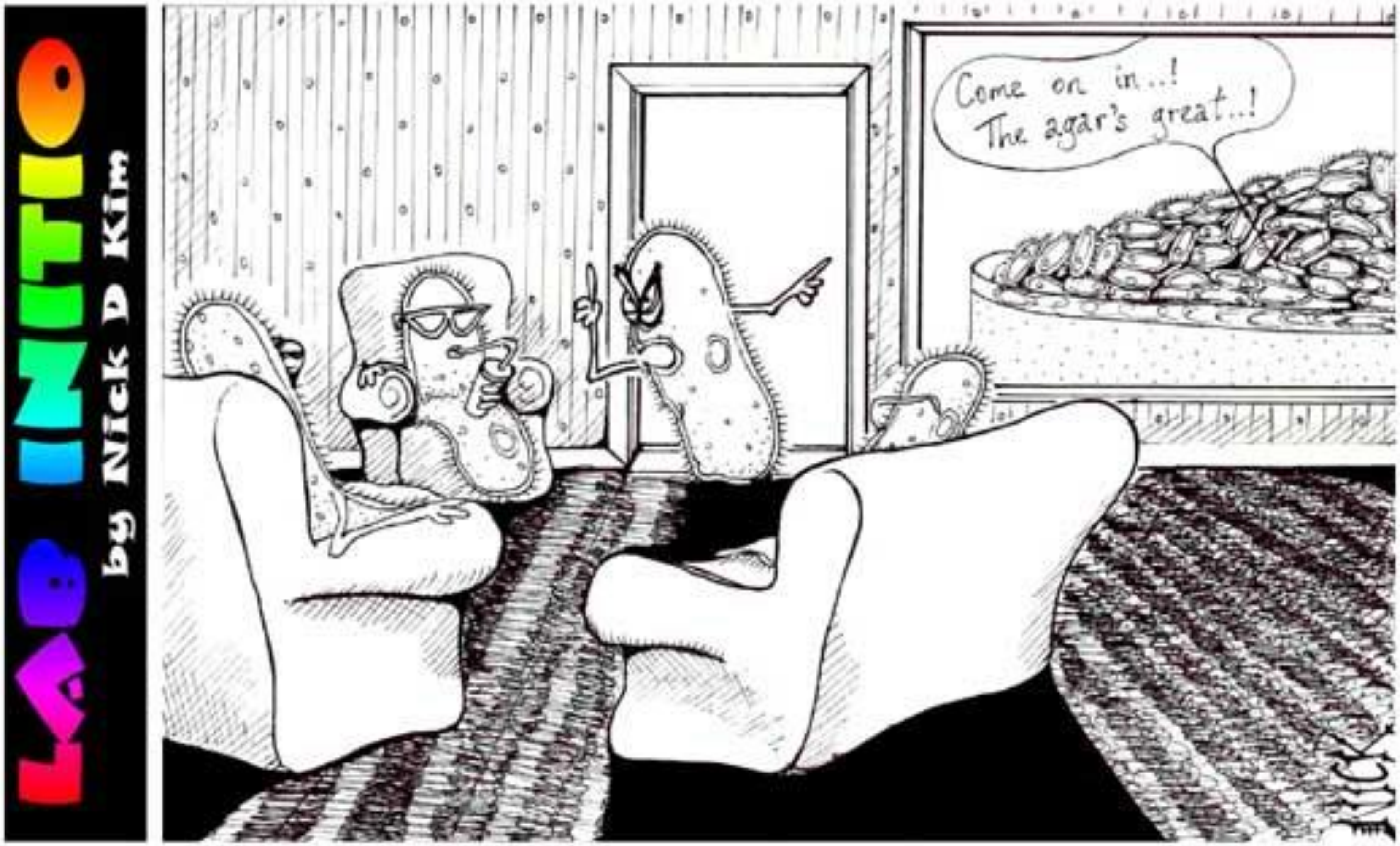
The streak plate technique

- Bacteria are “streaked”over the surface of an agar plate so as to obtain single colonies.
- Obtaining single colonies is important as it enables;
  - the size,
  - shape and
  - colour of the individual colonies to be examined.
  - It can also highlight the presence of contaminating micro-organisms

The Streak Plate Technique



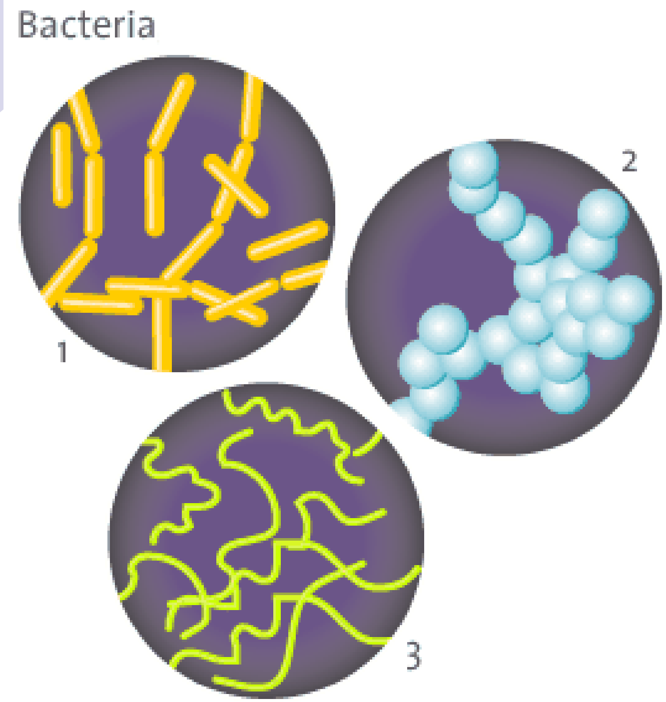
When conditions are right bacteria can double in number every 20 minutes



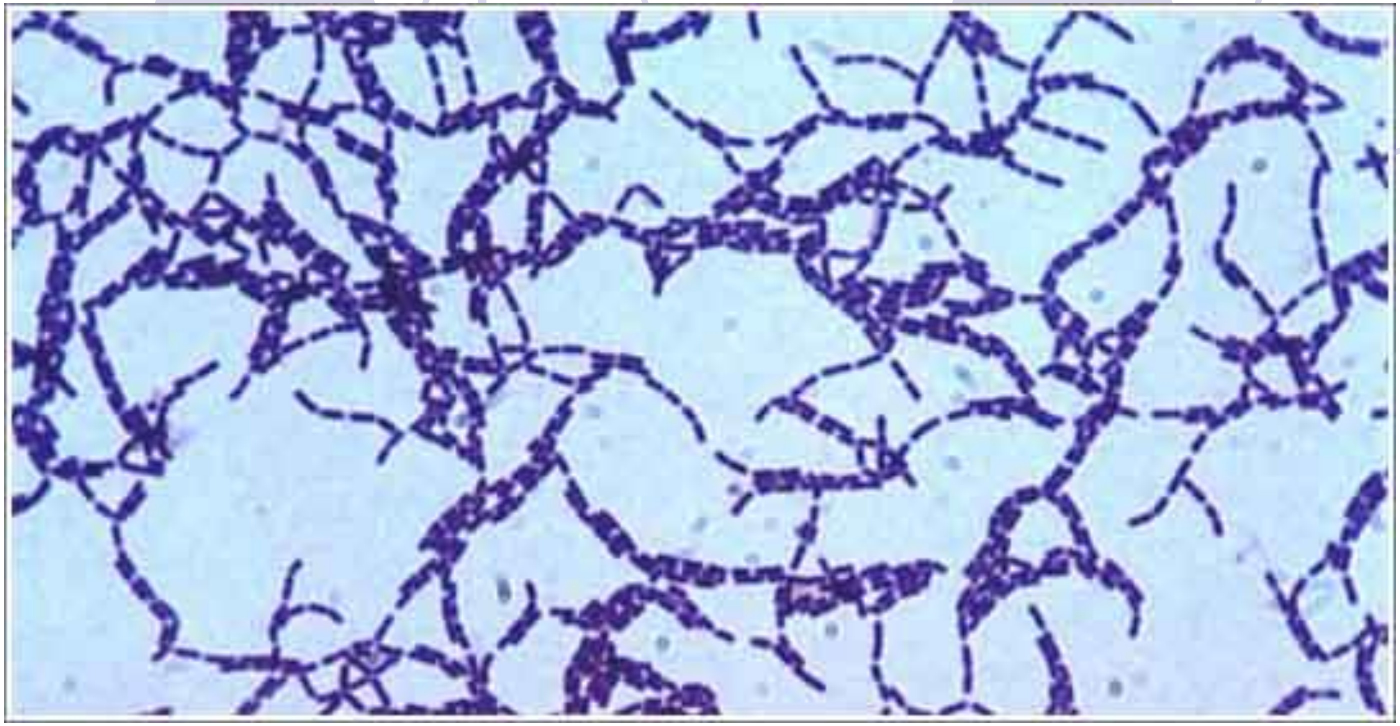
"I wish you'd learn to put the lid on your Petri dish, Harry..!! We came here with four kids, and now it looks like we've got twenty million..!!"

roscop xamination

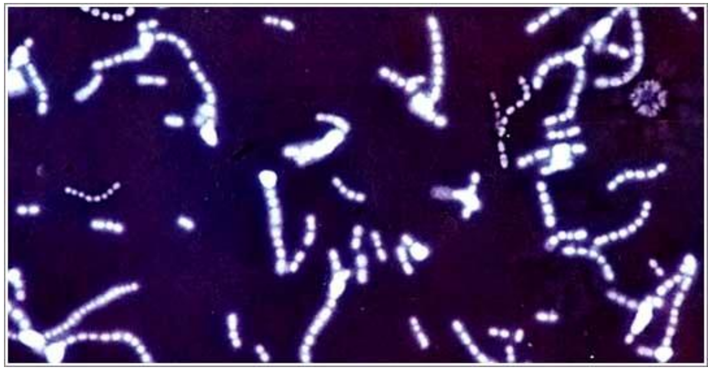
- Can provide information on the size and shape of the bacteria
  - Rods (1)
  - Cocci (2)
  - Spiral (3)
- It cannot provide enough information to enable bacteria to be identified



Microscopic views of stained bacteria



Lactobacillus spp.



Lactococcus spp.

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