# FEDERAL UNIVERSITY OF TECHNOLOGY

## DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

# FST 503

## (MILK AND DAIRY TECHNOLOGY)

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## 1.0 COMPOSITION, PHYSICAL AND CHEMICAL PROPERTIES OF MILK

Milk is defined as the whole fresh lacteal secretion obtained by the complete milking of one or more healthy cows excluding that obtained within 15 days before and 5 days after calving or such longer period as may be necessary to render the milk practically colostrum- free. The name "Milk" unless it is qualified means cow's milk.

**Table 1. Average Composition (%) of Milk of Various Mammals**

| Species | Moisture | Fat | Protein | Lactose | Ash | Caesin | Non fat Solids | Total Solids |
|---|---|---|---|---|---|---|---|---|
| Woman | 87,43 | 3.75 | 1,63 | 6.98 | 0.21 | - | 8.82 | 12.57 |
| Cow | 87.2 | 3.7 | 3.5 | 4.9 | 0.7 | 2.78 | 9.1 | 12.8 |
| Coat | 87.0 | 4.25 | 3.52 | 4.27 | 0.86 | 2.80 | 8.75 | 13.0 |
| I~gyptian Buffalo | 82.09 | 7.96 | 4,16 | 4.86 | 0.78 | - | 9.95 | 17.91 |
| Water Buffalo | - | 7,45 | 3.78 | 4.88 | 0.78 | 3.00 | - | 16.77 |
| Sheep | - | 5.3 | 6.3 | 4.60 | 0.8 | 4.60 | - | 17.0 |
| Camel | 87.61 | 5.38 | 2.98 | 3.26 | 0.7 | - | 7.01 | 12.39 |
| J\ss | 89.03 | 2.53 | 2.01 | 6.07 | 0,41 | - | 8,44 | 10.97 |

13abymilk producers adjust the protein and lactose composition of cow milk to resemble that of \\oman as well as substituting the milk fat (saturated) with unsaturated vegetable fat (for easier digestion in the baby). The relation of fat to solids non fat (SNF) % in mixed milk is fairly regular. An increase in fat content of 1% is accompanied by increase of about 0.4% in SNF. The milk ordinance approved by the US Public health service in 1965 proposes 3.25% fat and 8.25% SNF as a reasonable minimum standard.

## 1.1 Milk Fat

!;ats are mixtures of the glycerides of certain fatty acids. Milk fat contains 19 or more fatty acids i.c. more fatty acids than any other fat of animal or vegetable origin. The fat is the solvent for the rat soluble substances in milk. The fat soluble vitamin "A" and its provitamin - carotene; vitamin "J)" and its provitamin cholesterol; vitamin "E" and vitamin "K" are carried in milk fat. The yellow colour of milk fat derives mainly from carotene. The pure triglycerides are colourless.

## 1.2 Proteins

The 3 principal classes of proteins in milk are casein, lactalbumin and lactglobulin. The caseins account for approximately 80% of the total protein content..

Thc caseins are precipitated by acids at their isoelectric point of pH 4.6. The isoelectric point of a protein is the pH at which the protein does not migrate in an electric field. Casein occurs in milk as a calcium salt and it is probably dispersed as a colloidal complex with CaS04. It may be coagulated by acid, rennet or alcohol.. This property is used in cheese making where milk is usually coagulated. Casein is found only in milk. The whey proteins are left in solution when caseins have been precipitated. Casein is responsible for the white color of milk..

## 1.3 Lactose

This is a sugar found only in milk, it is a disaccharide composed of glucose and galactose. Lactic acid bacteria produce the lactose splitting enzyme called lactose. This enzyme is also produced in the mammalian digestive tract.

## 1.4 Mineral Constituents

These are salts found in milk.. In the analysis of milk this fraction occurs as the ash, the minerals of significance in milk $Ca^{+}$, Ph, Mg, Na, K and $Cl^{-}$. Milk is a good source of provides a good quantity oflnetabolizable $Ca^{2+}$ for human nutrition.

## 1.5 Chemical Reactions of Milk

Thc pH of normal milk is about 6.6 (6.5 - 6.7) fresh milk when titrated with alkali (phenolphthalein being used as indicator) may show variations of 0.1 - 0.62% acidity calculated as lactic acid. This is known as "apparent" acidity and is due to proteins and acid salt substances that can bind alkali. The higher the SNF content of the milk the higher its "apparent" acidity. The "apparent" acidity of fresh milk of average composition is about 0.14% made up as follows:

$CO_2$ - 0.01 - 0.02%

Citrates - 0.01%

Casein - 0.05 – 0.08%

Albumin - <0.01

Phosphates - the remaining of the acidity

### 1.6 Physical Properties

Milk normaly varies in specific gravity (s.g) between 1.027 - 1.035 with average of 1.032 at room temperature. Milk freezes at -0.54°C and boils at 100.17 °c

## 2.0 SANITARY PRODUCTION OF FLUID MARKET MILK

Fluid market milk should possess the following attributes

1. Low bacteria count
2. Free from visible dirt
3. Free from pathogenic organisms
4. Produced on a clean, hygienic and attractive premises

Fluid market milk has higher sanitary standards than manufacturing milk.

The 4 essential factors in production of milk of low bacterial content are:

1. Healthy clean cow
2. Small-topped milk bucket
3. Sterile utensils
4. Prompt and efficient cooling

Other requirements include:

- Cow wash and wiping of udders with a cloth moistened in a sanitizing solution.
- Prompt and efficient cooling of milk (max 10°C) with mechanical refrigeration.

The production of clean low cell count milk starts with a healthy clean cow. Any cow with physical disability such as inflamed or defective udders or teats, running sores or enlarged glands should be isolated and her milk not mixed with milk from other cows.

Clean milk cannot be produced from healthy cows, if the flanks, belly, udder, teats and tail of the cow are soiled with manure, earth, bedding or loose hair, considerable extraneous materials will Callinto the buckets.

**Table 2. The Effect of the Small- Topped Milk Bucket on the Bacterial Content of Milk**

| Conditions | Bacteria per ml (Average) | |
|---|---|---|
| | Open bucket | Small- Topped Milk Bucket |
| Cows dirty, utensils sterilized | 22,600 | 17,027 |
| Cows dirty, udders and teats washed utensils sterilized | 6,166 | 2,886 |
| Cows clean udders and teats washed, utensils sterilized | 4,949 | 2,677 |

## 2.1 Prompt and Efficient Cooling

**Table 3: Effect of Storage Temperature of Milk on Bacterial Growth**

| Cirade of Milk | Temperature Held (0C) | Fresh | 48h | 96h |
|---|---|---|---|---|
| | | (Bacterial Count [x loj]) | | |
| Low Count and Original Milk | 4 | 4.3 | 4.6 | 19.7 |
| | 10 | 4.3 | 127.7 | 39,490.6 |
| | 15 | 4.3 | 33,011 | 962,785.7 |
| Ifigh Count and Original Milk | 4 | 136.5 | 538.8 | 852.8 |
| | 10 | 136.5 | 13662 | 41,270.3 |
| | 60 | 136.5 | 639,884.6 | 5,346,666.7 |

## 2.2 Sanitized Utensils

The use of properly sanitized utensils is the most important single factor in producing low bacterial count milk.

**Table 4: Effect of Sanitized Utensils**

| Conditions | Bacteria per ml (average) |
|---|---|
| Sterilized Utensils | 31,040 |
| Not Sterilized, washed directly after milking | 666,520 |
| Not Sterilized, held 8h before washing | 1,667,000 |

The utensil should be rinsed in cold or lukewarm water immediately after milking and then brushed thoroughly on all surfaces with a washing solution, heated to a temperature between 38-50°C. Finally they should be rinsed in clean water and then sanitized. The "sanitization" of dairy equipment usually refers to the destruction either by heat or by chemicals of the bacteria in vegetative form remaining in the equipment after washing.

## 2.3 The Milking Procedure

Accepted milk practice demands

1. That milking is done in a milking barn, stable or palour
2. Brushing is completed prior to milking
3. Flanks, belly, tails and udders are clipped as often as possible to facilitate cleaning of areas and are free from dirt.
4. Udders and teats of all milking cows are cleaned and treated with a sanitizing solution and are relatively dry prior to milking.
5. Wet-hand milking is probihited
6. The teats should be dipped into a sanitizing solution after the milking machine or hands have been removed.

## 3.0 Pasteurization of Milk

Pasturization of fluid milk consists of heating the milk to a temperature sufficiently high and for a time sufficiently long to kill most of the bacteria. This is followed by cooling to a low temperature; Pasteurization destroys 90 - 99.9% of the total microorganisms in milk. Two general in use for pasteurizing fluid milk are:

1. The low temperature holding method (LTH)

   This consists of holding milk at a minimum temperature of $63^{0}$C continuously for at least 30 min

2. The high temperature short time method (HTST)

   This involves the heating and holding of milk at nOc for 15sec.

   Milk products which have a higher milk fat content than natural milk must be heated to at least 66°C for 30min or 75°C for 15sec. Higher pasteurization temperatures are currently being used for fluid milk.. The advantages of higher temp are more efficient bacterial destruction and a longer shelf life provided that post pasteurization contamination has been prevented.

## 4.0 PRODUCTION PROCESS FOR DAIRY PRODUCTS

4.1 Frozen Desert: The popular ones are ice cream, ice milk and sherbets.

4.1.1 Plain Ice Cream: This is frozen as a single flavour and containing not less than 10% milk fat, flavours added include: vanilla, coffee, chocolate and caramel..

4.1.2 Ice milk: This is plain ice cream mix adjusted to a low final fat content (3 – 6%)

4.1.3 Sherbet: This is a blend of cream, milk or ice cream mix to water-ice

Ice cream and related frozen desert contain a number of ingredients that are essential to the properties of the final product.. These are:

1. Milk fat - this is provided by the cream. Cream is a concentration of milk fat obtained by separation from the rest of the milk SNF.
2. SNF - The use of concentrated milk products such as condensed skimmed milk or skimmed milk powder fulfils this requirement..

3. Stabilizers - These are generally polysaccharides in nature and are used to improve the *melt down characteristics* of the frozen products. Important ice cream stabilizers include gelatin, carrageenan, carboxymethyl-cellulose, sodium alginate, pectin, gum"gum.

4. Sweetening agents: They include cane sugar, beat sugar and corn syrup solids (CSS). CSS is made by the acid or enzyme hydrolysis of corn starch and includes a mixture of simple sugars such as glucose, maltose or fructose and dextrins.

5. Emulsifiers: These improve the whipping properties by way of affecting the structure of the air micelle in the ice cream. They also contribute to the desired body in the final products examples include: lecithin, mono glycerides and diglycerides. A typical ice cream formulation (Table 5) contains the following:

**Table 5: A Typical Ice Cream Formulation**

| **Ingredients** | **% Solids** |
|---|---|
| Milk Solids- Not Fat | 10.0 |
| Butterfat | 10.0 |
| Sucrose | 12.0 |
| 36 D.E Corn Syrup | 5.0 |
| Stabilizer / Emulsifier | 0.3 |
| **Total Solids** | 37.3 |

### 4.2 Ice Cream Freezing

Thc ingredients listed are blended, pasteurized 80°C for 25 sec and the mix is then transferred to a storage tank for ageing prior to flavouring or freezing. Aged mix pumped from the storage tank to the flavouring tanks where colouring and flavouring ingredients are incorporated. After flavouring the mix is pumped to ice cream freezers and the frozen ice cream is discharged to fillers.

Freezing must be very rapid to provide small ice cream crystals and a smooth body. The freezer pcrforms tvyo functions:

a) Freezing of a portion of the water in the mix

b) Incorporation of air into the frozen product to give it the desired body

Icc cream is drawn from a continuous freezer at about -5.5 °c with about 50% of the water fi·ozcn. After freezing and packaging the ice cream is transferred to the hardening room to complete the freezing operation. A hardening room is maintained at -23 to -34°C. The increase in the volume of ice cream due to air is termed "over run". "Over run" ranges from 60-100%. "Prestige" or high value ice creams generally contain 12 - 14% fat and about 80% over run. Incorporation of air prevents the ice cream from being heavy bodied, icy and unpalatable. A low "over run" gives a heavy body and a high "over run" gives a weak body.

### 4.3 Butter

This is defined as a spread which contains 80% milk fat and not more than 16% moisture. The process for the manufacture of butter is summarized below.

I. Cream Separation- to concentrate milk fat to 25 - 40% fat to facilitate the churning operation. Milk is warmed to 32 - 43°C to improve separation efficiency.

2. Pasterization - to eliminate pathogens and enzymes that would cause off-flavours. Cream is heated to 71 - 76°C for 30min

3. Cooling – to solidify part of the milk

4. Churning - to invert the emulsion from oil-in-water to water-in-oil; to form butter granules. Cream is tempered to 10 - 13°C and made to rotate in a cylindrical vessel.. The heart of the butter making process is the churning of the cream which subjects the cream to agitation until a heavy foam is formed which is collapses upon further agitation, to yield butter granules and butter milk. When the butter granules have acquired about the size of peas the churn is stopped and the butter milk is drained from the churn.

5. Washing - After draining, the butter granules are flushed with a small amount of chlorinated water to remove butter milk. Another wash is done with a larger amount of cooled water to firm up the butter granules and water is drained from the churn.

6. Working - This involves revolving the churn after the butter is washed at a speed that is somewhat slower than that used during churning. After a short initial working, water exudate is drained.

7. Salting - Salt is added to give 1 -1.5% salt, working is then continued to distribute the salt and moisture uniformly throughout the butter.. Salt gives flavor and reduces microbial activity.

## 4.4 Concentrated and Dried Milk

Milk may be concentrated as a necessary initial step in a drying operation or as the concentration process leading to the manufacture of evaporated milk. It is also carried out in the preparation of infant formulae. Similar equipment is used in all cases the singular most important equipment in thc concentrated milk industry is the evaporator. Single, double and triple effect refers to the number of vapour stages that are set up. The conventional single effect removes about lkg of water for each kg of stream utilized. Double and triple effect evaporators are used in conjunction with drying operations for producing various types of milk powders. Evaporation of water under vacuum is more efficient and gives better product quality than removing water by drying.

In milk drying operations the evaporator system incorporates the cream separator and pasteurizer. Cream produced by the separator is HTST pasteurized, cooled and transferred to cream storage tanks for use in manufacturing butter or for sale to ice cream manufacturers. The skim milk (or whole milk if the separator is by passed) is pasteurized and pumped to the $1^{st}$, $2^{nd}$ and $3^{rd}$ cvaporator. The temperature of milk entering the $1^{st}$, $2^{nd}$ and $3^{rd}$ Effect Evaporators is approximately 74, 68 and 57°Crespectively. The concentration of the product after the $1^{st}$ and $2^{nd}$ cffects is approximately 20 and and 33% Total Solids. The concentrated product is then transferred to spray dryer for final drying to a product containing about 3 - 4% moisture content.

Four basic types of concentrated milk products are:

a) Concentrated skim milk or whole milk for use as a source of milk solids for dairy products requiring higher solids content such as ice cream and for fortifying fluid products.

b) Sweetened Condensed Milk - for use as a solid source or as a canned product for the retail market.

c) Evaporated Milk

d) Infant formula – These may be fluid concentrated or dried powders.

Lvaporated milk manufacture involves a key step called fore warming. This is used to control viscosity and to improve the heat stability of the product following sterilization. This involves heating to 87 - 100°C for 10 - 15min and phosphate salts are added to prevent protein precipitation (grain formation during sterilization) the maximum amount of phosphate added is about 0.02%. Canning used to be done with vent-hole cans on a Dickerson filler at 4.5 - 7.0 °c to minimize foam, after filling the cans are soldered and a leak detector used to check the seals.

Standard sterilization is to heat the can and contents to 115 - 118°C for 15 -20 min and cooled afterwards. Agitation of the can is stopped after the sterilization temperature is reached to achieve optimum consistency.

Dairy - based infant formulas generally utilize Skim milk, vegetable oils, carrageenan, added carbohydrates and citrates and suitable nutritive additives. The products may be concentrated and dried or they may be canned. The sterilization procedures are similar to those for evaporated milk. Dry milk may be made by spray drying or by roller drying. Spray drying is generally profitable.

### 4.5 Cultured Milk Products

These are milk products manufactured by inoculation with lactic starter cultures.

**Yoghurt** - The initial step in manufacture of yoghurt is heating the milk to about 85°C and holding same for 30 min. The SNF content of yoghurt milk is usually in the range of 11 - 14% and the fat content varies from <1 to 5%. If the fat content of milk is appreciable milk should be homogenized first before it is cooled to 45 - 46°C and inoculated with 2% culture and incubated at about 45 °C for about 3h. The time of incubation is governed by:

1. Rate of acid development
2. The acidity desired in the final product

The lactic starter cultures of choice are *Streptococcus thermophilus, Lactobacillus bulgaricus* and *Lactbacillus acidophilus.* Strains are selected which grow well as a combined culture. Yoghurt should be cooled and maintained at low temperatures preferably at 4.5 °C or slightly below. Problems encountered in yoghurt manufacture are:

1. Lack of characteristic flavor - this is due to insufficient acid development leading to low concentration of flavor compounds.
2. Whey separation – is due to a number of factors such as:
   a) Insufficient heat treatment (for whey entrapment) of milk to increase the water binding capacity of the proteins by denaturation.
   b) The development of too high acidity levels (causing casein proteins to precipitate)
   c) Agitation of coagulated yoghurt in a vat at too high temperature.

### 4.6 Cheese

Cheese is made by rennet coagulation of milk except for one variety known as cottage cheese which is acid coagulated. The general process for cheese making involves:

1. Coagulation of milk
2. Cutting of the curd
3. Expulsion of the whey
4. Firming of the curd
5. Acid development in the curd
6. Pressing of the curd
7. Salting after desired acid development to stop further acid formation

Differentiation of the cheese variety is achieved by variation in one or more of the following.

a) The type of starter organisms used
b) The procedure for cutting and whey removal
c) Method and extent of cooking etc.

### 4.6.1 Categories of Cheese

Cheese can be divided into 2 groups

A) Unripened Cheese
   1. Low fat Cheese (Cottage Cheese)
   2. High fat (Cream Cheese)

B) Ripened Cheese
   1. Hard Cheese (Internal ripening)
      i) Those ripened by bacteria e.g. Chedder & Swiss Cheeses
      ii) Those ripened by mold
      e.g. requefort and other blue cheeses

   2. Soft Cheese (in which ripening proceeds outside)
      i) By bacteria e.g. limbugur
      ii) Those ripened by mold e.g. camembert cheese

### 4.6.2 Cheddar Cheese Production

This is a very popular cheese manufactured from heat (less than pasteurization) treated or pasteurized milk. It contains not more than 39% moisture and not less than 50% of milk solids as fat i.e. on-a-dry-basis. If cheddar cheese is from non-pasteurized milk, it must be held for at least 60 days at a temp of not less than 1.5°C. Enzymes are not used its manufacture. The manufacturing process generally conforms to that described above.

## 5.0 SIMULATED MILK PRODUCTS

### 5.1 Production of Margarine

Margarine is defined as a plastic or liquid emulsion food product containing a minimum of 80% Cat.It is made from optional fat and aqueous phase components in addition to a series of other optional compounds with separate functions.

Ingredients:

1. Fat ingredients include vegetable oils and /or treated animal fat
2. Optional aqueous phase compounds include:

a) Water, milk or milk products including butter and butter fats

b) Others are suitable edible proteins, whey, albumin, casein or caseinates, vegetable proteins, soy proteins, soy protein isolates and other materials.

c) Vitamin A is a mandatory ingredient

d) Vitamin D is an optional ingredient

e) Salt

f) Colour additives are optional.. When p-carotene is used, it is considered to be a colourant although it has Vitamin A activity.

g) Food grade emulsifiers (e.g. mono, di- glycerides) used to prevent leakage of water from the margarine emulsion and to prevent spattering during frying.

h) Preservatives used include Benzoic acid (bacteriostatic) and Sorbic acid (fungistatic) but they are optional..

i) Antioxidants or preservatives against oxidative rancidity in fats and oils e.g. Ascorbyl palmitate, BHA and BHT.

## 5.2 Processing Methods and Equipment

Margarine production involves a very intimate mixing of the oil and aqueous phases and chilling the resulting emulsion in batch and semi continuous batch operations. The mixing tank or vat is called a churn. It is jacketed for temperature control and usually has 2 high speed counter rotating propellers. The emulsion formed is not stable in melted form. It begins to breakdown within seconds after agitation is halted. The distance from the final mixing tank to the chilling machine should be as short as practical. In order to achieve suitable plasticity both liquid and solid triglycerides must be present. Newer systems in use today force the chilled hardened emulsion directly into print moulds without going through the noodle stage, it is thereafter packaged. Butter may be incorporated into margarine by melting and mixing it with the margarine emulsion so that they may be incorporated into margarine emulsion so that they may be chilled together. It is important to note that the oil phase (consisting of a blend of refined and hydrogenated oils) should have a bland taste and a wide plastic range.

## 5.3 Types of Margarine

1. Table grade margarines: Regular magarine is formulated by blending soybean oil hydrogenated to 2 or 3 different degrees of hardness. This permits the margarine to be spreadable directly out of the refrigerator and to hold together at room temperature.

   Soyabean oil is the most acceptable liquid oil of the various polyunsaturated oils. Margarine *must melt readily in the mouth with minimum waxiness or greasiness.* Low cost margarines with solid fat index (SNF) range of 3.5 at 33.3 °C will not soften excessively at room temperature. Such margarine does not have to be refrigerated. Unfortunately margarine of this type is waxy in the mouth and will melt with difficulty on food that is only warm on being served. SFI is a measure of the dilatometric or expansivity of solid fats when they melt during heating to liquids.

   Margarine with SFI value below 3.5 at 33.3 °C will melt well in the mouth when the SFI value falls below 1.5 the margarine will require refrigeration'.

2. Bakery Margarines: Ordinary bakery margarines thus have a wide plastic range, like its shortening counterpart it is in effect a general purpose margarine. It is used in bakery biscuits and pastries most of these margarines are made from the same oil type as is used for table margarines with 4 - 8% hard fat added as a plasticizer.

## 6.0 Vegetable Equivalent of Mammalian Milk

A liquid that simulates mammalian milk in many respects especially in chemical composition and appearance could be produced from vegetable sources especially in the regions of the world where milk producing animals are scarce or too expensive to keep.

Legumes typically soybeans contain components which are almost nutritionally equivalent to those of milk.

**Table 6. Composition of Cowmilk Powder and Soy Flour**

| Constituents | Cow-milk Powder% | Soybean Flour |
|---|---|---|
| Protein | 26.5 | 40.5 |
| Sugar | 36.0 | 10.9 |
| Fat or Oil | 28 | 23.6 |
| Ash | 6.5 | 5.6 |
| Moisture | 3.0 | 3.2 |
| Complex Carbohydrates | - | 12.1 |
| Crude fibre | - | 4.3 |

### 6.1 Production of Soymilk

J:or laboratory scale production lkg soybean is soaked in 3 times its weight of tap water.. The weight ratio of dry bean to water is at 1:10 taking into account the water absorbed during soaking. The slurry is filtered through 2 layers of cheese cloth or calico to remove the insoluble and boiled for 3 min.

Other vegetable sources of imitation milk are tiger nuts and coconuts.

### 7.0 Milk Microbiology

Usually milk from a healthy cow is not sterile. The interior of the udder is open to invasion by bacteria when the opening of the teat comes in contact with the air.. The bacteria present in the udder are distributed internally by their own growth as well as physical movement. . Milk in the udder may contain up to 500 organisms per ml. If the udder is diseased the count may rise up to 20.000 cells per ml or more. Milk contains a number of anti-bacterial substances which are known to control the growth of organisms in the udder and for the 1st few hours after milk is taken.

Contamination occurs from many external sources through which microorganisms can come into milk during milking as well as during subsequent handling of the milk.

1. Stable air: This may contain dust in considerable particles especially in a dirty stable.

2. Flies and other insects - A fly may carry as many as 1 million bacteria. Such a fly falling into a litre of milk will increase the bacterial count of the milk by 1000lmi even without bacterial reproduction.

3. Skin of the animal - soil, feed or manure adhere to the cow's skin. During the milking process, this material may fall from the skin and a portion of it may get into the milk.. Dry manure is a source of heavy contamination. Proper care and preparation of the cow prior to milking can reduce the effect of this contamination.

4. Feed - hay and silage often contain a great number of spores. Milk may be easily contaminated portions of the feed.

5. Milk Equipmentt - Equipment such as pails, cans, coolers, pipelines, bulk tanks and milking machines are the most serious sources of bacterial contamination. It is very important that utensils be made without seams and sharp corners to facilitate cleaning.

6. Milking Personnel - if the milking personnel are not in good health or have infections on their skin and hands, pathogenic bacteria may be added to the milk. Milk may serve as a carrier of human pathogens from one person to another and hence the need for pasteurization.

## 7.1 Microorganisms of Importance to the Dairy Industry

There are saprophytic and pathogenic microorganisms that grow in milk. Saprophytic microorganisms live on dead or decaying matter.. The important ones found in milk and dairy products include:

1. *Lactobacillus* - species of this family found in milk convert milk sugar to lactic acid and other by-products. Important species are *Streptococcus lactis* which is the cause of spontaneous souring of milk are widely used for making of cheese. S. *thermophillus* found in fermented milk products e.g. yoghurt.. *Lactobacillus losei* present in cheese and *Leuconostoc citroverium* responsible for the butter aroma.

2. Enterobacteria - these are gram negative non-spore forming, rod shaped bacteria commonly occurring in the large intenstines of animals. Best known species are the *Echerichia coli* and *Acetobacter aerogenes*. Their presence in pasteurized milk serves as a sensitive index of fecal contamination after pasteurization.

3. *Pseudomonas* - These are typical bacteria of surface water and are often motile. The genus pseudomonas is well known for causing spoilage frequently with pronounced biochemical activity especially on proteins and fats.

4. *Bacillus* - these are rod - shaped spore forming bacteria. The genus *Bacillus* includes aerobic bacilli like *Bacillus* spp. can be important in causing spoilage of pasteurized and sterilized milk. Some species of the anaerobic genus *Clostridium sporegenus* attack proteins and some produce gas. They are well known for causing defect in cheese.

5. Yeasts - they sometimes ferment sugars and produce gas, they could cause lipolysis. They occur as contaminants in sour milk products, butter and cheese.

6. Molds - they actively metabolize sugars, fats and proteins often spoil milk and dairy products but some are useful e.g. *Penicillum roqueforti* is used in making blue veined cheese.

7. Pathogenes - the milk of diseased animals may contain living germs or pathogenic microorganisms and if such milk is consumed without heat treatment by man or animals diseases such as tuberculosis and brucellosis may be transmitted.

## 7.2 Defects in Milk

Some defects observed in milk and milk products are as follows:

1. Cooked or Heated Flavour - This results from heat treatment.. Prominent in sterilized milk and baby formulation is a heated flavour.. Conventional pasteurization generally does not cause noticeable flavor.. Prolonged exposure of milk to elevated temperatures will also cause some discolouration or browning. Most of this colour change is amino acid and sugar reactions (maillard reaction).

2. Feed Flavour - Milk is a good absorbent for flavor.. It could absorb flavor from the feed or barn air. Factors that could cause objectionable flavor in milk include:

   a) changes from one forage crop to the other
   b) feeding of silage within 2h of milking
   c) feeding milking cows with cabbage, onions or other highly pungent and flavoured crops and weeds.

3. Rancid Flavour - Rancid flavor is caused by chemical breakdown of milk fat. Each fat globule in milk has a surface coating composed of phospholipids among other constituents. Moreover the enzyme lipase is present in raw milk. Raw milk is stable to the action of lipase until some physical force disrupts the membrane around the fat globule. As in extreme agitation, heat treatment, pumping transfers in pipelines. Lipases act on the fat to cause hydrolysis of the triglycerides into glycerol and free fatty acids. Because milk fat contains a significant propOliion of short-chain fatty acids which have strong aromas, the defect is easily detected by taste. Lipase like most enzymes in milk is inactivated by proper pasteurization. Raw whole milk is never homogenized until after pasteurization.

4. Oxidized Flavour - this is probably the most important single flavor defect in milk and milk products. This flavor is also described as tallow flavor, metallic and card board (lipid material is the source) but the specific flavor compounds differ apparently among milk products. The phospholipids appear to be responsible for the development of oxidized flavor in fluid milk. Of the factors essential to the development of the flavor atmospheric oxygen, iron, copper are important. An adequate heat treatment is a commonly used process to retard the development of this flavor. The chemistry of this oxidation is a complex phenomenon.

5. Sunlight Flavour - When milk is exposed to light for any period of time, this defect occurs. This sunlight or activated flavor is attributed to a reaction with the amino acid, methionine, changing to aldehyde methional in the presence of vitamin B2' Milk in metal or proper containers is resistant to this change since light can hardly penetrate. Some years ago, amber coloured glass bottles were used to prevent this defect in homogenized milk. Glass of this type reduces the amount of energy transmitted but it does not give complete protection.

6. Acid Flavour - acid milk results from bacterial growth, generally *Streptococcus lactis*. It is detectable long before the taste will appear in the milk. Acid flavor develops rapidly in the milk if it is not properly heat treated. This flavor is characterized by a sharp sour taste on the tongue.

7. Bitter Taste - it might occur in milk when cows eat harsh weeds, bitter compounds from such weeds may be absorbed into the milk. Bitter taste may be absorbed into the milk. Bitter taste may appear in milk late in lactation. Growth of microbials in milk held several days at low temperatures may also cause bitter taste.

8. Foreign Taste - If a cow eats of feed contaminated with oil, paint, kerosene, spray etc. the taste will be transferred through the blood to the milk.

9. Flat Taste – Generally water added to milk causes flat taste.

**8.0 Quality Parameters of Milk**

1. Fat – this is often determined by solvent extraction

2. Total Solids / Moisture Content - The residue left after all moisture has been dried or evaporated out of the milk is considered as total solids.

3. Pasteurization efficiency - this determined by estimating the quantity of phosphatase enzyme remaining. Properly pasteurized milk normally gives a negative test as only 0.1% of phosphatase is left.

4. Homogenization Efficiency - this is done by determination of the size of fat globule under an oil immersion lens of a microscope.

5. Inhibition and other foreign substances - this is necessary because milk may be contaminated by the antibiotics used on the cow. Such antibiotics even in low amounts may impair the production of fermented milk products especially cheese.

6. Bacteriological Determination - the microbial content of milk and milk products is an important determination because it relates directly to the sanitary quality and condition of manufacture. A direct microscopic technique or an agar plate is used.

## 9.0 Homogenization f Milk

The fresh milk contains fat globules varying in size with the type of animals and breed. With timc the globules start clumping, depending on temperature, agitation acidity, number and size of particles of the fat. The fat globule now forms a layer on top called cream layer.

Before homogenization, the milk is first pasteurized. The process retards the development of oxidized flavor and when properly refrigerated retains fresh taste.

Milk may be homogenized by forcing it through a tiny hole(s) under high pressure. The milk fat will break up into tiny particles (about 1 -2 microns) too small to rise to rise up as cream. llomogenization increases the fat globule surface such that more protein is adsorbed than in unhomogenized milk. The homogenized milk do not clump together again and fat is more uniformly distributed with fat - soluble vitamin A and D.

llomogenization has tremendous effect on the properties of milk. It prevents the cream from scparating out and it gives the milk a higher viscosity and richer taste. Homogenization destroys naturally occurring emulsifiers (e.g. lecithin) and this affects the stability of the milk protein, which becomes easily coagulated when heated in the preparation of certain dishes.

Uliciency of homogenization can be ascertained by examining the size of the fat globules under an oil immersion lens of a microscope.

## 10.0 Definition of Different Milk Products

1. Whole milk- this is milk which has been pasteurized and contains not less than 8.25% milk solid not fat and 3.25% milk fat.

2 Low fat milk - This is milk from which some milk fat have been removed to produce any of the following milk fat content - 0.5%, 1.0%, 1.5% and 2% low fat milk is pasteurized and contains not less than 8.5% solids. Since the vitamin A of whole milk is removed with fat, it is required by law (USA) that not less than 3000 LU. of vitamin A be added to each quart of low fat milk.

3. Skim milk (or non-fat milk). This is milk that contains not more than 0.5% milk fat and contains other ingredients in low fat milk. When cream is separated the remaining milk is skim milk.
Skim milk retains most of the minerals and proteins contained in the original milk but have less caloric value since the most of the high calorie fat has been removed. It also contains less fat soluble vitamins which are concentrated in the cream.

4. Condensed milk - this is whole milk that has 50-60% of its water removed. The product contains not less than 8.5% milk fat. It mayor may not be sweetened condensed milk, the sugar accounts for 40 - 45% of the total weight. Sweetened condensed milk need not be refrigerated until it will be opened because the high sugar content inhibits microibial growth.
Sweetened condensed milk is manufactured by evaporating a mixture of refined sugar and milk to a concentration that is not less than 28% total milk solid and not less than 8.5% milk fat. The addition of sugar to condensed milk is done to reduce the total available moisture for growth of bacteria. The product is not sterile but reaches pasteurization temperature during processing and is preserved by high sugar content. Processing and is preserved by high sugar content. It should not be used for feeding infants.

5. Dried skim milk powder - this is made of fresh raw whole milk from which water and fat have been removed and processed in the same procedure as dried whole milk.
After the non-fat dried milk (skim milk powder) is dissolved in water (reconstituted) it has the same food value as fresh fluid skim milk. Skim milk is also dehydrated using the following processes employed for the dehydration of whole milk since skim milk is low in fat, the milk produced does not readily develop tallow flavor associated with whole
milk powder. If stored at high humidity and temperature it cakes, browning reactions occurs which goes with the loss of protein solubility and biological value. Once opened it has to be kept dried and cool in refrigerated storage, usually packed in an air tight container. When reconstituted it approximates fresh milk in terms of nutrient contents except vitamin C.
6. Dry whole milk powder - this is made up of fresh raw milk from which water has been removed. After part of the water has been removed by vacuum and heating, most of the remaining water is removed by spray drying.

7. Chocolate milk - this is whole milk flavoured with chocolate syrup or powder and sugar to sweeten it. Then milk fat content is 3.25%. Chocolate milk is pasteurized after all ingredients are mixed together and sterilized subsequently from settling, while sugars add calories to the product.

## 11.0 Developments in Modern Dairy Products

Intcrest in dairy products is not limited to these traditional uses but also to a variety of ingredients for prepared foods that are extracted from milk. These products comprise about 20% of the milk utilization in the US. In addition to various types of fortified, condensed and dried milk products these ingredients are used as emulsifiers, texturizers and to enhance nutrition products such as cake, bread, candy and sausage. An example is whey proteins which has become important as an ingredient in many sports nutrition products due to its more complete amino acid composition and easy digestion. Many factors influence the composition of milk including age of the animal, stage of lactation, season of the year, feed, time of milking, time between milkings and physiological condition of the cow. The principal milk producing cow breeds are Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey (USA) and Freiser (Dutch). While the llolsteins produce the most milk, Guernseys and Jerseys produce the milk with the highest fat content. Identification and breeding of specialized cow breeds has enhanced development in dairy products. Eg. Cows that produce skim milk have been bred.

Although quality and safety steps such as homogenization and pasteurization for fluid milk are we!l known, the process to produce many products require a series of steps to separate, concentrate and modify the structural components of the milk.

Milk is naturally produced to nourish the young and contains significant amounts of protein. The protein in rnilk is of extremely high quality because it has a high content of most of the essential amino acids. Milk proteins are easily digestible and have a good protein to calorie ratio. The protein contained in milk is not one single compound but three major proteins and lesser amounts of others. Casein accounts for approximately 80% of the protein in milk and is unique in its versatility. In milk, casein is sometimes found in combination with calcium and called

calci um caseinate. Caseins are in the form of small gelatinous particles that are dispersed in fluid milk. In its pure state, casein is odorless, tasteless and snow-white in colour. Casein coagulates in the presence of rennet/acid to form the cheese curd. Coagulated casein forms a 3-dimensional lattice or backbone structure which then entraps fat, water, minerals and starter cultures and results in cheese curd formation. As casein coagulates, whey begins to separate from the curd. The amount of casein at the beginning of the process is the single biggest factor affecting cheese yield. The raw milk used for cheese making is often standardized to a specific casein 10 rat ratio. The exact ratio depends on type of cheese being made. Addition of protein from ,arious sources is causing controversy in the dairy industry.

Yoghurt is a Turkish term for milk of cow origin. This product is derived from milk that has been allowed to sour or ferment naturally or by added bacteria. It is believed to have numerous health benefits. The longevity of the peoples inhabiting the Russian mountains has been credited to yoghurt (Metchnikov, 1908). However in the study areas such as Probiotics, researchers continue to explore how live and active cultures in yoghurt may have a beneficial to lower cholesterol and help combat certain types of cancer-causing compounds, pmiicularly in the digestive tract.

Milk fat is one of the most complex naturally occurring lipids. A major portion (98%) of the fatty acids in milk exists as triglycerides. Some of the other components are di- and mono - acylglycerols, free cholesterol, cholesterol esters, free fatty acids and phospholipids. In addition milk fats contain significant amounts of short chain fatty acids (e.g. C4 and C6) which are easily digested and absorbed. Conjugated linoleic acid (CLA) is a fat of certain ruminant animal meats. Milk fat is a particularly rich source of CLA which is the only fatty acid shown to unequivocally inhibit carcinogens in experimental animals.

The safety of milk has been an issue for centuries and public health organizations began serious investigations into the role of milk consumption in food borne diseases in the early 1900s when unpasteurized milk was found to be associated with many serious diseases, sanitation measures would need to be applied at all points in the food systems from farm to the consumer.. The appropriate laws e.g. Standard Milk Ordinance in 1924 and more recent Pasteurized Milk Ordinance (USA) which provide for sanitation standards and microbiological testing at every stage of processing, have apparently succeeded to a great extent.. As at 1938 dairy products were responsible for more than 25% of food contaminated illnesses. Currently they account for less than 1%.