Meat Technology and Preservation

Definition of Meat Processing:

All processes utilized in altering fresh meat except for simple grinding, cutting and mixing. It includes curing, smoking, canning, cooking, freezing, dehydration.

Purposes (Importance or Benefits) of Meat Processing:

1- Preservation of meat through inhibition of growth and multiplication of m.o.
2- Production of safe, stable, acceptable product through improving its flavor and texture.
3- Major changes in the demand for certain cuts of meat as using mutton, pork, beef and boneless poultry meat.
4- Production of poultry frankfurters and other cured poultry meat products.
5- Meat products are of low price because they are manufactured from cheap meat cuts and byproducts.
6- Meat products are of high nutritive value because they contain high quality proteins, minerals and vitamins.
7- Meat products are easily and quickly prepared, because some of them are ready to cook and others are ready to eat.
8- Modifying or upgrading less noble cuts of meat.

Nutritional Value of Meat:

1- Proteins: meat contains **high quality proteins** due its content of essential aa which stimulate metabolism.

2- Fat: meat contains **fat** which:

- Act as carrier for fat soluble vitamins (A, D, E, and K).
- Supply essential fatty acids which are precursors in the synthesis of phospholipids, the main structural molecules of all biological membranes.
- Act as energy reserve.
- Play an important role in improvement of taste and flavor of meat products.
- Delay the movement of food from stomach → delays the feeling of hunger.

3- **Vitamins:**

- Meat is an excellent source of **vitamin B – complex as vitamin B_1 (thiamin) and B_{12}.**
- Meat is poor in **fat soluble vitamins (A, D, E, and K) and vit. C.**
- Most of the vitamins are relatively stable during cooking or processing **except B_1 and B_6** are **heat labile** as they are partially destroyed during cooking and canning.

4- **Minerals:**

- Meat contains minerals as Ca, P, Na, K, Cl, Mg, Fe, Cu and Zn.
- **Fe** intake is important to combat **anemia.**
- **Fe in meat** has a **higher bioavailability, better resorption and metabolism** than Fe in plant products.

5- E**xtractives:** Meat contains **extractives** which are good stimulant to the gastric and intestinal juices → helping in digestion of proteins and carbohydrates.

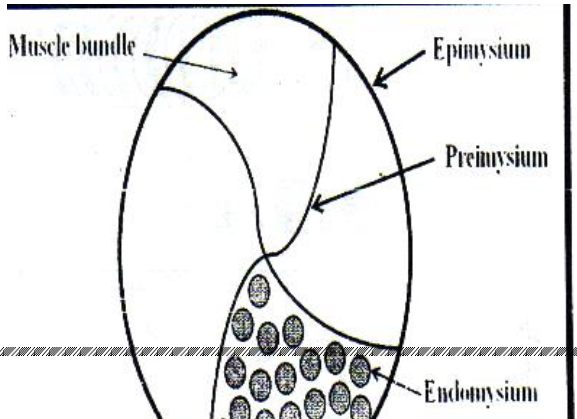
Histological Structure of Muscle:

*Skeletal muscle comprises **35-85%** of the total carcass weight.

*Skeletal muscles are separated from each other by **epimysium.**

*The individual muscle is divided into separate several muscle bundles by **perimysium.**

*Each muscle bundle contains 30-80 muscle fibers which are individually wrapped with a thin C.T. sheath called **endomysium** which is made up from basic



proteins; collagen, elastin and reticulin.

*The epimysium, perimysium and endomysium extend beyond the fleshy part of the muscle to form a thick **tendon** which forms indirect attachments from muscles to the periosteum of bones or to the C.T. of other muscles.

* **Myofibers (muscle fibers)** are the basic cellular units of muscles and meat.

*Each muscle fiber is surrounded by a cell membrane called **sarcolemma.**

*Within the sarcoplasm of each individual muscle fiber, there are so many **myofibrils** which are solid protein chains which account for the major and nutritionally most valuable part of the muscle cell proteins.

*Myofibrils are made up of **myofilaments** which have two types: **myosin** (thick filaments) and **actin** (thin filaments).

Skeletal muscle → muscle bundles → myofibers → myofibrils → myofilaments → actin and myosin.

***In Meat Trade there are 3 types:**

1- **Meat with bones:** half or quarter of the carcass.
2- **Meat cuts:** after deboning.
3- **Lean meat:** after deboning and removal of visible fat, tendon, b.v. and Ln.

Dressing Value %: It is the carcass after removal of head, skin, blood and evisceration. It varies according to:

*species *breed *sex *age *nutrition

Chemical Composition of meat:

1- Water:

- Water is the largest component comprising about **70%** of lean tissue.
- There is a **direct relationship** between water and protein content of meat while **inverse relationship** between water and fat content of meat.
- Water content of meat is subjected to variations:
  a- **gain** which occurs during processing.

b- **losses** through drip and evaporation.

c- Such gains or losses affect **K.Q.** especially juiciness and palatability.

- There are **three forms of water** in meat:

a- Bound water: bounded tightly to hydrophilic groups of proteins even during the application of severe mechanical or physical forces.

b- Immobilized water: weakly attached to proteins but easily extracted.

c- Free water:

- loosely attached.
- very dependant upon **capillary space** between and within muscle proteins; so any changes in free water lead to observed changes in **WHC** (water holding capacity) of meat.
- can be extracted by normal centrifugation.

2- Proteins:

a- Sarcoplasmic (plasma) proteins:

- 25-35% of the total muscle protein.

- soluble in water, and easily lost through improper processing procedures as thawing frozen meat as drip seen in the bottom of tanks of thawing meat.

*contain **myoglobin** (1% of the total muscle protein) which is responsible for:

1- Meat color:

a- light or dark muscle in the same carcass is due to the difference in myoglobin concentration.

b- Myoglobin concentration is affected by:

- Species - Age
- Maturity of the animal (older animals have darker pigmentation)
- Type of muscle fibers (beef has more myoglobin than pork, veal or lamb).

c- myoglobin contains Fe which when oxidized or reduced, changes in the color of meat occurs.

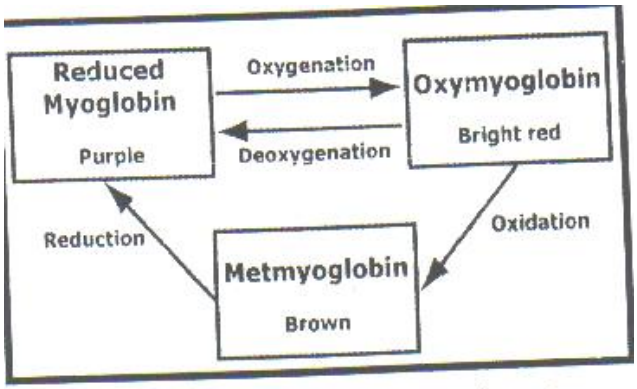


Fig (7): changes in colour of meat

2- Curing capability of meat:

a- myoglobin + nitrite → red curing color of meat.

b- ↑ myoglobin → more intense curing red color.

b- Myofibrillar (Structural or contractile) proteins:

- **55%** of the total muscle protein.
- composed of myosin, actin, troponin and tropomysin.
- salt soluble.
- myosin is a long molecule composed of 6 separate peptide chains: **4 of low molecular weight and 2 of high molecular weight.**
- responsible for **muscle rigidity:** myosin provides a protein matrix which binds the meat particles together, so it is the most functional protein in the production of cooked meat products.
- the best way to extract myosin from meat is to remove the meat from carcass prior to the development of rigor mortis, and mix the meat with salt immediately, to prevent the development of the contracted form of actomyosin. Once actin and myosin have contracted to form actomyosin, it is much more difficult to extract myosin from meat.

***extractability of myosin is improved by** salt, alkaline phosphatase, mechanically induced cell rupture and comminution.

***protein binding strength is improved by** myosin extraction, comminuting, salt and alkaline phosphatase.

***protein binding strength is inhibited by** heating above 100°C, excessive fat or C.T. in the formula and tenderizing enzymes

c- Connective tissue (stromal) proteins:

- **10-15%** of the total muscle protein.
- composed mainly of **collagen** and **elastin**.
- They are of **low biological value:**
  1- **Collagen** is deficient in **tryptophane.**
  2- **Elastin** is deficient in **cystine, tyrosine and tryptophane.**

***Collagen:**

- collagen is the main stromal protein (**20-25%** of total body protein).
- collagen is made up of 3 aa coiled together to form the **tropocollagen** molecule which is embedded in amorphous material called **"ground**

substance". The high tensile strength of collagen is due to the **intermolecular cross linkages.**

- collagen forms a **fibrous network** which transmits the force of contraction from the muscle fibers to the bones by connecting muscle fibers and muscle bundles.

- collagen is the main component of tendons and ligaments.

- collagen is found in fore-shank, skin, lips and muscles that are most active and/or involved in the movements e.g. the leg muscles.

- the amount of collagen in the raw material will greatly affect the properties of the finished product.

- old meat is tough because as the animal ages → no more C.T. is produced → C.T. (collagen) which is present becomes more cross linked and less soluble → collagen becomes more difficult to be broken down by heating.

***Collagen can be rendered (broken down) tenderer by:** mechanical methods, fine comminuting and enzymatic methods e.g. plant source enzymes (tenderizing enzymes) as papain and promelin.

***Overuse of tenderizing enzymes (plant source enzymes) leads to:**

a- Over tenderize the meat
b- Mushy texture of the final product.
c- ↓ Binding capacity of other meat proteins.

*collagen detrimens the stability of meat products due to its relation to heat and mechanical operations:

d- Collagen **at 70°C** → collagen fibers shorten by **1/3** its original length which release fat and moisture from its structure.
e- Collagen **at 80°C** → **gelatin** which is also undesirable in meat products.
f- Collagen at **100°C** → **glue.**

***Elastin:**

- yellow elastic fibers.
- less abundant than collagen.
- found in ligaments, walls of arteries, organs and muscles.
- high content of glycine.

3- Fat (8-30%):

*fat of animal tissue contains triglycerol, cholesterol, esters, pigments and fat soluble vitamins (A, D, E and K).

*fats accumulate under the skin (S/C), around the organs (kidney and heart), between muscles (intermuscular) or inside the muscles (intramuscular), where 70% of fat is subcutaneous or intermuscular.

***Marbling appearance:**

a- intramuscular fat in higher accumulations → marbling appearance → tenderness and flavor of meat.

b- fat can be sliced at a very cold temperature → marbling appearance to the finished product.

*Fat has an important role in the improvement of flavor and taste of meat products and make them softer.

***Polyunsaturated FA "vit. F"** which is:

a- Important for the normal physiology of hair and skin.

b- Antisclerotic factor because it combines with cholesterol forming a complex which is easily excreted from the body.

*↑ unsaturated FA → lower melting points → fat more susceptible to oxygen, metal ions, UV and storage for long period → oxidation of unsaturated FA → development of rancid flavors and off-colors.

*the degree of saturation of the fat in the raw meat affects:

a- processing properties of the raw material.

b- mouth feel of the product.

*highly saturated fat → comes from sheep → beef → pork.
→ kidney fat.

*least saturated fat → S/C fat of brisket area.

*the selection of fatty tissue used for manufacture of certain meat products depend on the taste and flavor of fat which vary between animal species:

a- **Brisket fat and fresh fat from younger animals** are the most suitable fats for processing.

b- fat of older animals is darker and carries off flavor.

c- buffalo is more suitable for processing than beef fat because it is more white in color than beef fat.

d- mutton fat of adult animals is unsuitable for most consumers due to its typical unpleasant flavor and taste.

e- lamb fat is relatively neutral in taste and commonly eaten with lamb chops.

f- chicken fat:

- It is neutral in taste and well suited as a fat component for pure chicken products.

- It adheres as intramuscular fat to chicken muscle tissue and processed without separating it from the lean meat.
- The majority of chicken fat derives from high S/C fat content → mincing of chicken skin → fat emulsion before being added during chopping.

4- Extractives:

a- **Nitrogenous compounds** → creatin, creatinin, carnosine.

b- **Non nitrogenous compounds** → ATP, ADP, free aa.

*they are present in the sarcolemma of muscle fibers.

***Function:**

a- responsible for the different aroma and flavor of different kinds of meat.

b- they stimulate the flow of gastric and intestinal juices → helps in the digestion of proteins and carbohydrates → play an indirect important role of nutrition.

5- Minerals:

*Na, Ca, S, K, P, Mg and Fe are found in muscles.

* Na, Ca, S constitute 90% of the total minerals.

* Meat contains highly available Fe (mainly in liver).

*Meat contains microelements as Cu, Zn, Co and Al which are very important in the normal physiology as they enter in the structure of enzymes and hormones.

6- Vitamins:

*Muscles and organs are good sources of vit. B_1, B_6, B_{12}, riboflavin, biotin, folic acid, pantothonic acid and nicotinic acid.

*liver is an excellent source of vit. A, C, B_6, B_{12}, biotin and pantothonic acid.

*amount of vitamins loss depend on method, time and temperature of cooking.

Ex.: vit. B_1 loss → 15-40% → on cooking (boiling)
→ 40-50% → on frying
→ 30-60% → on roasting
→ 50-70% → on canning

7- Reducing bodies:

*they have enzymatic action with marked reducing properties.

*their action is manifested typically in carcass affected with icterus, when this carcass is detained in the chilling room for 24 hrs., this yellow color disappears due to the action of reducing bodies.

8- Enzymes:

*meat contains many enzymes which play important role in the process of **RM and ripening of meat** e.g. lipase, amylase, maltase, phosphatase, carboxylase, katepsine and peroxidase enzymes.

Non-Meat Ingredients (Meat Additives)

Definition:

*Any substance, which is not normally consumed as food by itself, but are added to develop certain technological and quality characteristics.

*Any substance results **direct or indirect effect** on the characteristics of meat products after its use during processing, treatment, packaging or storage.

N.B.: Other non-meat ingredients (vegetables, flours, eggs, etc.) could be considered as full food ingredients.

Significance and criteria for utilization of functional non-meat ingredients:

1- Keeping safe meat products.
2- Improve the nutritional value of certain meat products.
3- Improve the processing technological characteristics of meat products.
4- Improve sensory quality of meat products (taste, color, flavor and texture) so become more acceptable for consumer.

Classifications of Non-Meat Ingredients:

1- According to the source:

a- Chemical Substances: salt, nitrite, ascorbic acid, phosphates, antioxidants, monosodium glutamate (MSG) and food colorants.

b- **Ingredients of Plant Origin:**

***Spices:** used in small quantities to provide flavor and taste to meat products.

***Binders: rich in protein** and used to ↑ **water binding and prevent fat separation during heating.** Ex.: isolated soy protein and wheat gluten.

***Meat Extenders:** rich in proteins as soy concentrates (70% proteins).

***Fillers: rich in carbohydrates and low in proteins**, so its addition is not an extension of the protein mix. Ex: cereals, legumes, vegetables, roots and soy flour (50% proteins).

c- Ingredients of animal origin: (milk caseinate, whole milk, non-fat dried milk "NFDM", gelatin and eggs) which ↑ **water binding and prevent fat separation during heating.**

2- Additives – Full Food.

3- a- Functional: have the ability to improve certain quality characteristics including taste, flavor, appearance, color, texture, water binding, preventing fat separation.

b- Non Functional: as **meat extenders and fillers:** not intended for change of appearance or quality improvements but used for:
- Volume filling capacity
- ↓cost through replacing meat in lower or medium grade products by cheaper ingredients.
- ↑ water or fat binding as some starches and flours.

Non-Meat Ingredients:

***Water / Ice**	***Common Salt**
***Phosphates**	***Salt petre**
***Extenders**	***Sugar**
***Preservatives**	***Glucono δ lactone (GDL)**
***Ascorbic acid**	***Antioxidants**
***Flavor Enhancers**	***Food colorings**
***Fillers**	***Seasonings (Spices)**
***Acid and Liquid Smoke**	***Hydrolysed Vegetable Proteins (HVP)**

Water / Ice:

1- Compensates for cooking losses which may reach up to 30%.

2- Prevents dryness of the final product.

N.B.: Excess water leads to **fat and jell separation.**

3- **Salt + water** + **phosphates** → solubilization of myofibrillar proteins (myosin) (since myosin dissolves in low salt solution) → myosin separates alone forming coat around the fat globule → myosin gel upon heating → creating protein network structure → entrapping moisture and fat → ↑ water and fat binding holding capacity in the final product → ↓ cooking loss → firmness of the final product.

N.B.: Salt and phosphates in meat emulsions are **synergistic:**

a- Phosphates exert more effect on **pH and protein solubility.**

b- Salt exerts more effect on **ionic strength and water-holding capacity.**

4- Lubricates the meat mass → improves the consistency of the emulsion and reduced-fat product.

5- ↓ initial temperature during emulsifying, chopping or mixing → prevents protein coagulation during the emulsifying stage.
6- ↓ cost of the product.
7- Used as a substrate for curing substances or other non-meat ingredients → better distribution in the meat mass.
8- Used for re-hydration of meat extenders.
9- Gives fluidity to the emulsion → proper filling of the casings.
10- Helps in fat emulsification.

Common Salt (Sodium chloride):

***Advantages:**

1- Seasoning of food.
2- Curing of meat since it is the basic ingredient to all curing mixtures.
3- Preserving of food.
4- Contributes to the basic taste characteristics of the final product.
5- ↑ cooking yield of meat (cooking loss is minimum at 5-8% salt).
6- **Bacteriostatic rather than bactericidal through:**
   a- ↓ a_w → inhibits the growth of spoilage and pathogenic m.o → extends the shelf life of meat product.

   b- **Plasmolysis:** when bacteria enter hypertonic soln → they rapidly become dehydrated → cytoplasm of the bacterial cell contract and separate from the cell wall → sharp cytoplasmic destruction → bacterial cell died:
   G-ve bacteria → sensitive to plasmolysis.
   G+ve bacteria → resistant to plasmolysis due to high internal osmotic pressure.

   c- $NaCl \rightarrow Na^+ + Cl^-$ (which are harmful to m.o).
9- Dehydration of food by drawing out and tying up moisture.
10- ↓ solubility of O_2 in moisture.
11- Interfere with action of proteolytic enzymes.
12- Sensitizes the bacterial cells against Co_2.

***Disadvantages:**

1- Using salt alone gives harsh, dry salty and dark final product.
2- High level of salt → **hypertension** and to solve this problem use:
   a- NaCl : KCl in a ratio of 1:1. **High level of KCl → bitter taste.**
   b- K lactate 20%. **High level of lactate (> 30%) → chemical taste.**
3- Trace amounts of **Cu, Fe and chromium** which may be found as impurities in salt → **oxidative rancidity → flavor and color problems.** Therefore, **only food grade salt** should be used.

Phosphates (0.5%):

*Used alone or in combinations as Na tripolyphosphate, Pyrophosphate, Polyphosphate and Na acid phosphate.

***Advantages:**

1- **Alkaline phosphates** → ↑ pH → unfolding of muscle proteins → making more sites available for water binding → ↑ water holding capacity → ↑ product yield.

N.B.: Acid phosphates → ↓ pH → shrinkage.

2- ↓ shrinkage of product during cooking.

3- **Antioxidant:** Phosphates → ↓ pro-oxidant activity of heavy metals in the salt → retard oxidative rancidity.

4- Improve the color stability and flavor.

5- ↓ the microbial growth.

6- Chelate undesirable ions in meat.

***Disadvantages:**

1- Excessive amount of phosphates → **soapy taste and rubbery texture** in high protein meat mix.

2- Corrosive to metal equipments so they must be stainless steel or plastic.

3- Phosphates may form **crust or crystals** over the surface of the cured products **(disodium phosphates)** and can be prevented by:

a- ↓ the level of phosphates in the curing mixture.

b- Maintaining high RH in the product environment**.**

Salt petre (Na nitrite or Na nitrate):

***Advantages:**

1- Color stabilizer:

Nitrate (by nitrate reducing m.o) → Nitrite (in the absence of light and oxygen) → Nitric oxide + H_2O

Nitric oxide + Myoglobin (Mb) → Nitric oxide metmyoglobin (NOMMb) → Nitric oxide myoglobin (NOMb) (unstable) by acidity or cooking → Nitric oxide haemochromagen (stable pickling pink attractive colour).

N.B.: Without nitrite meat products turn **grey** in color when heated.

2- Antibotulinum factor: nitrite **+ Fe** found in meat which is an essential nutrient for growth and multiplication of ***Cl. botulinum*****,** → inhibiting growth of ***Cl. botulinum*** and delaying the production of botulinal toxins.

3- **Antioxidant:** retard development of oxidative rancidity, off-odors and off-flavors during storage.

4- Inhibit development of warmed-over flavor (WOF).

5- It preserves the flavor of spices and smoke.

6- It acts as **flavoring agent in bacon production**, (**bacon** is salted, cured, smoked, and canned hindquarter of pigs).

N.B.: If nitrite is not added to brine soln. the product is not considered bacon but considered **pickle ham.**

7- ↓ temperature used → ↓ cost of the final product.

***Disadvantages:**

1- Excessive amount → hardness of meat products.

2- **Carcinogenic agent:**

Nitrite (in the presence of light and oxygen) → Nitrous acid + dimethylamine → (by cooking and high temperature of frying) **nitrosamine** (carcinogenic)**.** This problem may be reduced by adding:

a- **550 ppm Na ascorbate + 120 ppm Na nitrite.**

b- **K sorbate** c- ∞ **tochopherol.**

N.B.:1- It is prohibited to be used in canned baby meat.

2- Recommended dose of nitrite is 120 ppm in all meat products and 50 ppm in canned meat.

Extenders: Not standard ingredients in processed meats, since high quality products are often manufactured without them.

***Advantages:**

1- ↑ water and fat binding.
2- ↑protein content.
3- ↑ cooking yields.
4- ↑ slicing characteristics.
5- ↑ emulsion stability.
6- ↑ flavor.
7- ↓ shrinkage during cooking.
8- Extend the more expensive meat proteins → acceptable overall protein contents of lower cost meat products → ↓ formulation costs.
9- Soy concentrates and isolates aid in binding chunks of meat together in sectioned and formed meat products.

***Disadvantages:** Some preparations may not be effective due to their insolubility at normal pH of meat (5.2-5.8).

***Factors affecting functionality of extenders:**

1- Source of extenders.
2- Protein concentration.

***Sources:**

1- Plant proteins: from legumes of soybeans including soy flour, textured soy flour, textured soy protein concentrate, soy protein isolates and textured vegetable protein.

2- Animal proteins: milk proteins (including Na caseinates, granular Na caseinates, calcium sodium caseinates, whey protein concentrates and non-fat dry milk "NFDM") and eggs.

***Types:**

I- Soy Proteins:

1- Soy concentrates:

***70% protein.**

*Used in flour or granular form **"textured vegetable protein"** for finely comminuted meat products.

*Neutral in taste.

*Cause less **"beany"** flavor in processed meats than **soy flour.**

*Before processing, soy concentrates must be re-hydrated at a ratio of **1:3.**

2- Soy Isolates:

***90% protein.**

*Useful in **"weak"** formulations, where the meat protein content is low.

*It is the only soy product that functions like meat (interacts with meat protein) **in forming protein network structures and binding water and fat.**

3- Soy Flour:

a- Full fat flour: 30% protein and 20% fat.

b- Defatted flour: 50% protein.

II- Milk Proteins:

***Skim milk powder (Non fat dried milk) "NFDM":**

*It is dried defatted milk containing **36% protein** and **0.8% fat.**

***Legal limit: 3.5%**

***Advantages:**

- ↑ water and fat binding.
- ↑ the texture and flavor of emulsion type sausage.

***Disadvantage:** when used in large amounts render the product unpalatable due to its high lactose and ash content.

III- Yeast protein derived extenders: act as good protein extenders.

IV- Flours and Starch:

*prepared from cereal grains as corn, wheat and rice.

*they are of low price.

*they act as **a good binding agent because they can absorb large amounts of water** → meat particles adhere with each other.

Sugar:

***Advantages:**

1- Provides specific flavor.
2- Counteracts the salty taste of common salt.
3- Preventing some of moisture loss → counteracts the harsh hardening effects of salts and nitrite.
4- ↓ a_w value, which is important for dried and canned products.
5- **Effective preservative:** in dry fermented sausages and raw hams sugars (by m.o) → organic acids (lactic and acetic acids) → souring and retardation of bacterial growth.
6- Prevents oxidation of nitrite → prevents the formation of nitrosamine. Combines with aa → ↑ flavor of cured meat.

***Disadvantages:** high amount of sugar may give **burned flavor.**

Preservatives:

1- Some non-meat ingredients, mainly used for purposes such as reddening, binding or flavoring, also develop moderate antimicrobial effects e.g. **nitrite, phosphates and common salt** which has:
   a- **Direct** antimicrobial effects in **high** concentrations.
   b- **Indirect** antimicrobial effects in **lower** concentrations through ↓ a_w.

2- Organic acids as lactic, citric or acetic acids: ↓ microbial growth on **fresh meat surfaces**. **Sodium salts of organic acids** are better suited for meat products especially **sodium lactate alone or in combination with sodium acetate or diacetate.**

3- Potassium sorbate:

***Effective mould inhibitor** during drying and storage.
Potent inhibitor against *Cl. botulinum when used with low levels of nitrites.

Glucono δ lactone (GDL) (0.5-1%):

***Advantages:**

1- **Cure accelerator:** ↓ pH pf the meat mix by **0.2-0.3** units → accelerates the conversion of the meat pigments to the desirable color.
2- Used in dry and semidry sausage **(1%),** where it ↓ pH by **0.5** units → control the growth of spoilage microorganisms until the development of fermentation.

***Disadvantages:**

Dry and semidry sausages containing GDL have **bitter acid taste.**

Antioxidants:

1- Moderate antioxidants: e.g. nitrite, ascorbic acid, phosphates and some spices, provide sufficient protection in the **short term,** but for **longer storage,** the products should be:

a- vacuum packed.
b- not exposed to light.
c- kept under refrigeration.

2- Fat soluble antioxidants: e.g. butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT).

*Used at levels of **0.002-0.003%** of the finished product weight depending upon fat level in the finished product.

*BHA and BHT are **carcinogenic** to human.

***∞ tochopherol** may be used in products with **high fat content.**

Ascorbic acid, Sodium ascorbate, Erythrobate:

***Advantages:**

1- Cure accelerator:

a- reduce metmyoglobin to myoglobin → accelerate the reaction of nitrite with the red pigment **(↓ 1/3 curing time)** → development and intensification of the uniform red curing color which develops in heat treated meat products.

b- Complete chemical curing reactions and less residual nitrite will be left in the product.

2- Antioxidant

3- Color and flavor stabilizer.

4- Interferes with the carcinogenic effect of nitrite where it prevents the formation of nitrosamine.

5- **Slightly** ↓ pH of the meat mixture → reduction of Na nitrite to nitric oxide. **A pronounced reduction of pH would negatively affect the water binding capacity** of the product which is not desirable.

Flavor Enhancers:

***Advantages:**

1- Provide the product with a flavor and substitute the flavor lost by different processing methods, so sold with high price.
2- Antioxidant.
3- Baceriostatic.
4- Save the shipping costs.

***Types:**

1- Food proteins as soy, milk or blood proteins or yeast extracts are partially hydrolyzed, broken down to simpler components (mainly peptides) which may have meat flavor or the ability to strengthen meat flavors.

2- Monosodium glutamate (MSG):

- Na salt of glutamic acid
- Fine white crystals similar in appearance to salt or sugar.
- Not have a distinct taste of its own.
- **Stimulates glutamate receptors in the tongue to augment meat-like flavors.**
- **Disadvantages:**
  a- Mental retardation in children.
  b- Carcinogenic effect.

3- Benzaldehyde → cherry flavor.
4- Ethyl butyrate → pin apple flavor.

Food colorings:

*The usual way of providing an attractive red color to most of meat products is by **curing.** The principle of curing is not dyeing the product, but chemical reaction of the red muscle pigment (myoglobin) with nitrite resulting in a stable red color that does not change during heating and storage.

***Advantages: intensify the product color** as in case of poor formulations with low meat content and extenders and fillers of plant origin.

***Types:**

1- Natural:

- Orange yellow beta carotene from green plants
- Red color from red beet juice
- Red oleoresin from paprika

2- Synthetic:

- Carmines
- Carmoisine

***Disadvantages:**

1- Some food colorings are toxic.
2- They mask the quality and hygienic defects in processed meats.

***Technological requirements of food colorings applied in meat products:**

1- Must be heat stable, at least to endure pasteurization temperatures around 80^{o}C.
2- Stable during exposure light or oxygen.

3- Stable with pH changes.

Fillers:

*__Rich in carbohydrates and low in proteins,__ so its addition is not an extension of the protein mix.

***Types:**

1- Unprocessed cereal grains, common legumes, vegetable roots are used as fillers to ↑ volume and ↓ costs and commonly used for simple meat preparations.

2- Flours, starches and soy concentrates are used as fillers and extenders.

3- Wheat gluten: very high protein content and applied as **water and fat binder** mostly in raw and cooked products including canned products.

Seasonings (Spices):

***Definition:** aromatic substances derived from vegetative plants or herbs.

***Advantages:**

1- Contribute to the flavor of meat products.
2- Bacteriostatic.
3- Antioxidant.

***Types:**

A- Natural spices:

*They include dried rootstocks, barks, flowers, fruits or seeds of different plants.

*They are mainly used in the ground form with particle size **0.1-1 mm.**

*The most common natural spices used in processed meat products are **pepper (most common in sausage),** paprika, nutmeg, cloves, ginger, cinnamon, cardamom.

B- Herbs:

*They are dried leaves of plants grown in temperature climates.

*The major herbs used in processed meat products are basil, marjoram, rosemary and thyme.

*The main natural seasonings originating from **vegetable bulbs** in processed meat products are **onions and garlic.**

C- Spices Extracts:

*It is used instead of natural spices which are contaminated with high no. of m.o. → a problem for the stability of the meat products. The microbial load of natural spices can be reduced by **irradiation or fumigation,** which are not allowed everywhere.

*They are used in **microbiologically sensitive processed meat products,** such as cured-cooked hams or cured-cooked beef cuts, **due to the absence of m.o. in spices extracts.**

*Spices extracts are produced by separating the flavor intensive fractions through phsico-chemical procedures (e.g. steam distillation) which results in germ-free flavoring substance.

*Extracts are used in **viscous liquid or oily form.**

Acid and Liquid Smoke:

* Food-grade acid is sprayed before smoking and cooking.

***Advantages:**

1- Free from carcinogenic substance.
2- Not require heat treatment.
3- Constant in structure.
4- Less environmental pollution.

Hydrolyzed Vegetable Proteins (HVP):

*as corn, wheat, soy and other proteins which are **hydrolyzed to yield meat-like flavor and effectively ↑ the protein content.**

*HVP is available as granules, powder, bullion and seasoning granules.

*In some cases, other components may be added to HVP as smoke, flavoring, caramel color and MSG.

The effect of HVP on the taste of the finished product depends on:

- Food acidity
- Kind and amount of seasoning
- Amount of salt used
- Processing and cooking techniques

Raw Meat Materials

Def.: A wide range of animal tissues used for formulation of processed meat products:

1- Skeletal muscle (meat)
2- Fat
3- Internal organs (tongue, heart, liver, kidneys, lungs, diaphragm, esophagus and intestine).
4- Slaughter byproducts (lips, blood, soft tissues from feet, head muscles).

*Raw materials are derived mainly from:

- cattle
- veal
- pigs
- poultry

- buffaloes - sheep - goats - turkey
- camels - horses - game animals

***Skeletal muscles of food animals vary in:**

- Fat/lean ratio
- Moisture/protein ratio
- Water binding properties
- Emulsifying properties
- Amount of pigment

*The characteristics of meat ingredients especially the **protein and fat content** determine:

- Taste
- Texture
- Aroma
- Overall quality

*The cost of raw meat materials will be reflected on the cost of the final product.

*The **quality of raw materials** is determined by its **chemical and microbiological states.**

***Criteria for selection of raw meat materials for processing of meat products:**

- Clean
- healthy (sound)
- Wholesome
- Not contaminated with m.o.
- Fresh as possible to fill the technological properties of each specific product **(within 7 days PM and stored at 2^{o}C).**
- contains **high % of myoglobin s**ince it affects the color of the final product **(heart and cheek are good sources of myoglobin).**
- Thoroughly cooled
- Properly boned and trimmed meat

***The use of aged meat may cause:**

- Bacterial degradation
- Enzymatic degradation → proteolysis of proteins → ↓ the functionality of proteins in particle to particle adhesion.
- Oxidative degradation
- Older meat is tough
- Off-flavor
- Off-odors
- Rapid color deterioration

*If **mutton and veal** used in excessive amount → **undesirable flavor** of the finished product → mutton should be restrict used in **20% or less** of the total meat block due to its pronounced flavor.

*Processed meat products tend to be **dry and tough** unless **sufficient fat** is present.

***The fat content of meat used for comminuted meat products is affected by:**

1- The carcass grade.
2- Cut or type of trimming from the carcass.

***The variety meat used in processed meat products:**

1- Tongue
2- Heart
3- Liver
4- Tripe

***Storage of raw materials is related to:**

1- Sanitation: raw materials are handled under strict hygienic measures.

2- Refrigeration:

a- Meat used directly after slaughter.
b- Meat should be chilled rapidly at **-1ºC (30ºF)** until used.
c- Trimmings should be frozen at **-18ºC** or below until being used within **5 days.**

- Primal cuts should be frozen and should be thawed before curing.

N.B.:
Tongue meat: tongue without glandular or C.T.
Tongue trimming: tongue with glandular or C.T.
Tongues: tongue after removal of m.m.
Cheek meat: head meat + glandular tissue + C.T.
Beef cheek: meat only of head without glandular tissue or C.T.
Chuck: meat around vertebral column.

Meat product	Raw material
1- Canned meat:	1- Lean skeletal beef and pork meat 2- Trimmings 3- Mutton and veal meat in small amount
2- Smoked meat:	Primal and sub primal cuts
3- Comminuted meat products **A) In cattle:**	1- Boneless primal cuts (chucks, plates, flanks) 2- Trimmings from primal cuts 3- Cheeks 4- Head meat 5- Giblet meat (diaphragm muscle) 6- Heart 7- **Weasand meat** (muscular tissue surrounding the esophagus) **8- Tripe (compound stomach):** the adhering fats and contents are removed → stomach is washed → scrubbed and

	remove the m.m. covering the inner side of tripe → scalded → cooked for manufacture. **N.B.: Weasand meat and tripe are the cheapest grades of processed meat products.**
B) In pork:	1- Boned primal cuts (heavy hogs) 2- Trimmings
C) In veal and mutton:	1- Whole carcass 2- Veal trimmings
4- Sausage:	1- **Binder meat:** classified according to its ability to bind water and emulsify fat into: **a- high binding properties:** lean skeletal tissue, whole bull, cow and mutton carcass. **b- Medium binding properties:** beef and pork cheek meat and beef shanks. **c- Low binding properties:** tongue, heart, cardiac and smooth muscles. 2- **Filler meat:** with very low binding property as trip, snout, lips, skin and its use in meat products should be limited.

***Raw meat materials include:**

1- Primal cuts
2- Boneless primal cuts
3- Selected trimmings
4- None selected trimmings
5- Mechanically deboned meat
6- Partially defatted tissues
7- Poultry meat

I- Boneless primal cuts:

*Primal cuts high in C.T are best used for production of finely comminuted meat products.

II- Trimmings:

***They are classified according to:**

- Fat content
- Protein content
- Moisture content
- Species of animal from which they originate.

*Beef free from fat as chuck and **neck trimmings** must be distinguished from larger portions of fat, such as flank or **rib trimmings.**

***Lean beef trimmings and lean beef cuts** are preferred for use in **fermented sausage products** where a large percentage of meat is essential.

*Trimmings used for making comminuted meat do not need to be thawed, but can be sliced or cut into small pieces to be fed into meat grinder or sausage chopper.

III- Mechanically Separated Meat "MSM" = Mechanically Deboned Meat "MDM" = Mechanically Recovered Meat "MRM":

*It is a paste or batter like product produced by using high pressure machinery that separates meat from flesh-bearing bones after boning or from poultry carcasses using mechanical means.

*It consists of meat and fat from bone, periosteum and sometimes bone marrow. When bone marrow present in MSM, the functionality may be improved by **higher pH value which ↑ water binding.**

*Depending on the equipments used and the yield of MSM extracted, there will be granules of hard bones which should not exceed **0.05%,** but levels as high as **5%** have been reported.

*It is **very perishable and excellent ingredient with very good nutritional and functional properties,** so used in **emulsified and other meat products as frankfurters, fermented sausage and hamburger.**

*The product must be labeled to indicate the presence of MSM.

***Disadvantages of MSM:**

1- Rapid onset of **oxidative rancidity** causing off-flavors and off-odors due to:
   a- high levels of **Cu, Fe and Mg**.
   b- unsaturated FA.

2- **Short shelf life** even under refrigeration because it contains **high microbial load** of pathogenic and spoilage bacteria such as *Pseudomonas* due to:
   a- Unsaturated FA so susceptible to oxidation and rancidity.
   b- Long bones are opened to air sacs.

***Thawing of frozen meat should be:**

1- in cooler operating at 50°C.
2- in cold running water
3- in microwave heating.

***High quality products are obtained from MSM through:**

1- Careful handling
2- Low temperature control
3- Rapid processing

***Types of MSM:**

A) The first category:

- contains **at least 14% protein and not more than 30% fat.**
- may be used in any amount in processed meat products, provided that the **Ca content** in the finished product not exceeds the permissible limit, because **if it contains high Ca content:**
  - Bacterial contamination.
  - Affects kidney function.
  - Easy adulteration by foreign protein.

B) The second category:

- Protein and fat contents are not regulated.
- May be used only in products in which the finished fat content is controlled.

IV- Partially defatted tissues:

*They are subjected to **50^{o}C** to remove fat without denaturation of proteins.

***Types:**

1- Chopped partially defatted tissue: used in meat sausage.

2- Fatty type: used in restricted amounts in meat products up to **15%** of the meat mass.

V- Poultry meat:

*Poultry meat can be purchased either:

1- Whole carcass

2- Specific cut up poultry parts which can be obtained **with or without skin: breast, thigh, wings, backs and neck.**

Poultry meat **without skin is more valuable** because it is **lower in fat**.

Poultry meat **with skin is less valuable because skin is high in fat and C.T.**

***Poultry meat share as a raw material in processed meat products due to:**

1- Widespread availability and popularity.
2- Its very competitive production cost.
3- Quick and easy preparation.
4- Good source of high quality proteins and more than that of red meat.
5- It is easily to digest.

6- Contains all the essential aa required in human diets.
7- The meat fibers are tender, easy to chew or grind.
8- The flavor is mild and blends well with seasonings and other ingredients.
9- Most fat in poultry meat is found under the skin rather than distributed throughout the tissue.

***Quality and price of poultry carcasses are affected by:**

1- TBA for detection of rancidity.
2- Amount of kidneys in backs.
3- TCC
4- Lean/fat ratio.
5- Skin content

*High quality fresh raw poultry carcass and parts should be used for processing.

Undesirable Conditions

1- PSE
2- DFD
3- PSS
4- Two – toning
5- Dark cutting beef
6- Sex odor
7- Mutton flavor

1- Pale Soft Exudative Pork (PSE):

*light in color, soft, with poor water binding ability and **should be not used in sausage and smoked meat.**

*Its incidence is related to:

a- Season: highest in **high environmental temperature or marked fluctuation of temperature.**

b- Breed: Poland Chinas, Landrace and Hampshire are most susceptible.

c- Sex: higher incidence in gilts (small female of pig) than in barrows (castrated male of pig).

d- Muscling or lack of fat: highest incidence in **meaty hogs** and those **with little back fat.**

2- Dark Cutting Beef (DFD): it constitutes a more serious problem than PSE pork due to its **high pH** which favors the microbial spoilage.

3- Porcine Stress Syndrome (PSS): manifested by:

***trembling and sudden death.**

*extreme susceptibility in live pigs.

*PSS meat is watery and pale in color than PSE meat.

4- Two – Toning:

*It is associated with muscular tissue of **swine and hams.**
*__Light and dark color in the same surface or muscle.__
*__High pH meat is dark, good water binding and emulsifying fat.__
*__Low pH meat is pale, poor water binding and emulsifying fat.__
*The reason for this condition is unknown but may be due to **metabolic activity of muscles.**
*It has no effect on tenderness, juiciness and flavor of meat but its effect is a **visual or aesthetic** view point for consumer.

5- Dark Cutting Beef:

*Dark lean muscles failed to brighten on exposure to oxygen in air.

*It is characterized by **low glycogen reserves and low reducing sugar content** → high pH (5.8 or above) → favors microbial growth → low oxidation reduction potential → low oxygen uptake by muscles.

*It is difficult to be cured because it does not take up the curing salts since the **water bind with the muscle proteins forming closed structure.** To overcome this problem, meat should be **chopped to facilitate curing and ↓ microbial spoilage which is due to high pH.**

6- Sex odor:

*It is present in **fat** not in lean tissues.
*It appears in **pork** meat when **heated.**
*Meat with pronounced sexual odor must be condemned and not used for food products.
*It is detected by using **boiling and roasting test.**
***It is recorded more in **boars** than other classes of swine.

7- Mutton flavor:

*It is a strong flavor associated with mutton meat.
*Meat from mutton carcass is less marketable than lamb.
*Mutton meat should be **20-25%** of the total meat block to avoid marked flavor.
*It is related to the age of sheep.
*Mutton meat is **dark red** in color and coarse in texture.
*Lamb meat is **pink** in color.

Selection and Grading of Raw Meat Materials for Processing

*The first step for processing of meat into meat products is the **selection of raw meat materials, taking into account their quality, processing suitability and the characteristics of the meat products:**

a- some meat products require lean meat without adhering fat or C.T.
b- Others require higher fat and/or C.T.
c- Others require firm animal fats.

d- Others require soft fats.

*In formulating **emulsion type products as frankfurter and luncheon,** the **collagen/total protein ratio must not exceed 25** to avoid the problem arising from collagen.

*Meat with **higher collagen** factor is suitable for **comminuted products.**

*Meat with **lower collagen** factor is suitable for the production of **high quality products like beef rolls.**

Grading of Poultry Meat for Processing

I- Grading of chicken meat for large operations:

1- Chicken white muscle with visible fat (CH1):

*Skin and C.T. are removed.

*For this grade mainly **breast and fillet** meat is used.

*The meat of this grade is used for **restructured chicken hams and chicken sausages** with visible coarse meat parts, all fat and skin must be removed from the lean meat.

2- Chicken muscle meat with adhering S/C and I/M fat (CH2):

*Deboned and skinless meat from all chicken cuts (breast, legs and wings) can be used.

*This meat is ground or chopped during further processing.

*Smaller quantities of S/C and I/M fat are usually not removed and incorporated in the final product.

3- Chicken skin/fat (CH3):

*Chicken skin is removed from the carcass or individual cuts and collected separately.

*Chicken skin is ground before adding to processed meat products.

4- Mechanically deboned chicken meat (CH4):

*This grade is manufactured in industrial chicken plants by **mechanical separation of the remaining muscle tissue from the chicken carcass after removing legs and wings and the breast muscles including skin.** Chicken necks are also used.

*Mechanically separated meat is an ingredient **for lower – cost meat products for partial substitution of the lean meat.**

II- Grading of chicken meat for small operations:

1- Grade 1: Trimmed lean breast and fillet muscle meat (light color).

2- **Grade 2:** Leg meat (darker color) and trimmings from carcasses.
3- **Grade 3:** Skin/fat.

Meat Particle Size Reduction

The method and degree of comminuting of meat ingredients of processed meat products affect:

1- Sensory characteristics of the product.
2- Technological characteristics of the materials.

1- Sectioning:

*The process of **separation of entire muscles by seaming**.
*It is very useful for **large muscles of the hind leg and shoulder**.
***Denuding:** removal of sheaths of epimysium C.T resulting in extremely high quality meat materials. It is preferred in case of **basterma.**

2- Chunking:

*Meat can be made into chunks with an **ordinary knife, a meat dicer, a bowl chopper or a coarse grinder plate.**

3- Slicing:

*Frozen meat may be sliced on **high speed slicers.**
*Slicing is useful for issues which are **high in fat intended for use in restructured products.**
*Careful control of **knife sharpness and meat temperature** are necessary.

4- Flaking:

*Boneless frozen meat blocks can be cut into **cubes or flakes of predictable size** by **frozen meat cutters or flakers.**
*It is the initial step in breaking down frozen blocks for further comminuting.
***Hydroflaking:** metal blocks are reduced to **coarse flakes or slices** of **unpredictable size.**
***Fat** portion should be tempered to about **0ºC** and the **lean** to about **-5ºC.**
*Frozen meat flakes can be directly minced or chopped without previous thawing avoiding **drip losses, bacterial growth and discoloration** which would occur during thawing.

5- Grinding:

*Larger meat pieces are reduced in size by passing them through meat **grinders.**
*Some grinders can handle **soft frozen tissues**,

*others can separate **hard tissues** as tendons and bone particles from the soft tissues,

*others can directly handle **frozen meat blocks**.

*Meat low in C.T. and fat can be coarsely ground through a plate with large openings; other plates can produce very finely comminuted ground meat.

6- Chopping:

***Bowl cutters (choppers)** are used to **mix and chop fresh or frozen lean meat, fat together with water, functional additives and extenders** to reduce particle size to coarsely or fine chopped material.

*Some of theses machines are **with vacuum and others add cooking operation** during the chopping.

*Careful control of **knife sharpness, spacing, and number of knives, proper bowl and knife speed** are essential.

7- Emulsifying:

*Meat to be emulsified must be pre-mixed with all other raw materials, seasonings and pre-cuts using **grinders or bowl cutters.**

*The pre-blend is passed through an **emulsion mill** equipped with an **impeller, knives and a high – powered motor.**

*This machine is widely used to **reduce the particle size to a very uniform state for the manufacture of frankfurters.**

Equipments Used in Meat Processing

1- Frozen Meat Cutter:

*Cutting frozen meat blocks into smaller pieces to be suitable for comminuting without previous thawing.

***There are 2 types:**

1- Working with knives cutting in vertical direction.

2- Using rotating drums with attached sharp knives.

2- Slicer:

*Meat blocks must be tempered to **-2°C** to be sliced on any of different types of machine.

***Slicers with circular blades** can be used **to reduce either tempered or cooked material to thick or thin slices.**

3- Meat Grinder (Mincer):

*Machine used to force meat or meat trimmings **under pressure** through a **barrel** → at the end of the barrel there is a cutting system consisting of **rotating star shaped knives** and **stationary perforated**

grinding plates. The simple type contains one star knife and one grinder plate.

*The degree of mincing is determined by **the size of holes in the last grinding plate.**

*Mincing of frozen meat and meat rich in C.T. into small particles, should be minced first through **a coarse disc** → followed by a **second operation to the desired size.**

4- Bowl Cutter (Bowl Chopper):

*Bowl cutter produces **finely comminuted** meat and fat particles for production of **finely comminuted products** such as **frankfurters, liver sausage.**

***It consists of:**

a- Horizontally revolving **bowl**

b- Set of curved rotating **knives: whose number, shape, arrangement and speed** are the main factors determining the performance of the cutter.

c- **Strong cover (lid):**

*Protects against accidents.

*Has a role in the efficiency of chopping.

d- **Thermometer** displaying the temperature of the meat mixture in the bowl during chopping.

e- **Devices to operate under vacuum (in modern large scale bowl cutters)** which:

***Improve color and texture of meat products by keeping oxygen out of the meat mix.**

***Avoid air pockets.**

f- **Mechanical discharger devices (in modern large scale bowl cutters)** for emptying the cutter.

4- Emulsifying Machine:

*It is used to prepare **very fine meat emulsions.**

*Compared to the bowl cutter, the emulsifier operates at **much higher speed producing a finer emulsion-like mix.**

*It is perfectly used with **semi-processed products** such as pig skin emulsion.

5- Filling Machine "Sausage Stuffer":

*They are used for filling all types of meat mixtures into containers as casings, glass jars and cans.

*The most common type is the **piston type.**

*Modern filling machines are designed as **continuous vacuum stuffers** which remove part of the enclosed air from the product → improve color and texture of the finished products.

6- Clipping Machine:

*They place **small aluminum sealing clips** on the sausage ends.

*They can be **connected to the filling machines** and can be used for both **natural and artificial casings.**

7- Desinewer:

*It is used in **poultry processing** for the production of **poultry rolls and ham.**

*It removes **C.T.** which can be passed through emulsion mills to produce finely comminuted C.T. All hard tissues also could be removed.

*Materials which come out of the desinewer are **low in C.T.** and acceptable for use as **coarsely chopped product components**.

8- Mechanical Separator (Deboner):

*Used in poultry and fish industries to remove adhering meat from bones.

9- Mixer "Massager = Tumbler" and Blender:

*They apply **mechanical energy** to products of various particle sizes.

***Mixers** blend coarse and finely chopped meat with **additives.**

*Some mixers are **vacuum mixers** as the mixing under vacuum leads to the **development of desirable product color and texture.**

***Blenders** come in many sizes, shapes and capacity.

***Rotating drum with steel paddles** slowly move the meat pieces → **mechanical massaging** effect → dropping the meat in the **tumbler** → internal structure of meat disrupted → enhancing its ability to entrap water and fat upon heating → **vacuum** during tumbling ↓ **entrance of air into the extracted myofibrillar proteins.**

***Tumbling process** is assisted by the addition of **salt and phosphates** to:

a- Achieve equal brine distribution.

b- Extraction of myosin from the meat tissue.

***Tumbler** should be placed **below 10°C** to avoid **excessive microbial growth during long tumbling times (more than 4 hrs or even overnight).**

*In specific cases, tumblers should be operated **refrigerated or inside a cold room below -1°C,** as these temperatures are best to **extract as much soluble protein as possible** from the muscle meat.

10- Former and Portioner:

*Restructured products must be formed into the desirable size and shape.

*Product may be refrigerated and formed before freezing or cooking.

*Product may be placed in a forming container in which it is cooked and chilled.

11- Patty Former:

*It is used for shaping **burger patties.**

*It can shape steaks or chops at **high speed** → delivering the shapes onto a belt → for transfer to a freeze tunnel or continuous cooker.

*Using proper belt, patty stacking and boxing equipment helps to assure:

a- Efficient operation

b- Minimal damage to the patties.

12- Brine Injector:

*It is used for various types of ham, bacon and other whole muscle products.

***Brine** is water containing dissolved salt, curing substances, phosphates, spices, and sugar and/or soy proteins.

*Injection is done by introducing pointed needles into the muscle tissue.

*It is available in different sizes from **manually operated single needle** devices to **semi-automated brine injectors with up to 32 needles and more.**

*All parts of brine injectors must be cleaned thoroughly and **rinsed with warm water** due to:

a- particles left in the system can block the needles.

b- m.o remaining in the system would be injected deep into the meat pieces during the operation.

13- Cooker and Smokehouse:

*Meat products are cooked either in **dry or humid** atmosphere.

*Cooking chamber is made of **stainless steel.**

*At the top of chamber there is a very strong **fan** at its middle → air passes through a group of **heaters** → cooking chamber → hot air enters the cooking chamber from the **middle and circulates to the**

periphery → after cooking, the product must be **showered** to cool to the room temperature.

*__Humid cooking: water spray__ is introduced on the functioning fan at the top of cooking chamber → water spray converts into **vapors** to saturate the cooking chamber with humidity.

*The cooker must be supplied with **3 sensors:**

1- Sensor for the chamber temperature **(dry bulb)**
2- Sensor for the product temperature.
3- Sensor for the relative humidity **(wet bulb).**

*In factories with high production power, cooking units are used for **both cooking and smoking → sawdust smoke generators** are used, these generators:

a- **Facilitate the control of density of smoke**
b- **Facilitate washing undesirable particles formed during combustion process** → then the generated smoke is drawn by a fan into the smokehouse.

*Wet-bulb and dry-bulb thermometers are used to control temperature and humidity in the smokehouse.

*__Smoking, cooking and cooling operations__ can be combined in one continuous process by using **automatic stirring systems,** in which the smoke generation, temperature **(up to 100^{o}C)** and relative humidity **(up to 100%)** needed to dry, smoke, or steam-cook any product can be pre-set.

***Additional refrigerated units** installed in the smokehouse, and can be also used as a **fermenting/ripening room** for the first steps in production of fermented sausage, where temperature, humidity and velocity are controlled.

14- Ice Flaker:

*Ice flakes are continuously produced from potable water.

*Water is added in the form of ice in order to:

1- Enhance protein solution.
2- Keep the temperature of the meat batter low.

*Ice flakers with **built-in UV-water disinfection device** are available for areas with unsafe water supply.

Manufacturing Cuts

Type	**Noble Cuts**	**Less Noble Cuts**
Quality	**High** quality properties for	**Low** quality properties for

	manufacturing.	manufacturing and **more likely** to be used in manufacturing.
Properties	1- ↑ Content of muscles. 2- ↓ Amount of C.T. 3- Small amount of external fat and bones which are easily removed. 4- Easily cooked by grilling or roasting. 5- Tender when lightly cooked. 6- Simply served and provides desirable lean meat. 7- Highly regarded and highly priced.	1- ↓ muscle content 2- ↑ C.T. 3- Complex bone structure.
Source	taken from **hindquarters** due to: 1- Less moving parts. 2- Simpler bone structure. 3- Less large muscles. 4- Less C.T. 5- Fat deposits mainly on the outside.	taken from **forequarter** whose muscles are characterized by: 1- Many and complex moving parts. 2- Complex bone structure. 3- Many smaller muscles. 4- More C.T.

Technical problems found during modifying or upgrading of less noble cuts of meat:

1- Removal of bones.
2- Making C.T. less objectionable.
3- Presenting the available fat in more acceptable form.
4- Improving of flavor and nutritive value.

Toughness of meat may be due to:

1- **Cutting** of meat before or during RM → **muscles shorten** → tough meat when cooked.
2- **Chilling** of meat rapidly after slaughter → **cold shortening** → tough meat. It is common in **sheep and cattle** but not in pig and poultry.
3- **Freezing** of meat before or during RM → **thaw rigor** (strong contraction **without toughness** when meat is thawed).
4- **Cooking** of meat **before** the onset of RM → **very tender meat.**
   Cooking of meat **during** RM → **tough meat.**
   Cooking of meat **after** the resolution of RM → **tender meat.**

Methods of reduction of toughness of meat:

1- **Tender stretch process:** carcass is hanged from certain bone immediately after slaughter → proportion of noble muscles are stretched → ↑ tenderness.

2- **Hot meat processing:** salt treatment before RM to prevent contraction and ↑ water holding capacity.

3- **Electrical stimulation:** electrical shocks immediately after slaughter → rapid onset of RM → rapid chilling without the risk of cold shortening. This method is used in frozen lamb and beef meat but not in pork meat due to:
   a- Pig carcasses are not generally frozen.
   b- There is a danger of PSE.

Processing Principles

Factors must be attended in meat processing:

1- **Moisture:** natural moisture content must be retained to optimum extent during manufacturing, distribution, storage and cooking.
2- **Fat:** natural fat content of meat and any extra fat should be retained to optimum extent during manufacturing, distribution, storage and cooking.
3- **C.T.:** should be presented in more acceptable form.
4- **Cohesion:** product should retain its physical integrity.

***Water Holding Capacity (WHC):** the ability of meat to retain the tissue water present within its structure during application of external forces as heating, cutting, mincing, grinding or pressing.

***Water Binding Capacity (WBC):** the ability of meat to bind with the added water.

***Cooking Loss:** water and fat or jelly which is lost from a piece of meat or meat mixture on cooking.

***Meat Binding:** adhesion of meat pieces with each other especially after cooking.

*The water content of lean meat is **75%:**
a- 5% bounded to protein. **b- 45%** held firmly.
c- 25% held by capillary forces and may be squeezed out.

*Fatty tissue contains **10%** water.

Measurement of Moisture Retention:

1- **Drip:** Put pieces of meat in polyethylene bags and held under standard conditions → weigh the liquid collected in the bottom of bags. Drip from unprocessed meat is usually quite **low (0.3%). Large drip loss** is usually associated with **abnormal pH.**

2- **Pressing:** Put a weighted sample on filter paper → pressed between 2 plates → note the area of the filter paper wetted by the exudates from meat.

3- **Centrifugation:** amount of liquid removed depending on the speed of centrifuge.

4- **Cooking Loss:** water and fat or jelly separated from a meat product under standard cooking conditions. It may be measured directly through the product yield.

N.B.: Addition of water alone → ↑ yield of lean meat on cooking.
→ Apparent ↑ in cooking loss.
100 gm lean meat on cooking → 80 gm cooked meat + 20 gm cooking loss.
100 gm lean meat + 20 ml water on cooking → 88 gm cooked meat + 32 gm cooking loss.

Color of Meat

Color develops as a result of the reaction of **nitrites** with the muscle pigments.

Myoglobin:

*It is the **predominant pigment in muscle** and **serves as the storage mechanism for oxygen at the cellular level.**
*It has a greater affinity for oxygen.
*It becomes the major pigment after slaughter by bleeding.
*It accounts for only **10%** of the total iron in the live animal, but after bleeding it may account for **95%** of the iron in beef skeletal muscle.

Hemoglobin:

*It is the red pigment found in blood and acts as the **carrier for oxygen** to the tissues.
***It is the **predominant pigment in the living animal.**

Factors affecting the amount of myoglobin and hemoglobin in various tissues:

1- Amount of muscular activity of tissue:

Tissues of **high degree of muscular activity** tend to have **greater proportions of both myoglobin and hemoglobin.**
e.g. Heart is the most active muscle in the body.

2- Blood supply:
Tissues with a relatively **good supply** tend to have **more hemoglobin** and **less myoglobin** than muscles having a poorer oxygen supply. e.g. wing muscles of birds.

3- Oxygen availability:
If the tissues are able to store **large amounts of oxygen,** the **myoglobin content is relatively high and the hemoglobin content is relatively low.** e.g. Whales have the ability to store large amounts of oxygen because of its extremely high myoglobin content and thus can remain submerged for extended periods of time.

4- Type of packaging:
- a- ↑ O_2 permeable film → bright red meat (oxyMb).
- b- Vacuum packs → purple (MMb).
- c- Gas impermeable packs containing a high concentration of O_2 → color maintained for up to **14 days.**

5- Age of the animals:
The **young** animals have **less myoglobin and more hemoglobin** than **older** animals of the same species. ↑ Mb with ↑ age.

6- Species of animals: beef contains much more Mb than **pork.**

7- Sex: males have more Mb than **females.**

8- Products of bacterial metabolism:
- a- **H_2S:** H_2S + Mb → green sulphamyoglobin in uneviscerated poultry and over aged vacuum packed meat.
- b- **H_2O_2 products**: strong oxidizing agent → pigment breakdown → greening or pale color.
- c- **Colored bacteria:**
  Pseudomonas species → blue green.
  Sarcinia and *Micrococcus species* → red color.

9- Temperature:
- a- ↑ **temp.** → ↑ MMb (dark red).
- b- ↓ **temp.** → Stable red color due to ↓ **O_2 consuming reactions and O_2 is more soluble and penetrates into the meat.**

c- **Rapid freezing** → small ice crystals → ↑ light scattering → pale meat.

d- **Slow freezing** → large ice crystals → ↓ light scattering → dark color.

e- **-18ºC or below** → red color.

f- **Thawed meat** → brown color (less stable).

10- pH:

a- DFD → alkaline pH → ↑ swollen muscle fibers with H_2O enclosed inside the muscle fibers → ↓ O_2 penetration → ↓ MbO_2 + ↑ MMb + ↓ light scattering on the surface of meat → dark color.

b- PSE → acidic pH + carcass is warm → partial denaturation of proteins → oxidation of part of the pigment + ↑ light scattering on the surface of meat → pale color.

11- Light: UV light → protein denaturation → browning in longer time.

12- Reducing agents: promote the formation of bright red oxyMb. Meat containing reductants (e.g. ascorbic acid, nicotinic acid and sulphur dioxide) shows improved color while in fact it is bacteriologically unhealthy.

13- Oxidizing agents: promote the formation of brown MMb. So avoid the cleaning agents, ozone, rancid fats and nitrite.

14- Metals:

a- Cu promotes the autooxidation of oxyMb into MMb (brown color).

b- Citrate or phosphates improve the red color stability.

Composition of Myoglobin and Hemoglobin:

*They are composed of a protein known as **globulin,** complexed to a non protein iron containing fraction known as **heme.**

*The heme is composed of 2 parts: **iron and porphyrin.**

*Heme + globulin → myoglobin or hemoglobin.

***Myoglobin → 1 heme group/molecule (molecular weight 16000 – 17000).**

***Hemeglobin → 4 hemes/molecule (molecular weight 64000).**

Color of the pigments:

***In living tissues,** the color exists in equilibrium between reduced dull purple red form and oxygenated bright red form, and **metmyoglobin** is

continuously **reduced** back to **myoglobin** by the action of **reducing enzymes** which are naturally present in tissues.

*__Upon death,__ the efficiency of reducing system gradually ↓ → **O_2** in tissues is rapidly **depleted** → there is a gradual build up of **metmyoglobin** until it predominates → the meat color becomes **dull purple red or brown.**

*__Metmyoglobin__ is the undesirable brown red pigment and is typically observed on the exposed surface of aged meat.

*There are **3 forms** of myoglobin: **myoglobin (Mb) (purple red), oxymyoglobin (MbO_2) (bright cherry red)** and **metmyoglobin (MMb) (brownish red to black).**

*Although the 3 forms of myoglobin are reversible, changes from metmyoglobin to other forms are **slower** and require more favorable conditions.

*The relative proportion of metmyoglobin and oxymyoglobin depends on the **partial O_2 pressure:**
Low O_2 pressure → favor **metmyoglobin** formation.
High O_2 pressure → favor **oxymyoglobin** formation.

Type of meat	Color	Cause
Fresh meat	Bright red	**Oxymyoglobin**
Decomposed meat	Green choleglobin + colorless bile pigment	Haeme detached from protein → porphyrin ring disrupted → loss of **Fe** atom from haeme → **Green choleglobin + colorless bile pigment**
Aged meat	Brown color	Efficiency of reducing system gradually ↓ → O_2 in tissues is rapidly depleted → there is a gradual build up of **metmyoglobin** until it predominates → the meat color becomes dull purple red or brown.

Role of Nitrite and / or Nitrate in Meat Color:

1- Nitrate (by nitrate reducing microorganism) → Nitrite (in the absence of light and oxygen) → Nitric oxide + H_2O

3- Nitric oxide + Myoglobin **(Mb)** → Nitric oxide metmyoglobin **(NOMMb)** → Nitric oxide myoglobin **(NOMb) (unstable)** by acidity or cooking (heat + smoke) → **Nitric oxide haemochromagen (stable pink attractive color).**

Binding Meat Products

Binding between meat particles in processed meat products can be induced:

1- **Naturally** through the **technological behavior** of the meat components in a comminuted meat system including:
   a- Emulsion model
   b- Mechanical massage model
   c- Protein coagulation through acidification

2- **Artificially** by the help of some **edible non-meat additives** which can bind meat particles and other ingredients together.

I- Meat Emulsions: emulsion is a **colloidal suspension** composed of:

1- Internal (dispersed) phase: Fat particles which must be reduced in size to form small droplets distributed throughout the external phase.

2- External (continuous) phase: Matrix which is an aqueous solution of **salts where soluble proteins and particles of muscle fibers and C.T.** are dispersed.

3- Emulsifying agent: Muscle proteins especially myosin:

a- Required for the development of a **stable** emulsion. Emulsion is **thermodynamically unstable** because the free energy of **internal** phase is **higher** than that of the **external** phase.

b- Must have both **hydrophilic** and **hydrophobic** characteristics.

c- Physical Entrapment and Emulsion Theory: This theory proposes that the fat is stabilized by **physical entrapment within viscous protein matrix prior to heating and within a three-dimensional gel matrix after heating.** Therefore, **both physical entrapment and emulsification** are very important in stabilizing meat batters.

Comminuting of meat with **salt + water** + **phosphates** → muscle fibers are cut into small fragments → ↑ **solubilization and extraction** of salt soluble myofibrillar proteins (myosin) through **physical (chopping)** and **chemical (salting)** treatment of meat → myosin absorbs water and swells forming **continuous protein film** which acts as **interface** between fat and water → **fat globules are coated with liquid myofibrillar protein films and/or entrapped in the viscous**

protein matrix before cooking to prevent coalescence of fat → ↑ **in the viscosity of the meat mix → during thermal processing (cooking to 70-72ºC core temperature),** myofibrillar proteins undergo denaturation or coagulation forming **three-dimensional gel matrix which physically entraps fat particles** preventing their coalescence → water is either bound to proteins or entrapped as fat in the protein matrix and kept in place upon protein denaturation → ↓ cooking loss → firmness of the final product.

Symptoms of instability during processing and handling of meat emulsion are:

1- Coalescence of fat particles.
2- Water exudation.
3- Fat separation.
4- Aggregation of the matrix.

Factors enhancing meat emulsion formation and stability:

1- Alkaline pH → ↑ protein solubility and extractability.
2- ↓ in size of **fat** particles providing that there is sufficient **protein** to adequately coat the fat particles.

Causes of instability of meat emulsion:

Basic causes:

I- Improper or incomplete formation of salt-soluble proteins coat around the fat particles.

II- Destruction of protein coating during thermal processing.

Secondary causes:

1- Frozen storage: ↓ protein solubility and extractability after **1 week** of freezing → no acute emulsion stability can be obtained after **37 weeks** of frozen storage.

2- **Short chopping time** → coarse fat particles which are not able to be coated with protein.

3- **Incorrect temperature during chopping and comminuting:** as chopping continues → emulsion temperature enhances the fat particle reduction → ↑ the surface area of the fat particles→ more protein is required to coat the fat globules → the uncoated fat separates from the mixture during heating → **fat separation and water exudation.**

Final batter temperature (ºC) for different meats:

	Fresh meat	**Frozen meat**
Beef	**18**	**6-8**
Pork	**13-16**	**7**
chicken	**7**	**5**

4- Over chopping leads to **water exudation and fat separation,** where the fat globules which measures 5 units in diameter are chopped to give 1 unit in diameter → on continuous chopping, the volume remains the same, the fat particles become smaller and smaller in diameter and the surface area of the fat ↑ 5-folds → more protein is required to coat the fat globules → the uncoated fat separates from the mixture during heating → **fat separation and water exudation.**

5- Imbalance of myosin to collagen in the meat mass and low content of lean meat in the formula → low content of myosin → **too much collagen (short meat)** → fat particles become coated with **collagen instead of myosin** → it seems identical, but on **thermal processing,** the collagen shrinks → collagen converts into **gelatin** → collagen drains from the fat surface → fat particles coalesce together → **fat cap at the top of the product and/or a jelly pocket at the bottom.**

6- Not enough or too much water → ↓ protein solubility and extractability.

7- Insufficient salt → ↓ protein solubility and extractability.

8- High fat level.

9- Rapid or excessive heating: protein coating entraps the fat particle → the **fat particle expands** on continued heating, whereas the **protein shrinks → the coated protein sac ruptures** → entrapped fat separates → **fat separation.**

II- Mechanical Massage Binding:

Raw meat is just chunked, sectioned or **coarse** comminuted **(without fine reducing of the meat particle size)** → binding is developed **naturally** through mechanical means as mixing, massaging, tumbling and mechanical tenderization.

III- Protein Coagulation by Acidulation:

*Water has 2 positive and 2 negative poles. Each water molecule binds 4 others (one at each pole), therefore water attracts water (water-water interaction).

*Proteins are composed of amino acids, each have polar and non-polar properties and they are charged.

***Myofibrillar proteins** are most important and have the **most polar and charged amino acids** and consequently **hold the majority of water** in meat → followed by the **sarcoplasmic proteins** → finally the **stromal proteins.** So, any significant changes in the

distribution of water within the muscle must originate from changes in **myofilament structure.**

*Water of meat is held by proteins to different degrees referred to as:

1- Free water: water held only by surface forces.

2- Bound water: tightly bound to the charged amino acids groups of muscle protein and reduced only when muscle goes in rigor mortis or during cooking.

3- Immobilized water: attracted to the bound water molecules in layers that become successively weaker as the distance from the reactive group on the protein becomes greater.

*The isoelectric point is the pH at which the no. of + ve charges equals the – ve charges. In meat, the isoelectric point is at pH 5.4-5.6.

*Proteins have both – ve and + ve charges on their side chains. At the time of death, the predominant charges on muscle proteins are **– ve charges** → which cause the proteins to repel one another → providing more spaces to bind water → **high WHC** of meat.

*PM → production of lactic acid → ↓ in pH → elimination of – ve charges on protein surface → fewer charges are available on the protein molecules → no available binding sites to hold water → water is physically forced out between the protein chains → **low WHC** of meat.

Meat Cooking

Action of cooking:

1- Denaturation of muscle proteins.
2- Change the solubility of muscle proteins through its effect on hydrophilic and lipophilic bonds.
3- Coagulation of surface proteins → dryness of the meat surface → skin formation especially in skinless products as frankfurter giving product of good appearance.
4- Partial destruction of the bacterial flora → ↓ spoilage → ↑ K.Q and extension of shelf life of meat.
5- Intensifying the flavor and altering the texture → improvement of palatability.
6- Inactivation of endogenous enzymes by high temperature where internal temperature 57-62ºC can prevent further proteolysis.
7- Color development through stabilizing the action of nitrite on myoglobin and Hb resulting in attractive pink color.

Factors affecting flavor and aroma of meat:

1- **Animal species.**
2- **Amount and kind of fat:** mutton and lamb meat have undesirable odour on cooking so they must be used in limited amount.
3- **Age:** old aged meat has stronger odor than young one.
4- **Preslaughter feeding:** fish meal, garlic, onion affect flavor.
5- **Post slaughter aging of meat:** meat must be used as rapidly as possible to prevent rancidity.
6- **Method of cooking:** each method has a characteristic flavor.

Traditional methods of cooking:

1- **Dry heat cooking:** meat is surrounded with **hot air** as oven roasting. It is recommended for **tender cuts** as steaks.
2- **Moist heat cooking:** by using **hot water or steam** leading to gelatinization of collagen. It is recommended for **tough cuts** as shank and breast beef to ↓ skrinkage losses and such cuts may be cooked in casings to hold the meat juice.
3- **Microwave cooking:**

***Advantages:**

a- Rapid and uniform heating.
b- Wide range of selectivity
c- Ease of control
d- ↓ energy used.

***Disadvantages:**

a- Excessive steaming may produce sogginess in some meat products.
b- Its speed depends on the food quantity.
c- Thawing may be externally but the centre of food is still frozen.
d- Heating may not be the same in all areas of oven.
e- Microwave cannot penetrate the metal.
f- It cannot produce the desirable brown color of cooked product.

Specific cooking methods:

1- Broiling: dry heat with wire grill.
2- Roasting: 121-204ºC / 20 minutes.
3- Frying: dry heat through frying pan containing oil.
4- Braising: moist heat at first then dry heat after smearing with fat.
5- Pot roasting: vegetables should be added at proper time of processing.
6- Stewing: small pieces of meat are usually covered with water and boiled.
7- Pressure cooking: by using high cooking temperature with lower time.
8- Simmering: cooking is done below the boiling temperature.

Preservation of Meat

Def.: The application of measures:

a- To control deteriorative changes in flavor odour, texture, appearance and nutritive value of meat, which render the meat unfit for human consumption.

b- To retard or prevent pathogenic microbial growth.

Principles of Meat Preservation:

I- Prevention (bactericidal) or delaying (bacteriostatic) the growth of the microbial decomposition by:

a- Keeping out m.o→ by asepsis

b- Removal of m.o → by filtration

c- Prevention of microbial decomposition → canning and irradiation

d- Hindering the growth and activity of m.o by:

* Low temperature (chilling and freezing) *Curing
* Drying *Smoking

II- Prevention or delay of self decomposition of meat by:

a- Destruction or inactivation of meat enzymes: by blanching as in canning.

b- Prevention or delay purely chemical reactions as:

*Prevention of fat oxidation by using antioxidant as vitamin E (natural antioxidant).

*Sorbic acid, ascorbate, tocopherol and phosphates in 100-200 ppm which are used:

- As additives
- Color stabilizer
- Prevent formation of nitrosamine
- Improve cooked meat flavor

III- Prevention of damage caused by insects, animals or mechanical:

Three types of deteriorative or spoiled changes:

a- Microbial spoilage: from contamination of meat as intrinsic or extrinsic factors or microbial enzymes

b- Enzymatic spoilage: self – meat enzymes

c- Mechanical or insects' damage

Factors affecting the selection of method of preservation:

1- The effect of the method of preservation on the quality of the product.
2- Health hazards involved for food handlers and consumers.
3- Method's possible misuse.
4- Distribution and marketing problems.
5- Engineering and economic evaluation of the method's commercial application.

Growth curve of microbial cultures:

1- In food preservation, it is very important to lengthen the **lag phase** by:
   a- Reducing the contamination.
   b- Avoiding the addition of actively growing organisms from the **log phase** of growth because their **generation time is the shortest.**
   c- Applying one or more unfavorable environmental conditions → the longer → will be the delay of the initiation of growth.
   d- Actual damage to organisms by processing methods as heating or irradiation.

2- **More favorable** environmental conditions → **generation time** of m.o **shortens** → **shortening** of shelf life of food**.**
   Less favorable environmental conditions → **generation time** of m.o **lengthens** → **extension** of shelf life of food**.**
   These environmental conditions include:
   a- Type of food
   b- Temperature
   c- Available moisture
   d- pH
   e- Oxidation – reduction potential
   f- Presence of inhibitors

Methods of Preservation:

I- Physical means:

*Drying (dehydration) *Refrigeration (low temperature)
*Canning (high temperature & anaerobic conditions)
*Irradiation (mechanical destruction)

II- Chemical means:

*Salting *Pickling
*Smoking *Antibiotics

III- Combination of both physical & chemicals means

I- Physical means

1- Drying (Dehydration)

*It plays a **minor** role in preservation.
*It is suitable for **perishable food** which is rich in water and protein.
*It is used for fresh meat, blood, sausage, meat and bone flour, skin.
*The **humidity** of dried meat must be **not more than 8-10%,** because if dried meat is kept in **humid atmosphere** → ↑ **moisture content** of meat → **favorable conditions** for microbial growth in meat.
***Dried raw meat** (4 months at 37ºC) is **less stable** than **boiled meat** (12 months at 37ºC and 28 months at 20ºC).
***Principle:** it depends on the removal of water necessary for microbial growth, where bacterial growth and multiplication are stopped **(bacteriostatic)** at **12-16%** moisture content.
*Meat should be cut into strips for easily removal of water (dried meat contains **10%** water) with controlled RH around the product.

Methods of Drying:

1- Sun drying:

*It is the most primitive method of preserving meat.
*It is limited to countries with hot climate and dry atmosphere (low degree of humidity).
*Exposed meat strips to sun rays without controlled temperature, RH and air drafts.

2- Mechanical driers:

*It involves the passage of heated air with controlled RH over the food or passage of food through such air.
*It does not affect the physical or organoleptic characters of the treated food.
*It is suitable for fresh food (non frozen products).
***Hot ovens for meat drying (hot air dryers).**
***Hot sprays for blood and milk.**

3- Sublimation drying (freeze drying):

***It is the process of removing water from **frozen foods.**

*The products must be in comminuted form and packaging must be completely moisture-proof.

*Since meat has high moisture content, it is expensive to preserve food by this method, so it can be used as a supplement to traditional methods of refrigeration.

*Some **heat** must be supplied to the frozen product to provide energy for **sublimation of the ice to water vapor** but it must be done without raising the temperature of the product high enough to produce thawing.

*The stability of these products depends on:

a- Quality of the products before drying.
b- Residual moisture content
c- Storage temperature
d- Method of drying
e- Method of packaging

*Deterioration of freeze dried products is due to:

a- Fat rancidity
b- Non enzymatic browning
c- Protein denaturation

*It can be applied in different methods as:

a- Dehydration of frozen product under vacuum **(at 58ºC under 1.5 mm. / HG and with 2% moisture)** plus **gentle heat** applied at the drying

b- Slow freezing of meat then transferred to a vacuum chamber then dried giving much better product that remains acceptable for one year.

4- Smoking then drying: the preservative effect of smoking is due to ↑ of temperature during burning of wood leading to:

a- Evaporation of water.
b- Precipitation of volatile materials on the meat surface.

5- Cure drying:

Meat strips are firstly cured in salt solution, sometimes immersed in acetic acid and then dried.

6- Electronic drying

Affections of Dried Meat:

1- Mould growth on the surface: because RH of air is **75% or more,** at lower humidity, moulds develop but too slowly, where a visible mycelium appears in three months or more.

2- Hardening and toughness of dried meat: due to more rapid evaporation of moisture from the surface. It must be soaked in water to make it soft before eating.

Public health dangers associated with consumption of dried meat:

1- The possible contamination with ***Salomonella*** which leads to food poisoning (meat especially from septicaemic animals). *Salmonella* may be viable for **six months or more** in dried meat.

2- Dangers due to handling, preparation and storage of dried meat.

2- Refrigeration or Cold – Storage

***Def.:** The extraction of food heat and cooling it to a temperature below that of the surrounding environment.

***Principle:**

1- Artificial lowering of the temperature than that required for microbial growth and multiplication → removal of the available water used for bacterial growth & converting it into ice crystals → reducing or delaying of the growth and multiplication of harmful, ordinary spoilage bacteria and fungi **(bacteriostatic).**

2- Inhibition of the action of the natural autolytic enzymes and deteriorative chemical reactions.

Methods of Cold - Storage:

A- Natural methods:

1- Cooling on or in ice: meat saturated with water leading to mould growth.

2- Cooling through ice: by using ice - cellars to give cold air.

3- Using dry ice: solid Co_2 either in block or crushed to provide temperature between **0 – 10°C** as in meat transport wagons.

B- Mechanical method:

- The main refrigerants used in commercial refrigeration are **liquefied gases with low boiling points as methyl chloride and freon** → compressed → passed through pipes → **condenser** where it is **cooled** (lowering much of its original heat) and **condensed to a liquid** → the liquid refrigerant is stored in a high pressure → expansion pressure reducing valve → the release of pressure cause the liquid refrigerant to **vaporize and extract heat from the surrounding atmosphere** → the gas is then recompressed by the **compressor** and cooled to be condensed into liquid to be used again.

- Some gases have been used but nowadays cannot be used as:

1- **Co_2** is uneconomical.
2- **Sulfur dioxide** is corrosive and toxic.
3- **Ammonia** is corrosive and has a penetrating odour which can affect stored products.

- These gases are harmful, so they are circulated in pipes placed in the chilling rooms, then recompressed again until use for another chilling cycle.

Conditions of Cold Stores: Cold stores must be kept at:

1- Constant temperature
2- Good air circulation of fresh air.
3- Maintained RH between **88 – 92%** since:

a- above 92%→ condensation of moisture on surface of cold meat → ↑ slime and mould formation.

b- below 88% leads to:

- ↑ dryness
- Moisture loss
- Undesirable economic weight losses
- ↓ nutritive value of meat
- Affect maturation and tenderness of meat.

Types of Cold - Storage:

A- Chilling (short term storage)
B- Freezing (long term storage)

A- Chilling (short – term storage)

Def.:

*Preservation of meat in a condition approaching its natural state for periods adequate for commercial requirements with minor changes in its weight, sensory attributes (flavor and appearance) and nutritional value in comparison to fresh meat.

*It is the best method for preserving meat for **short time,** where the enzymatic and microbial activities are not prevented but are **slowed down.**

***Chilled meat is maintained at:**

a- **0 – 1ºC,** in **dark chamber** to prevent fat oxidation
b- **Dry atmosphere** to prevent mould growth.

Chilling Methods:

1- Traditional chilling (Slow chilling)
2-Quick chilling
3- Ultra - rapid chilling

1- Traditional chilling (Slow chilling):

*It depends upon the environmental or ambient temperature where the carcass is hanged in an open hall for **12 – 24 hrs** at room temperature to allow the lowering of carcass temperature from that of the body **(39ºC).**

*Then the carcass is passed through chilling rooms where the last room is of temperature **-1ºC.** This step takes **28 – 30 hrs.**

***Disadvantages:**

- Time needed for this method is **2 – 3 days.**
- **5%** loss of weight.

2- Quick chilling:

*****Rapid lowering of carcass temperature from that of the body temperature not later than 1 hr after slaughter and avoiding freezing.

*The chilling rooms are pre-cooled to **(-3 to -4ºC)** before being loaded with carcasses.

*Then the compressor is stopped till the carcasses are loaded as quickly as possible after slaughter and/or under low air speeds.

*After loading, the doors of chilling rooms are closed and all fans are switched on and the chill room air temperature is controlled at **(-3 to -4ºC/ 3 – 4 hrs).**

*Then raise the temperature to (**0 - 1ºC),** with **air speed more than 1 m/sec. for about 14 hrs** → this step will raise the temperature of the inner carcass to **(7 ºC)** and RH of (**88 – 92%)** (about **95%** for stored meat) in less than **72 hrs.**

***Precautions:**

1- The carcasses should not be subjected to **too low temperature or too high air circulation for the first 24 hrs.**

2- Chilling rooms should be loaded as quickly as possible.

3- Temperature must be kept at **not less than 5ºC with an air speed of not less than 1 m/sec. for the first 24 hrs for beef carcasses.** For **lamb,** the temperature should **not be less than 10ºC** for the **first 10 hrs.**

***Advantages:**

a- Less weight loss.
b- Minimal changes in tenderness, quality and flavor.
c- It saves time, labor and building space.
d- It reduces shrinkage.
e- It enhances the appearance and bloom of the carcasses.

f- It keeps better meat quality, since lower air temperature retards the rate of bacterial growth on the surface.

***Disadvantage: Cold–shortening phenomena:**

- Lower temperatures and higher air speed leads to **Cold–shortening phenomena**. This phenomena is due to extreme contractions of muscles subjected to **5 - 10 ºC,** before the onset of **normal rigor mortis**, pH is still **6.2** and ATP is still present → so this leads to toughness of meat mainly occurring in beef loin and lamb carcass.

- This phenomenon could be avoided by:
  a- Delaying of chilling for **10-12 hrs** till decline of pH to below 6.2 and development of RM.
  b- Avoid chilling **below 10ºC in less than 10 hrs.**
  c- Using electrical stimulation which advances the onset of RM.

3- Ultra - rapid chilling:

*It occurs mainly in pork, where the carcass is exposed to **(-7 to -30ºC) with air speed 1 m/sec. for 4 hrs.**

***Advantage:** it is safer.

***Disadvantages:**

a- dehydration b- toughness of meat c- ↑drip loss

Factors affecting chilling storage of meat:

1- Air circulation:

*Proper air circulation helps movement of **heat** away from the meat surface toward refrigerator cooling coils and plates.

*Control of air velocities within the storage rooms is important to:

a- Maintain a **uniform RH** throughout the chilling storage room, since meat in areas of **high RH** undergo **microbial decomposition.**

b- Remove stale odours and flavors.

2- Temperature: 0 – 1ºC, since at this temperature the growth of pathogens and the important spoilage organisms is prevented or greatly slow down. ***C. botulinum type E*** can grow and secrete toxins at **3.3ºC.**

3- Relative humidity (RH): 88-92%, changes in **RH and temperature** during chilling storage may cause precipitation of moisture **"sweating".**

4- Composition of storage atmospheres:

*Introduction of **CO_2 (10% for chilled beef and up to 100% for bacon)** and ozone or removal of O_2.

*Using of **gas in combination with chilling storage** helps in:
a- Maintaining the meat **unspoiled for a longer period.**
b- Maintaining **higher RH** or **storage temperature** without harming the KQ of meat.

5- The combination of **UV rays with chilling storage helps in:**
a- Preservation of some food.
b- Permit the use of **a higher RH or storage temperature** than that applied with chilling alone.

N.B.:
*Heavy beef carcass requires **72 hrs** to chill.
*Light beef, pork, veal and lamb require **24–36 hrs** to reach **3ºC i**nside the meat.
*The shelf life (durability) of chilled meat varies from **25–30 days** depending on:
a- The initial bacterial count of meat.
b- RH of the external environment.
c- The introduction of **CO_2 10%** and **ozone** which delay the spoilage up to **60 -70 days.**
*Ozone is a powerful oxidizing agent and may produce fat rancidity.
***CO_2** should be not more than **20%** since it **prevents the formation of metmyoglobin and so bloom loss.**
***CO_2** at **10% and 0 ºC** (storage temperature) double the shelf life and no bloom loss.

Changes (affections) in chilled meat:
1- Conditioning (ripening or maturation):
*Means marked increase in tenderness, juiciness and flavor of meat by autolysis or self- digestion by **autolytic enzymes** as tissue proteinases e.g. cathepthin which act on muscle fibers. Those enzymes are inhibited when meat is stored at freezing temperature.

*The tenderness is produced by softening and swelling of the **collagen** fibers which convert to more digestible and softer **gelatin** by the action of lactic acid.

*Tenderness of meat is affected by breed, age and condition of nutrition.

2- Shrinkage:
*Freshly slaughtered carcasses lose about **1.5 - 2%** of their weights during the **first 24 hrs** of hanging as a result of evaporation of water from the meat surface.

* Further losses depend upon the RH of the storage room, the drier the air the greater amount of evaporation **(up to 2.5%).**

*Higher temperature and lower RH → ↑ the weight loss due to drying out. High RH facilitates the mould growth. Therefore, accurate balance between temperature and RH is maintained by the use of a high velocity- cold air system (turbo- chill) to reduce moisture losses.

*Evaporation can be inhibited by:

a- dry impervious film on the carcass surface is the best trial to protect the meat against growth of spoilage organisms.

b- Membranes as pleura and peritoneum.

c- Solidification of the superficial fat and drying of C.T. in carcasses of well nourished animals.

3-Soiling:

Means meat contaminated with skin of undressed calves of from living animals brought to chilled room.

4- Absorption of foreign odour (for unsaturated fat):

*Over ripened unsound vegetables and fish previously stored without adequate cleaning.

*Using a strong smelling substance as carbolic acid, ammonia, formalin, and ozone to disinfect or to deodorize the chilling rooms.

5- Sweating:

*It is the condensation of water vapor on meat surface, when brought from a cold store into ordinary room temperature.

*This occurs because the cold refrigerated carcass lowers the temperature of the air surrounding it to **below the dew point,** (in winter below **4.5ºC** no sweat, but in summer over **7ºC,** so sweat deposit).

6- Loss of bloom:

*Bloom means that color and general appearance of the surface of carcass of freshly slaughtered animal (semitransparent C.T., muscle & fat).

*Loss of bloom may be due to:

a- Semitransparent C.T., muscle & fat become moist → collagen fibers in C.T. swell and become opaque and meat surface assumes a dull or lifeless.

b- Dehydration

c- Undue oxidation

*This phenomena can be **prevented by:**

a- Avoid temperature fluctuation.

b- Keep high RH.

c- Good air circulation.

7- Darkening in color:

Myoglobin may be converted to **metmyoglobin (brown color)** due to exposure to air and in little or no consequence except in case of frozen meat which undergoes prolonged storage.

8- Chemical changes:

*Slight degree of break down of protein due to either endogenous enzymes (proteolytic enzymes) or microbial enzymes.

***Odour** of meat becomes **more marked but never undesirable**

***Stale flavor,** rendering the meat **unpalatable but not repulsive.**

*Storage life of meat is dependent on **chemical changes of fat** rather than **muscle (fat rancidity) especially kidney fat.**

***The unpleasant odour or flavor in fat may be due to:**

a- Absorption of foreign odour.

b- Atmospheric oxidation.

c- Action of lipolytic m.o which hydrolyses fat with the liberation of FA → fat rancidity which in even slight degree renders the meat repugnant and unmarketable.

9- Spoilage:

a- Mould formation:

Mould flavors lead to lipolytic rancidity due to (lipase enzyme) and impart moldy odour (musty odour). Its prevention is by fumigation by air containing sulphurous acid gas, formalin vapor 3% ozone prior to meat refrigeration.

b- Bacterial decomposition:

***Slime formation:** due to **psychrotrophic** bacterial growth.

***Bone taint:** due to **anaerobic spore formers.**

Cold store taint:** due to ***Achromobacter which can grow at **0°C** forming small glistening **brown droplets** which eventually coalesce to form a **brownish slime** on the meat surface with the production of **sour odour**.

Phosphorescence:** due to ***Pseudomonas phosphoresens (found in sea water) and ***Photobacterium phosphoreum*** which may contaminate the chilling rooms. In dark, the surface of meat

shows scattered luminous areas which appear as stars. It disappears when decomposition develops.

B- Freezing (long term storage)

Def.: during freezing the following occurs:

1- Water present in the muscle fibers diffuses from the muscle plasma to form ice crystals.
2- ↑ the concentration of dissolved substances (salts, sugars, minerals and soluble protein) in the unfrozen moisture.
3- ↓ available water.
4- ↓ the freezing point of the liquid.

Principle:

1- Freezing inhibits the vital metabolic, chemical and enzymatic processes of the bacteria contaminating the meat and they are unable to produce toxins until favorable conditions for their growth are available.

2- Prevention of multiplication of bacteria, yeasts and moulds by lowering of the temperature lower than **-9ºC** → change of the available water into ice.

N.B.: It is a better to freeze **a well nourished heavy beef carcass** as it has a layer of **S/C fat** protecting it from drying. Fatty beef suffer from loss of weight **3-9% every 2 months** during storage according to R.H. of the environment. Meat should be well trimmed to avoid fat rancidity on long storage.

Cold store should have the following criteria to prevent growth of ordinary spoilage and food poisoning m.o:

1- Temperature must be checked regularly. Avoid temperature fluctuation by more than **0.5ºC,** since big temperature changes can cause partial thawing which damages the structure of meat.
2- Avoid over loading and carcass must not touch each other to prevent cross contamination.
3- Door opening and closing must be kept to minimum.
4- Adequate air flow around carcass.
5- Carcass of different species must not occupy the same area.
6- Cold stores must be cleaned with cold & hot water (under pressure) and potassium permanganate or formalin solutions or NaOH **(at 80ºC)**, for cleaning smooth surfaces, or New gram 50.
7- Cold shortening phenomena must be avoided **by not chilling below 10ºC in less than 10 hours.**

Freezing rate:

1- It is an important bearing factor affects on the size of the ice crystals and the future quality of the stored meat.

2- According to air speed, time, temperature & RH, the freezing rates are divided into:

a- Slow freezing (-15 to -29ºC) → freezing time: 36-72 hrs.

b- Rapid or quick freezing (-18 to - 40ºC) → freezing time: 30 minutes.

3- The mechanism of slow & rapid freezing:

a- Meat is consists of myofibrils floating in a solution (sarcoplasm) inside the muscle fibers.

b- The concentration of sarcoplasmic solution is more than that fluid between muscle fibers.

c- Pure water is frozen at **0ºC** but due to presence of the colloidal substances in sarcoplasm proteins (albumin globulin & casein) & minerals (Na or K) so, it is frozen (ice crystals are formed) between **- 1.5ºC** and **- 5ºC** after that degree no further crystallization so, its called **"zone of maximum ice – crystal formation".**

d- According to previous, if the temperature or the time length is not so enough to freeze the solution inside the muscle fiber but enough to freeze the solution in between the muscle fiber, lead to formation of the ice- crystals in between muscle fiber at first.

e- In case of **slow freezing** the **largest extracellular ice** crystals (12 mm x 3 mm) are formed outside the muscle fibers at the zone of maximum ice crystal **(-1.5 and -5ºC),** which leads to:

1- Destruction of sarcolemma of muscle fiber.
2- High dripping losses during thawing.
3- Denaturation of protein is irreversible where there is no reabsorption of water – soluble nutrients by meat.
4- Increase damage of the tissue cells.
5- Decrease in meat quality and palatability.

f- In case of **rapid freezing:**

*it begins by a temperature enough to freeze the solution in between muscle fibers, at the same time leads to formation of **ultramicroscopic ice- crystals (0.001- 0.002 mm)** which are evenly distributed, **inside and outside muscle fiber**.

***it is better than slow freezing due to:**

1- No destruction of the sarcolemma of muscle fiber leading to low weeping during thawing.

2- Denaturation of protein is reversible due to reabsorption of water – soluble nutrients by meat.
3- Less mechanical destruction of intact muscle cell wall.
4- Does not affect the palatability of meat.
5- Appears as bright red in color (good bloom).
6- Shorter period of solidification.
7- Less time for diffusion of soluble materials and for separation of ice from the other nutritive materials.
8- More efficient prevention of microbial growth.
9- More rapid hindering of enzyme activities.

***Freezing methods**:

1- Still air freezing:

a- By convection at **-10** to **-30ºC:**

b- Accomplished by placing packaged or loose foods in suitable freezing rooms and remain until be frozen.

c- It is the cheapest and slowest method with no air speed.

d- The length of time required to freeze the food is longer so, depending upon:

* Temperature of freezing room.
* Type of food.
* Type, size, & shape of the food package.

2-Blast freezing (sharp or fast or forced air):

a- As still air, using a compressor, which pushed cold airs to pass over, under and through the food is used.

b- The temperature of air is between **-10ºC** to **-40ºC**.

c- Air velocity **15 m/s.**

d- Advantages:

* More rapid freezing due to high speed of air.
* Functional due to that this cold air blasts in an insulated tunnel.

e- Disadvantages for (1) & (2):

* Dehydration of food (drying) affects quality.
* Freezer burn (affected part is removed).

f- Freezing time: rapid freezing.

N.B.: Therefore, that food should be wrapped with aluminum paper, cellophane or polyethylene bag to avoid the **freezer burn and imperfect articulation of cooling pipes (brine stain).**

3- Direct immersion freezing:

a- Direct immersion of food in a **liquid refrigerant** offers the most rapid method of freezing because **liquids are good heat conductors by comparing with air or gases;** they are used as **sprays or in fog** systems.

b- Liquids which are used are **NaCl, glycerol & sugar solutions** (used as low temperature heat exchanger systems).

c- These liquids must be safe, non- toxic, cheap and with low viscosity.

d- Usually used for poultry, fishes and some meat types to be frozen.

e- **Freezing time** is **30 min.**

f- Advantages:

*Prevent the oxidative changes (rancidity) in sensitive food.

*Food must be packed to avoid taste of the liquid and if package contains holes or cracks, it renders the food unpalatable.

4- Cryogenic freezing:

a- The best method of quick freezing depends upon the **condensed gases** such as **liquid nitrogen (-195ºC)** or **liquid nitric oxide (-78ºC),** dry ice **(-98ºC)** and liquid air, liquid CO_2 **(-79ºC)** and Freon **(-30ºC)** used in meat practice.

b- The vapor of the liquid nitrogen passes through room containing meat or food products.

c- The liquid gases are used in the form of solid and the vapor passes through the meat, fish, meat patties and shell- fish.

d- Freezing time is rapid freezing.

e- Advantages:

* Non toxic and inert to the food constituents

* Minimize the oxidative changes during freezing

* Less dehydration loss (less than 0.3%).

* Less drip loss during thawing.

*Better flavor, color, aroma, texture and nutritive value than the conventional methods.

f- Disadvantage: Expensive than other methods of freezing.

5- Plate freezing:

a- Freezing by indirect contact with refrigerants.

b- The food is placed on cold plates or walls as a metal surface, which is cooled by a refrigerant

c- Food may be packed in a can and immersed in a refrigerant.

d- Food may be packaged in paperboard box, and the box is placed in contact with metal plates which may be moving in the form of a belt or be stationary.

e- Using "birds eye multiple freezing" performs another method that consists of a certain number of metal plates through which the refrigerant circulates. The food is usually placed between these plates.

f- Freezing time: 1-2 hr. for 5 cm. thick meat slices.

Changes of frozen meat:

I- Changes during freezing:

Physical changes:

a- Muscle plasma:

The concentration of albumin & globulin is considered altered when meat is frozen below **-2ºC.** So, the ice crystals formation raises the conc. of those proteins that they become insoluble or not return to normal even when meat is thawed.

b- Ice crystal formation:

Freezing of meat beings at **-1ºC.**

-1.5ºC→35.5% of the water content of muscle convert to ice.

-3.5ºC → 70% of the water content of muscle converts to ice.

-5ºC → 82% of the water content of muscle converts to ice.

-10ºC →94% of the water content of muscle converts to ice.

-55ºC →100% of the water content of muscle converts to ice.

So, the rate & method of freezing affect the keeping quality of the meat. With **slow freezing, larger ice crystals** accumulate between tissues which may crush cells than with **quick freezing.**

II- Changes of frozen meat during storage:

Changes in meat quality are less if meat is stored at **-18ºC.**

1- Fat Rancidity:

*Lipid autooxidation is the most serious change in frozen–stored meat.

***Fat rancidity depends on:**

a- Availability and contact with oxygen.

b- Action of lipolytic bacteria.

c- Lipase enzyme produced by moulds (lipolytic rancidity).

***Beef and lamb meat that contain saturated fatty acids are much more resistant to **oxidative rancidity** than pork meat which contains unsaturated fatty acids.

2- Freezer burn:

*It occurs on the outer surface of imported frozen offal (liver& kidneys) and is attributed to crystallization; dehydration and loss of moisture from the tissue surface due to:

a- Close to the opening of cold air pusher.

b- Coming in contact with refrigerating tubes.

c- Storage at lower RH.

*Surface becomes soft, spongy with yellow patches.

*It is **irreversible** and persists after meat is thawed.

Judgment: affected organs are unmarketable & unpalatable and when cooked require condemnation.

Prevention:

1- Enclosing in parchment paper to prevent dehydration before packing.
2- Tight fitting
3- Moisture proof packaging
4- Stable storage temperature

3- Brine staining:

*Meat stored on refrigerating chambers with imperfect joint or articulation or leakages in the circulating systems may be contaminated with **$CaCl_2$ or ammonium hydroxide,** producing a characteristic **dull or pale greenish colour on the carcass surface.** The stain frequently penetrates and **darkens the muscular tissue** which has extremely **bitter taste** differ from staining with **sea water** which giver **salty taste and no pale greenish colour.**

Judgment: carcass released after trimming.

4- Loss of weight:

***The loss of weight per **4 weeks** for unwrapped meat is about **0.2% at -30 ºC** and **1% at -8 ºC.**

*Wrapping of meat in polyethylene reduces the loss in weight per **4 weeks** frozen storage to **0.05% at -30 ºC** and **0.16% at -8 ºC.**

*Loss in weight is **greater** in partially **empty** stores than in **full** ones.

III- Microbiological changes:

1-Fungal formation (ubiquitous in nature):

***The chief causes for mould growth on imported lean meat are:**

1- Exposure to dust in between leaving the refrigerating chamber and sale.
2- Fluctuation in temperature in freezing rooms (intermittent freezing) leading to water condensation.
3- High humidity.
4- Long holding periods.
5- Bad ventilation of storage room.

***Meat containing mould growth may be unfit (unmarketable and unsafe) for human consumption due to:**

1- Muddy or musty odour.
2- ↑ alkalinity.
3- Decomposition of protein and fat.

4- Elaboration of mycotoxins.
5- ↓ nutritive value of the affected meat.

***Types:**

a- Stickiness: Mould growth makes meat surface sticky to touch.

b- Black spots: 6-13 mm diameter, not more than 3mm in depth caused by ***Cladosporidium herbarum, Clad. Cladosporioides, Aspergillus niger* & *P. hirsutum*,** grow well at **(0°C to -8°C),** commonly found in beef in (neck, diaphragm & pleura), while in sheep (legs, inside the neck, or in or on thoracic & abdominal cavities).

Judgment:

*Less extensive → **trimming** and the meat not refrozen → **rapid consumption.**

*Extensive cases accompanied with ***Achromobacter*** group with (decomposition) → **T.C.**

c- White spots: small flat, wooly spot, superficial, caused by ***Sporotrichum carnis*** and ***Mucor***, 6-13mm in diameter, develop at **-8°C** grows plentifully at **-2.5°C.**

Judgment: Removed easily by **wiping** the surface.

d- Whiskers: cottony or fuzzy appearance due to collapsed mycelial growth, grow at **0°C**, project more than 2.5cm cease to grow below **-7.5°C**, caused by ***Thamnidium elegans*, *Mucor* and *Rhizopus species.***

Judgment: Removed by **wiping.**

e- Green bluish patches: superficial grows with difficulty at **0°C** or slightly higher, caused by ***Aspergillus*** and ***Penicillium spp.* as *P. oxalicum.***

Judgment: Removed by **trimming.**

f- Yeast: may grow on meat surface causing sliminess, lipolysis, off - odour and discoloration to white, cream, pink & brown due to pigment formation.

Judgment: wiping.

2- Bacterial slime: appears as a small glistening like droplets at first, when RH is more than 90%. droplets coalesce to form a thin layer, finally a thick yellowish brown slime is formed on carcass surface with the production of a characteristic odour (cold- store taint or stall) this formation is mainly due to **psychrotrophic bacteria (*Pseudomonas, Flavobacterium, Achromobacter, Micrococcus, Bacillus,* Yeasts** as ***Candida*).**

3- Bone taint:

Def: It is deep seated spoilage of bacterial origin especially anaerobic bacteria.

Causes: **Anaerobic putrefactive spore forming bacteria as *Clostridium sporogenes.***

Predisposing Factors:

1- Exhausted or stressed animal pre- slaughter (fright and stock), since it not develop high degree of acidity as in well rested animal, and the anaerobic putrefactive bacteria causing bone taint prefer the neutral, non- acidic conditions which are found in carcasses of stressed animals.

2- High body temperature inside the meat after slaughter without rapid refrigeration (as in heavy = over fattened carcass).

3- Presence of synovial or alkaline media in joints.

4- No oxygen in joints or deep seated muscles.

Mechanism:

Anaerobic bacteria is found in digestive tract of animal before slaughter → after slaughter, the carcass temp. falls rapidly, but in heavy (over fattened) carcass the high temp. may persist for some time in deep- seated muscles → bacterial growth in these areas.

Area (Prediction seats):

1- Hip joint of cattle, pig where the synovial fluid of hip joint is a good media for bacterial growth with PH 7-8 (PH of normal muscle is around 6)

2- Shoulder area of cattle.

Appearance:

1- Putrefactive smell.
2- Brown to grey in colour.
3- Soft meat.
4- Possible discolouration of surrounding muscles.

Detection: by insertion of steel trier inside joints and smell the putrefactive offensive odour.

Prevention:

1- Good pre- slaughter care especially during hot weather.
2- Remove body heat by cooling of the carcass by rapid chilling.
3- Open the joints in heavy carcass.

Judgment:

1 Localized → condemn the affected parts.

2- Extensive putrefaction→ condemn the whole quarter.

IV- Changes during thawing of frozen meat:

***Conditions of thawing:**

1- Slow and well controlled thawing results in:

a- meat like the original meat.

b- Better return of moisture to the cells than rapid thawing.

2- Air thawing is better than water thawing:

3- Fans and cooler are needed to control optimum air temperature at **10°C** and air speed **0.5-1 m/sec** over the meat.

1- Weeping or Dripping:

***Def.:** The presence of watery blood - stained fluid which escapes from frozen meat when thawed and consists mainly of water, salts, extractives (creatin, creatinin, phosphatase), water soluble proteins and damaged RBCs (responsible for the pink colouration of the fluid).

***Causes:**

1- Permanent irreversible changes in the muscle plasma which prevent the frozen muscle from reabsorbing water on thawing.

2- The size of ice crystals in frozen meat has a **direct relationship** with the damage of cells and therefore the amount of drip:

a- Slow freezing produces large ice crystals which mechanically rupture the thin sheath of muscle fibers.

b- Rapid freezing produces small ice crystals causing little or no damage.

3- Faster rate of breakdown of ATP in muscle → the more rapid onset of rigor mortis → greater release of fluid from the muscle.

4- Meat with **high pH (6.1-6.3)** prior to freezing → low drip when thawed.

***P.H.H.:**

1- Thawing of frozen meat gives abundant water supply which is an excellent medium for bacterial growth especially **psychrophilic m.o** in case of slow thawing.

2- ↑ the rate of enzymatic action in food.

II- Chemical Means:

1- Salting **3- Pickling**

2- Smoking **4- Antibiotics**

***Salting:** Means the use of dry salt as it is superficially for short period of preservation.

***Pickling (curing):** Means the immersion of meat in a solution of salt and water called brine or pickle soln. for long period of preservation.

***Methods of Curing:**

1- Dry salt curing method:

a- This method is used for heavy fatty meat (bellies & fatty back).

b- Use salt alone or salt in combination with nitrate and/or nitrite.

c- Done by rubbing salt crystals over the meat surface and by placing in between meat layers. Salting period should **not be less than 40 days** and the salt crystals should be changed at **5, 15, 25th days** then washed in between with warm water at **26^{o}C** → **smoked for 24-36 hrs at 60^{o}C** → cooled in dark ventilated place → dusted with pea flour or meal to enhance smoked appearance.

***Advantages:**

1- Safe method (little spoilage if found).

2- Easy and little special care is required.

***Disadvantages:**

1- The end product is hard, too salty, unpalatable and with dark undesirable color.

2- Conventional dry curing method:

a- It involves salt, nitrate and/or nitrite and sugar (no water used).

b- Time required for dry curing:

Hams and shoulder → 2-2.5 days/pound.

Belly → 7 days/inch of thickness

Bacon → 10-14 days.

***Advantages:**

1- Production of special product of high price.

2- Products (cuts) are less perishable due to their dryness and firmness.

***Disadvantages:**

1- High cost due to the amount of labor required.

2- Harsh salty flavor of the final product.

3- Pickling (Curing):

a- The same ingredients used in conventional dry curing method but dissolved in water to form a brine or pickling or curing soln.

b- Types of curing solution:

***Plain curing:** using NaCl only.

***Dry curing:** NaCl + salt petre.

***Dry – sweat curing:** NaCl + sugar + salt petre.

c- The best brine solution is 8Lb salt, 2Lb sugar and 2 oz salt petre dissolved in 4 gallons of water for every 100Lb of meat.

d- Applied on **pork (fore & hind hams)** or **beef joints with a high fat content (brisket & flanks)**, but not on lean beef or mutton meat (which becomes dry and unpalatable on curing).

e- Temperature of curing soln. should be **60-70ºC**.

f- Time required for curing is the same as that of conventional dry curing method.

***Advantages:**

1- Requires less labor than dry curing.

2- Gives a product with a milder flavor than dry curing.

***Pickling (curing) can be applied by different ways:**

1- Meat packed closely in a clean vat or barrel and completely covered with brine using weight if necessary.

2- Direct addition to the final product as in minced meat and sausage.

3-Artery pumping:

*This method pumps the pickle soln. into the cuts through the **arterial system** where the needle is usually inserted in the **femoral artery.** It is limited to curing hams.

*Temperature of pump pickling is **65-80ºC.**

*The ingredients as dry curing in addition to **water phosphates** to aid in water retention and increase yields.

***Advantages:**

a- High speed of curing. b- Relatively high yield.

***Disadvantages:**

a- It is largely limited to curing of hams and cannot be readily used for other products.

b- Special care is required in cutting to maintain the artery intact.

c- Cured hams are perishable and require refrigeration.

4- Single – needle stitch pumping:

*It utilizes a needle with several openings, so it can be adapted to a variety of cuts. It does not depend on the arterial system.

***Advantages:**

a- It gives a wetter product than that of artery pumping.

***Disadvantages:**

a- It requires special care to produce a good quality product because the brine accumulated at the injection sites.

b- Longer time is required for cure diffusion by stitch pumping.

5- Multiple – needle stitch pumping:

*Pickling soln. is pumped through a large number of needles spaced relatively close together, so the distribution of pickling soln. in the desired weight is excellent.

***Advantages:**

a- Low production cost due to reduced labor costs and time required for production.

b- High yield due to lower production costs

***Disadvantages:**

a- Less desirable flavor.

b- Cooking shrinkage is greater than that of dry curing.

6-Thermal or hot cures:

*To achieve maximum advantages, the hot cures must be distributed into the tissues rapidly before the cure becomes cold.

*Hot pickle cures can best be injected by artery or stitch pumping.

***Advantages:**

a- The hot cures speed up the rate of curing and allow acceleration of the entire processing operation.

b- Greater amounts of improved smoke flavor.

c- Absence of pickle pockets.

d- Increased yields over dry curing, although lower than injection curing.

***Disadvantages:**

a- Difficulty and problems in heating and applying the curing soln.

b- Reduced yields as compared to the injection curing.

c- It is adapted only to relatively thin cuts.

Curing agents:

1- Common salt (NaCl)
2- Sugar
3-Na ascorbate
4- Monosodium Glutamate (MSG)
5- Hydrolyzed Vegetable Proteins (HVP)
7- Salt petre (Na nitrite or Na nitrate)
8-Phosphates
9-K sorbate

6- Glucone – Delta – Lactone (GDL)

Affections of pickled meat:

1- Decomposition detected by trier to deeper part and with boiling and roasting test.

2- Sourness (acidity).

3- Blown or puffed hams.

4- Bone taint of beef.

N.B.:

1- Putrefactive microorganisms are inhibited at 10% salt.

2- In brine: upper layer → *Micrococci*, yeast & lactic acid bacteria.
bottom layer → Lactobacteria, anaerobes.

***Effect of picking on pathogenic microorganisms & parasites**:

1- ***Salmonella*** remain viable for **80 days in 10-13 %.**

2- ***Erysipelothrix rhusiopathiae*** remains virulent for **4 months.**

3- **Swine fever** virus for **27 days.**

4- **Parasites: Brine salt 25%** destroy:

a- ***Cysticerci*** → 3 weeks.

b- ***Trichinella*** → 40 days and must be followed by smoking for 10 days at 45ºC with subsequent drying..

***Effect of temperature on curing:**

1- Temperature of 3.3ºC → gives efficient cure results.

2- Temperature lower than 3.3ºC → retards both the penetration of cure and the growth of favorable flavor – producing bacteria.

3- Temperature higher than 3.3ºC → used when very quick cures are desired and at the same time it favors the bacterial growth especially ***Cl. botulinum.***

So, it is important to hold the temperature of meat products below 3.3ºC during curing to render the bacteria relatively inactive until the salt penetrates the meat.