MILK

Topics covered

- Retrospect and prospects of milk industry in India.
- Composition and nutritive value of milk
- Physico-chemical properties of milk.
- Factors affecting composition of milk.

Retrospect and Prospect

- Kaira District Cooperative Milk Producers' Union (AMUL) – 1946
- National Dairy Development Board (NDDB) – 1965

- Operation Flood: landmark project of India's National Dairy Development Board
- **launched on 13 January 1970**
- **Phase I- (1970-1980)**
- **Phase II (1981–1985)**
- **Phase III (1985–1996)**

- Future Expectations - Total milk production by 2034: 330 million tonnes

Dairy industry Scenario in India

Total milk production	230.58 million tonnes
Top milk producing state	Uttar Pradesh (15.72%) Followed by Rajasthan and MP
Per-capita availability of milk	459 grams per day
Maximum per-capita availability	Punjab(1283 gms per day) Followed by Rajasthan and Haryana
Per capita milk recommendation (ICMR)	300gm/day

INDIA - 1st in the world in terms of total milk production

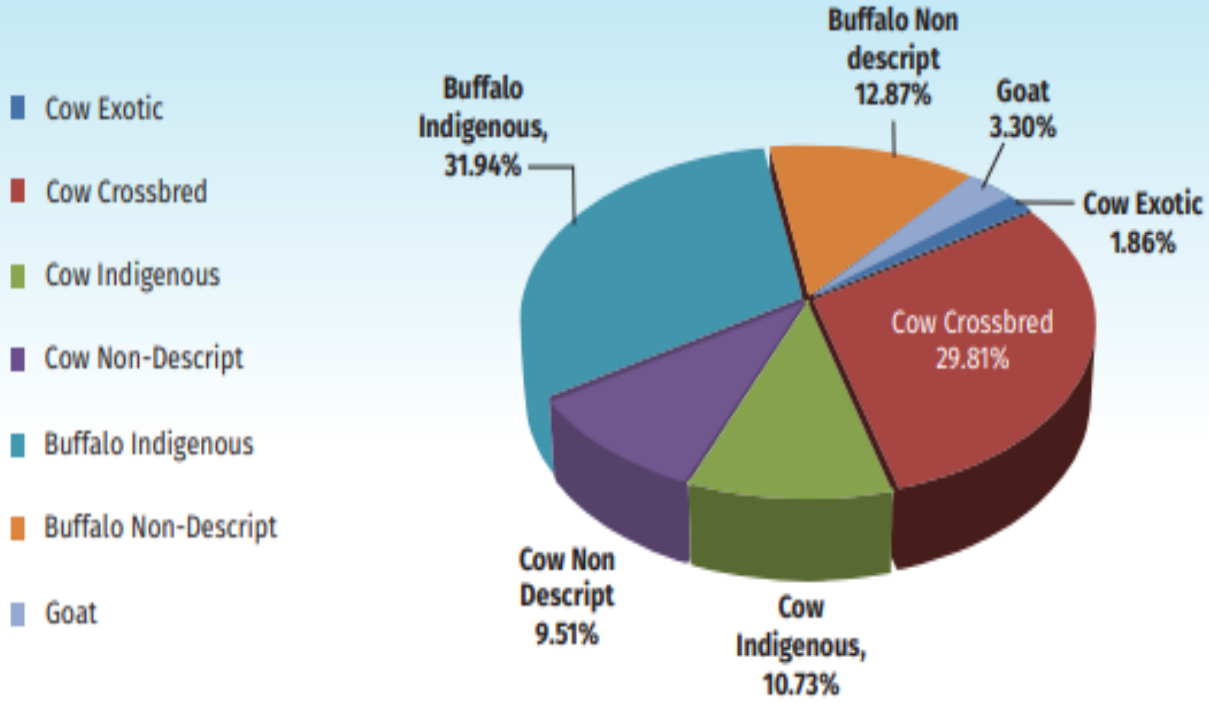
World Milk Day: 1st of June
National Milk Day: 26th November

Year 2024 theme - Moving towards a healthy tomorrow

Milk Man Of India/ Father of white revolution in India: Dr. Verghese Kurien

Type	Production
White revolution	Milk
Blue Revolution	Fish
Brown Revolution	Leather
Golden Revolution	Honey
Silver Revolution	Egg/Poultry
Red Revolution	Meat

GRAPH 2.2: SPCCIES-WISE MILK CONTRIBUTION IN 2022-23



Milk: whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy milch animals, excluding that obtained within 15 days before or 5 days after calving, colostrum-free, and containing the minimum prescribed percentage of milk fat and milk solid not fat (as per FSSR, 2011)

Composition – Water (85-87%)
- Total Solids (12-15%)

* Fat

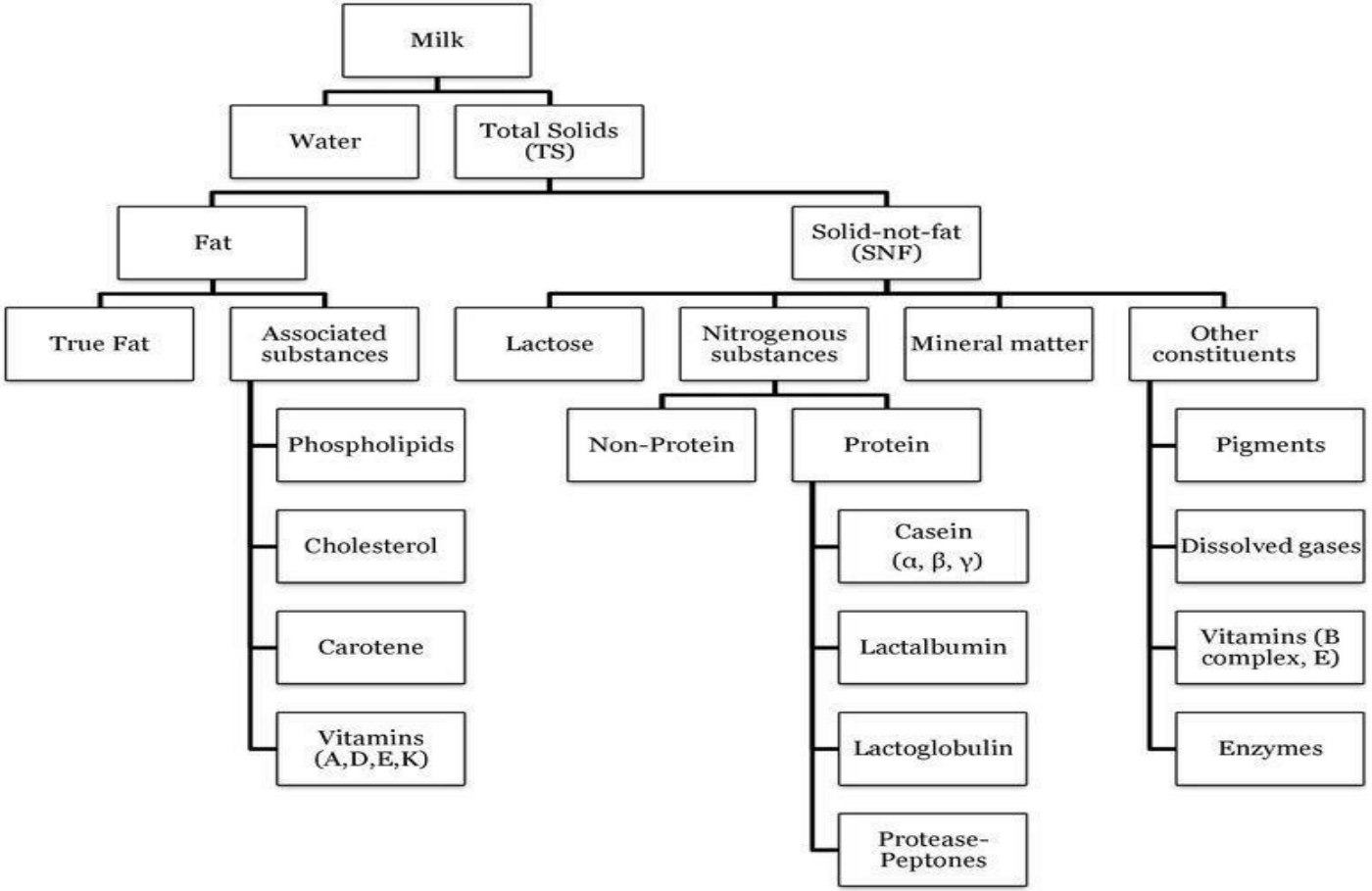
* Protein (Casein + Whey Proteins + NPN)

*Lactose (Milk Sugar)

*Minerals, Vitamins, enzymes, pigments

- Market milk: whole fluid milk sold for direct consumption
  - not includes which is consumed on the farm or used for manufacturing dairy products

Milk Constituents



MILK FRACTIONS

- Milk Plasma (Skim Milk) = Milk – Fat
- Milk Serum (Whey) = Plasma – Casein micelles
- SNF = Proteins, lactose, minerals, acids, enzymes, Vitamins
- Total Solids = SNF + Fat
- True constituents: fat, casein, lactose

Composition of Various Species

	Water	Fat	Protein	Lactose	Ash
Cow	86.6	4.6	3.4	4.9	0.7
Buffalo	84.2	6.6	3.9	5.2	0.8
Sheep	79.4	8.6	6.7	4.3	1.0
Goat	86.5	4.5	3.5	4.7	0.8
Sow	89.6	4.8	1.3	3.4	0.9
Mare	89.1	1.6	2.7	6.1	0.5
Ass	90.0	1.3	1.7	6.5	0.5
Camel	86.5	3.1	4.0	5.6	0.8

DIFFERENT TYPES OF MARKET MILK

Type of Milk	Fat % (min)	SNF % (min.)
Cow milk	3.5	8.5
Buffalo Milk	5	9
Standardized milk	4.5	8.5
Toned milk	3	8.5
Double Toned milk	1.5	9
Skim milk	0.5 max	8.7
Recombined milk	3	8.5

Sheep, Goat- 3% Fat 9% SNF

Skim milk - 8.7% SNF

Toned & recombined – 3% fat & 8.5% SNF

Cow, toned, standardized, recombined – 8.5% SNF (RCT S)

Buff, sheep, goat, double toned – 9% SNF (BDSG)

Fat percentage – buffalo > standardized > Cow > Toned, recombined > double toned > skim

MILK FAT

- Most Variable constituent/ Economically most important
- Exist in form of glycerides (glycerol + fatty acids) – most commonly triglycerides
- **oil in water type emulsion**
- present in form of fat globules (ranging from 0.1 to 22 microns) stabilized by fat globule membrane
- average size of 2 to 5 microns (cow 1-5 & buffalo 3-8)
- fatty acids---- Saturated FA -65% MUFA- 30% PUFA 5%

Elephant – 18%

Highest fat %- Aquatic mammals

True fat – 98-99% (most common triglycerides)

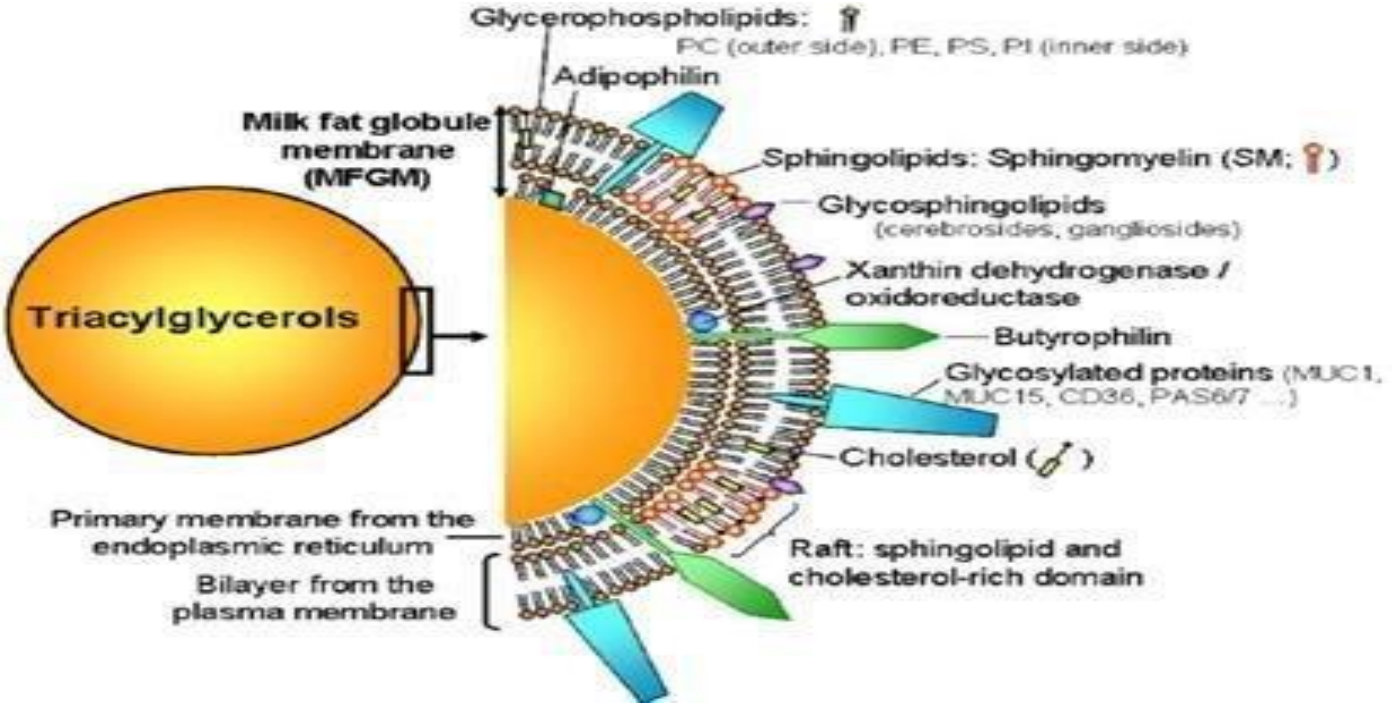
Associated fat – 1-2%

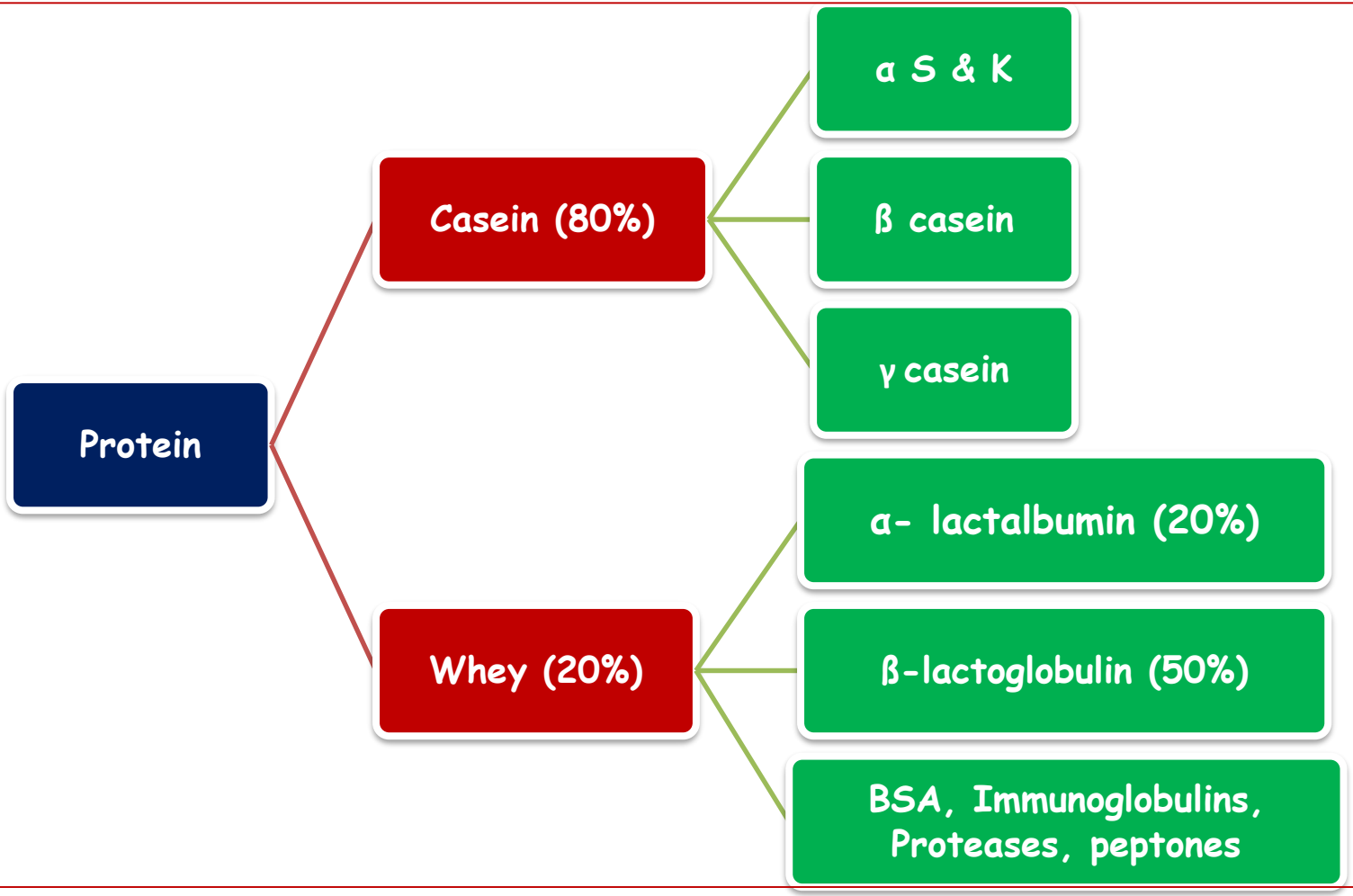
- phospholipids : lecithin, cephalin and sphingomyelin

-steroids, cholesterol, fat soluble vitamins (A,D,E,K)

-pigments: carotene, xanthophyll (fat soluble)

FAT GLOBULE MEMBRANE COMPLEX




Protein
Casein (80%)
α S & K
ß casein
γ casein
Whey (20%)
α- lactalbumin (20%)
ß-lactoglobulin (50%)
BSA, Immunoglobulins, Proteases, peptones

PROTEINS

- exists in colloidal form causing scattering of light responsible for white color of milk
- consist mainly of casein (80%) and whey proteins(20%)
- Casein exists only in milk (3%in cow and 4.3% in buff) and is **found in the form of a calcium caseinate phosphate complex.**
- casein- contains phosphorus and coagulate or precipitate at pH 4.6.
- serum (whey) proteins- do not contain phosphorus, and remain in solution in milk at pH 4.6.
- The principle of coagulation formation at reduced pH is the basis for cheese/curd formation
- Riboflavin gives color to whey protein while casein is responsible for white color of milk

CASEIN- Phosphoprotein

- The caseins in milk form complexes called micelles that are dispersed as colloidal suspension in the water phase of milk as Ca-caseinate phosphate complex
- casein micelles - subunits of the different caseins (α-s, ß, γ). α casein – responsible for stabilization of micelle in milk: Kappa casein: site of action of rennin
- ß casein two parts A1 & A2 (67th A.A.- A1 Histidine & A2 Proline). A1 produce Beta casomorphin 7 (BCM-7) during digestion
- Casein Can be Precipitated by acid, rennet, alcohol, heat
- Adhesiveness of milk – because of Casein – used for glue making

WHEY/ Serum Proteins

- approximately 50% ß-lactoglobulin, 20% a-lactalbumin
- blood serum albumin, immunoglobulins, lactoferrin, transferrin, and many minor proteins and enzymes.
- Responsible for milk allergy
- ß-lactoglobulin -----carrier of vitamin A
- a-Lactalbumin ------ critical role in the synthesis of lactose
- Lactoferrin and transferrin ---- role in iron absorption and transportation
- Immunoglobulins ---- major Ig G1
- Serum proteins present as colloidal solution

CARBOHYDRATES

- lactose – milk sugar - made up of Glucose + galactose
- Exists as true solution in milk serum
- Least variable component of milk
- Helps in absorption of calcium and phosphorus from intestine
- Maillard or Browning reaction: occurs at ultra high temp. between the lactose and protein (lysine A.A. in milk)
- Isomerisation: lactose to lactulose (laxative and and antineoplastic agent)
- two forms -- a- and ß-lactose anomers.
- a-monohydrate lactose crystals - sandy texture in the ice cream and condensed milk

VITAMINS AND MINERALS

- Ca:P in milk- 1:2
- Good source of Na, K, Mg
- **Poor source of Iron, Cu**
- Poor source of Vitamin C, K
- Good source of Vitamin B complex
- Lactose and minerals – responsible for osmotic pressure and taste of milk

Mineral	*Bovine (mg/dl)*
Calcium	125
Magnesium	12
Sodium	58
Potassium	138
Chloride	103
Phosphorus	96
Citrate	175
Sulfur	30

Source. Adapted from Jenness, 1974.

Most abundant mineral in milk - Potassium

MILK ENZYMES

- lipase - lipoprotein lipase - associated with casein micelles and FGM
- protease - plasmin (help in desirable flavor & texture in Cheese) - associated with casein micelles
- Alkaline Phosphatse : heat sensitive enzyme used as indicator of pasteurization. Causes oxidation and rancidity of fat
- lactoperoxidase: present in milk serum; antibacterial properties
- Catalase: insignificant in normal milk but increased concentration reflects udder infection
- Lysozyme: very limited amount in bovine milk

Preservation	e.g. Lactoperoxidase, sulphydryl oxidase, superoxide dismutase
Deterioration	e.g. Lipoprotein lipase, proteinase, acid phosphatase, xanthine oxidase
Markers of heat treatment	e.g. Alkaline phosphatase, lactoperoxidase, catalase, γ-glutamyl transpeptidase
Markers of mastitis infection	e.g. N-acetyl-β-D-glucosaminidase, catalase, acid phosphatase
Antimicrobial activity	e.g. Lysozyme, lactoperoxidase
Commercial source of enzymes	e.g. Ribonuclease, lactoperoxidase

PIGMENTS & GASES

- Carotene – responsible for yellowish color of cow milk

-- converted to Vitamin A in Buffalo by carotenase enzyme

- Carotene content – Cow milk 30 µg/g while in Buffalo 0.25 - 0.48 µg/g

- Riboflavin/lactochrome/lactoflavin – greenish tinge in whey

- **Gases : major Carbon dioxide, Nitrogen, Oxygen**

Q. Proteins in milk are present in one of the following form (PPSC 2016)

a) Emulsion

b) Soluble

c) Colloidal

d) Suspension

Q. According to norms of Preservation of Food Adulteration Act (PFA) 1976, cow milk should contain not less than (RPSC 2013)

(1) 8.5 percent SNF and 3.5 percent milk fat

(2) 7.5 percent SNF and 3.0 percent milk fat

(3) 6.5 percent SNF and 2.5 percent milk fat

(4) 9.5 percent SNF and 2.0 percent milk fat

Q. According to PFA Rules (1976), buffalo milk should not contain less than……percent of SNF and not less than ……..percent of milk fat. (MPPSC 2021)

(A) 8.5,6-0

(B) 9-0,5-0

(C) 9-0,6-0

(D) 8-5, 4-5

Q. One litre of normal milk from milch animal contains approximately gram of water. (MPPSC 2023)

- [A] 560 to 580
- [B] 760 to 780
- [C] 860 to 880
- [D] None of the above

- Sandiness defect during ice-cream making is due to higher content of (MPPSC 2023)
- [A] stabilizer [B] lactose [C] fat [D] emulsifier

- What are the main constituents of milk contributing to maintaining the osmotic pressure of milk? (MPPSC 2021)

(A) Sodium and Chloride

(B) Lactose and Chloride

(C) Sodium and Lactose

(D) Casein and Citrate

The most variable constituent of milk is (OPSC 2014)

(a) Protein (b) Fat (c) Ash (d) None of the above

- Standard milk contains (PPSC 2022)

a) 4.5% Fat & 8.5% SNF

b) 5% Fat & 8.5% SNF

c) 3% Fat & 9% SNF

d) 5% Fat & 8.7% SNF

- Fat content of cow milk is (MPPSC 2019)

(A) 2.5% (B) 3.5% (C) 5.5% (D) 4.5%

- According to the Prevention of Food Adulteration (PFA) Rules, 1976, the standards for different classes of milk in UP, which of the following is Correctly matched? (UPPSC 2022)

(a) Pasteurized Buffalo Milk 7.0, 9.0

(b) Raw Cow Milk 4.0, 8.5

(c) Toned Milk 3.0, 9.0

(d) Standardized Milk 4.5, 8.5

Casein constitutes _____% of milk protein (TPSC)

a. 50
b. 90
c. 99
d. 80

- Fat % of toned milk is (TPSC)

a. 1.5
b. 3
c. 4.5
d. 6

Names of the species are arranged with regard to an increasing order of fat% content in milk. Identify the correct order :

A) Cow, goat, sheep, buffalo
B) Goat, cow, buffalo, sheep
C) Sheep, cow, goat, buffalo
D) Goat, sheep, cow, buffalo.

Nutritive value

- Energy value
- Cow milk: 75 kcal/ 100gm
- Buffalo milk: 100 Kcal/ 100gm
- Milk Fat 9.3 Kcal/g; Protein and Sugar- 4.1 kcal/g
- Cholesterol content:
- Cow Milk: 3.14 mg/g
- Buffalo Milk: 0.65 mg/g
- Good source of Vitamins except C & K
- Good source of minerals except Fe & Cu
- High biological value proteins (85-95)
- Essential fatty acids like linoleic and Arachidonic acid

Antimicrobial properties of Milk

- Specific antimicrobial agents:
- Immunoglobulins, Complement, Bifidus factor

- Non Specific antimicrobial agents : Lactoferrin, Lysozyme, lactoperoxidase, Lactanins

Physico-Chemical Properties of MILK

Importance of Properties

- For detection of adulteration
- For determining quality of milk
- Helps in processing of milk & milk products
- Helps in evaluating the physical changes during processing

Physical State: Water-continuous phase

MILK	OIL IN WATER
Fat	oil in water emulsion
Lactose, ash	True solution in milk serum
Cholestrol	True solution in fat
Protein	Colloidal form in milk

Acidity and pH

* Freshly drawn milk: Amphoteric in nature - amino acids existing in zwitter ionic form
* pH of milk – 6.6
* cow 6.4-6.6
* Buffalo 6.7-6.8

- pH will be higher in mastitic milk and lower in colostrum

- Buffering action: proteins, phosphates, citrates, CO_2

- Titratable acidity = natural acidity + developed acidity

- Natural or apparent acidity : freshly drawn milk have some acidity because of its constituents like casein, acid phosphates, citrates, CO_2 (SNF) ranging from 0.13 to 0.14% for cow and 0.14-.15% for buffalo

Real or developed acidity: due to formation of lactic acid by bacterial fermentation

COLOR

- white ---- due to scattering of light by colloidal particles
- Yellow color because of carotene.
- intensity of yellow color increases when cow fed with green fodder.
- Buffalo milk is white in color due to the absence of carotene which is converted to vitamin A
- Dilute acid or rennet addition will result in a distinct greenish yellow color due to the pigment riboflavin (because of pptn of casein)
- Whey - greenish yellow (Riboflavin) while Skim Milk has bluish tinge (lactochrome)

- Yellow: *Pseudomonas synxantha*
- Blue: *Pseudomonas cyanogens*
- Black: *Pseudomonas nigrifaciens*
- Red: *Serratia marcescens*
- Green: *Pseudomonas fluorescens*

FLAVOUR

- Sensory property in which both taste and smell interact
- Most important parameter while judging
- sweet taste because of lactose
- chloride responsible for salty taste (in mastitis and in late stages of lactation)
- Richness in taste: due to Phospholipids
- Cooked flavor- **sulfhydryl** compounds – due to overheating
- Cowy flavor – in ketosis due to acetone
- Barny Flavor – poor ventilation
- Malty Flavor: *Streptococcus lactis var. maltigenes*

Density & SPECIFIC GRAVITY

- Density measured by – Pycnometer Or hydrostatic balance
- Specific gravity measured by Lactometer at 15.6 °C or 60 °F
- Lactometer – Quevevene or Zeal's
- SG= 1+ CLR/1000

- Cow milk : 1.028-1.030
- Buffalo milk : 1.030-1.032
- Skim milk : 1.035-1.037
- Colostrum : 1.070 (high concentration of TS)

Water : 1 Fat : 0.93
Protein : 1.346
Lactose : 1.666
SNF : 1.616 Ash: 4.12

- Fat – lightest constituent
- Milk Heavier than water

- Increased by addition of skim milk, removal of fat or lowering the temperature
- lowered by addition of water, addition of cream or by increasing the temperature

Recknagel phenomenon

- increase in SG of fresh milk by 0.001 as time advances due to hydration of proteins
- SG should be determined after
  - 1 hour of milking
  - heating milk at 40 °C and then cooling

Freezing Point

- lower than milk due to Lactose and salts
- No effect of fat and protein on freezing point
- Lowered FP by: sourness and addition of preservatives
- Increased FP: by addition of water

Average Freezing point	
Cow milk	- 0.555 °C
Buffalo milk	- 0.560 °C
Goat milk	- 0.575 °C
Sheep milk	- 0.588 °C

Freezing Point Depression

- Freezing point depression (FPD) - decrease in the freezing point of a solvent caused by the addition of a solute
- **Measured by Hortvet Cryoscope**
- Average FPD of cow milk is - 0.547°C and of buffalo is - 0.549°C
- Addition of water: Freezing point moves closer to 0 ° C (0.006 ° C for every 1% water added). Up to 3% water can be detected
- Boiling & Sterilization increase FPD while pasteurization has no effect

Surface Tension

- Stress at the surface of liquid
- The surface tension of milk at 20 ° C is 54.5 dynes/cm
- decreases as temperature raised (at 60 ° C: 40-45 dynes/cm)
- Measured by falling drop or Platinum ring method using **Tensiometer**
- ST of milk lower than water mainly due to proteins
- Presence of Fat, acidity and churning lowers ST

- **Oxidation Reduction Potential:** +0.2 to 0.3 volts
- MBRT, Resazurin test based on O R potential

- **Viscosity:** 1.5-2 centipoises (Cow 2 Buffalo 1.8 skim milk 1.5)
- Viscosity in milk - due to casein and fats
- Homogenization increases viscosity by uniform distribution of fat molecules

- **Boiling point: 100.15-100.17 ° C**

- Refractive index: measured by Zeiss refractometer
- Values 1.344 to 1.348

Q. Hortvet apparatus is generally used to determine which physical property of milk? (RPSC 2013)

(1) Boiling point

(2) Freezing point

(3) Electrical conductivity

(4) Density

- Non specific germicidal factor present in milk (KPSC)

a. Immnunoglobulins
b. Bifidus factor
c. Lactoferrin
d. None of the above

When the milk is adulterated with water, freezing point depression will

A) be lowered

B) increase

C) reach towards 0°C

D) be maintained

The pH of milk is

A) 7.0

B) 6.5

C) 4.5

D) 6.6

specific antimicobial compounds present in milk (KPSC)

a. Immnunoglobulins
b. Bifidus factor
c. Complement
d. All of the above

Milk boiling temperature is (OPSC 2014)

(a) 100°C (b) < 100°C (c) > 100°C (d) 80°C

Natural activity in milk is due to (OPSC 2014)

(a) Citrates (b) Carbonates (c) lactate (d) Acetate

Opsc 2018

Specific gravity of milk is:

(A) 0.94 (B) 1 (C) 1.030 (D) 1.050

Which contributes richness of flavour of milk?

(A) Phospholipid (B) Galactolipid (C) Glycolipid (D) Cholesterol

- Which of the following agents does not contribute to natural acidity of milk (HPSC 2023)

a. Lactic acid

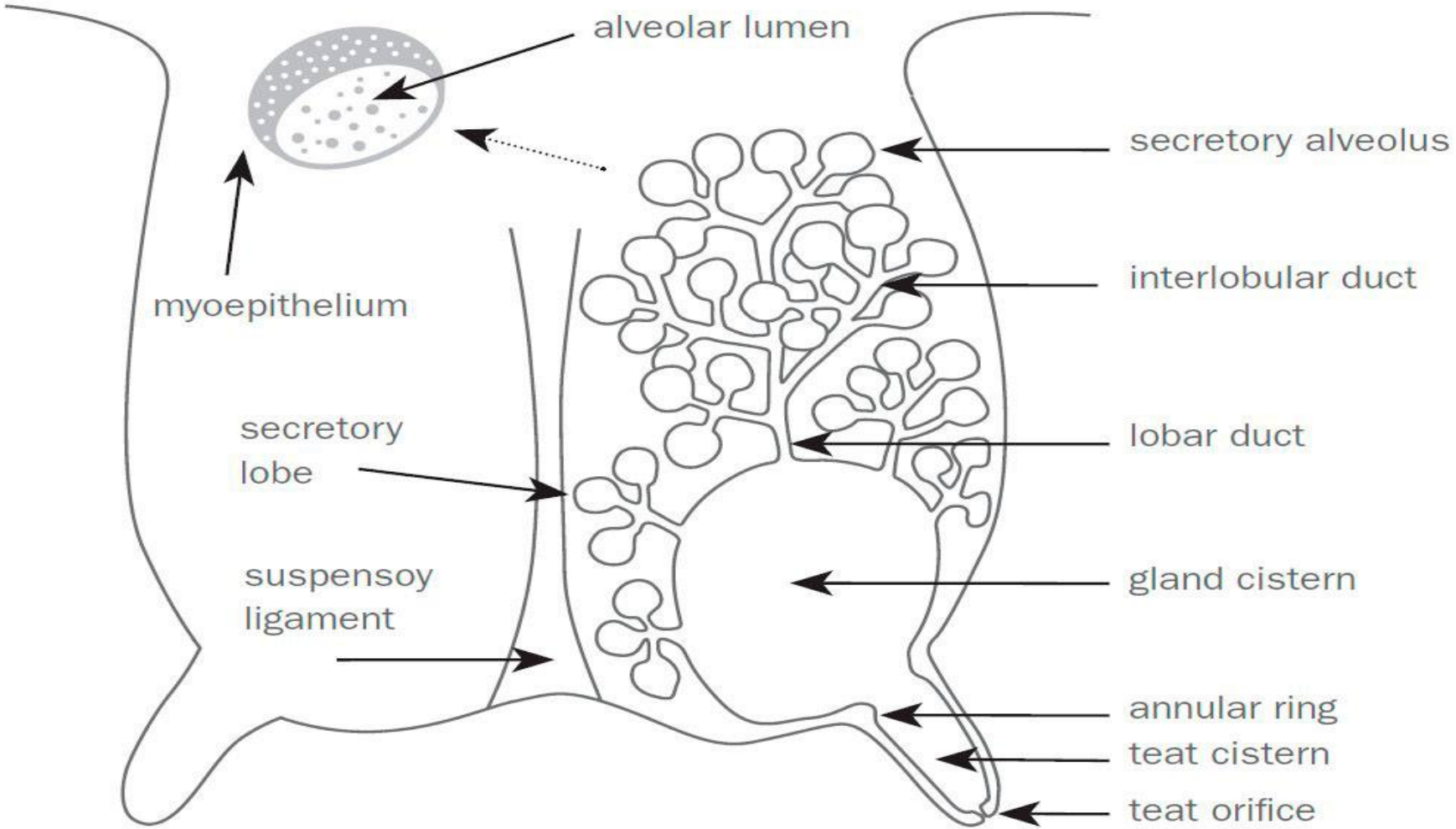
b. Citrates

c. Phosphates

d. Dissolved CO2

- Which of the following is not a part of lactoperoxidase system in milk (HPSC 2018)

a. Phosphatase
b. Hydrogen peroxide
c. Thiocyanate
d. Lactoperoxidase


alveolar lumen
secretory alveolus
myoepithelium
interlobular duct
secretory
lobe
lobar duct
suspensoy
ligament
gland cistern
annular ring
teat cistern
teat orifice

Physiology of lactation

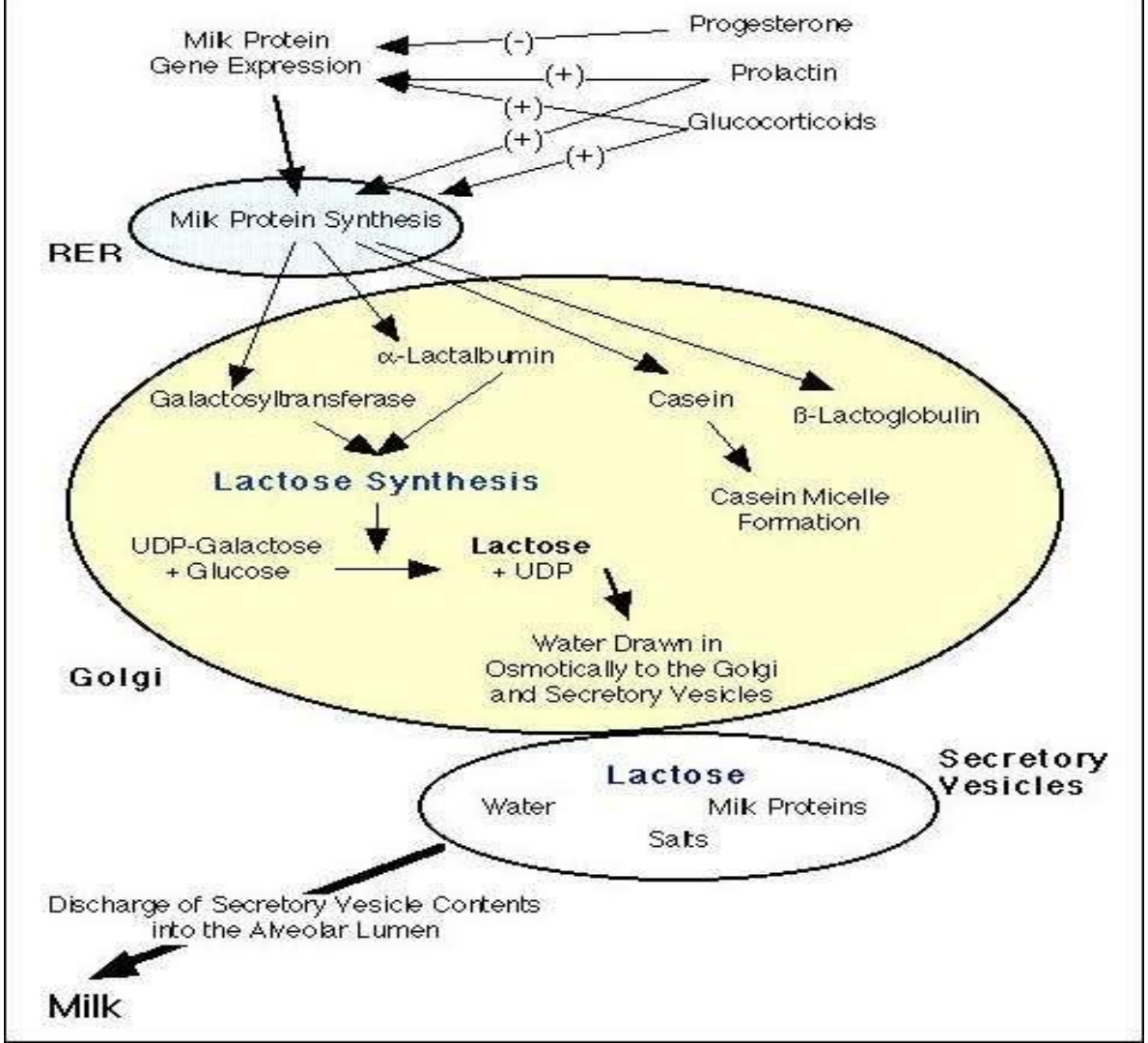
- Stages of lactation –
- Mammogenesis: development of mammary gland
- Lactogenesis: initiation of milk secretion
- Galactokinesis: ejection of milk
- Galactopoiesis: maintenance of milk secretion
- Process includes
  - uptake of amino acids
  - uptake of sugars
  - uptake of milk fat precursors
  - uptake of immunoglobulins, Vitamins, Minerals

Amino acids to proteins

- At rough endoplasmic reticulum (RER).
- transferred from the RER to the Golgi apparatus
- Caseins and other proteins undergo post-translational processing in the Golgi.

Glucose to Lactose

- Entry of glucose via GLUT1. Some part of the glucose is converted to UDP-galactose
- **In Golgi**, **Glucose, galactose and alpha lactalbumin** enters in reaction catalyzed by enzyme **Galactosyl transferase** resulting in formation of lactose.
- formation of lactose in the Golgi results in drawing water into the cell


Milk Protein
Gene Expression
(-)
Progesterone
(+)
Prolactin
(+)
(+)
Glucocorticoids
(+)
Milk Protein Synthesis
RER
α-Lactalbumin
Galactosyltransferase
Casein
ß-Lactoglobulin
Lactose Synthesis
Casein Micelle
Formation
UDP-Galactose
+ Glucose
Lactose
+ UDP
Water Drawn in
Osmotically to the Golgi
and Secretory Vesicles
Golgi
Secretory
Vesicles
Lactose
Water
Milk Proteins
Salts
Discharge of Secretory Vesicle Contents
into the Alveolar Lumen
Milk

Fat precursors to milk fat

- synthesized on the smooth endoplasmic reticulum (SER)
- **Acetate and ß – hydroxybutyrate-important precursors**
- Fatty acids are derived either from blood (mostly long chain C14 to C18) or *de novo* synthesis of short to medium chain fatty acids (C4-C12) in mammary gland.

Hormones Involved

	Prolactin	Mammary growth; initiation and maintenance of lactation
	GH	Stimulates milk production
Post pituitary	Oxytocin	Milk ejection
Thyroid gld	T3, T4	Stimulates O2 consumption, protein synthesis and milk yield
	Calcitonin	Calcium and phosphorus metabolism
Adr cortex	Glucocorticoids	Initiation and maintenance of lactation
Adr medulla	Epinephrine, norepinephrine	Inhibition of milk ejection
Ovary	Estradiol	Mammary duct growth
	Progesterone	Mammary alveolar –lobule growth, inhibition of lactogenesis
Placenta	Estradiol	Mammary duct growth
	Progesterone	Mammary alveolar –lobule growth, inhibition of lactogenesis
	Placental lactogen	Mammary growth