Conversion of muscle to meat

- After understanding structure of muscle we know that is highly complex contractile system.
- Exsanguination— It is removal of blood from the body of a slaughtered animal.
- Homeostasis comes into play as soon as the process of exsanguination begins. Homeostasis is a system of checks and balances which through these efforts tries to maintain a physiological balance of internal environment. It executes the efforts to support the desire of a living being to live. The biological systems function efficiently within a narrow range of physiological conditions (pH, temperature oxygen concentration and energy supply).
- Homeostatic system is regulated by nervous systems. These systems trigger mechanisms of checks and balances in an attempt to live. The homeostasis is important because–
- **a)** reactions and changes during conversion of muscle to meat are result of homeostasis.
- **b)** pre-slaughter conditions may alter postmortem changes and thereby have bearing on quality of meat.

Animal slaughtered

↓

Exsanguination

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Blood pressure drops
(In an attempt to maintain the blood pressure and ensure blood supply to vital organs)

↓

i) Heart pumping increases
ii)peripheral vasoconstriction

↓

Results in stoppage of nutrient supply to muscle and removal of waste products loss of oxygen supply to muscle. Temperature of carcass rises due to failure of temperature control mechanism.

↓

Myoglobin stores little oxygen which is sufficient for short period as a result stored oxygen is depleted.

↓

The above sets in anaerobic metabolism

leading to production of lactic acid.

↓

The energy so produced is less and is only sufficient to maintain structural integrity and temperature.

↓

Lactic acid produced as an end product of anaerobic metabolism can not be removed and is thus stored in muscles

↓

The above leads to fall in pH (the final pH would depend on amount of glycogen in the muscle at the time of exsanguination)

↓

As all homeostatic mechanisms have failed by this stage means that all defense mechanisms including those which protect a live animal against microorganisms are lost . As a result muscle becomes susceptible to microbial invasions.

- If pH continues to fall it will reach a range where the cathepsins get activated and lead to proteolysis.
- A normal pH drop should be from pH 7 to 5.6 - 5.7 in 6 - 8 hrs postmortem and to an ultimate pH in range 5.3 - 5.7 in 24 hrs post mortem.
- In some animals it will remain 6.5- 6.8 during the first hour after exsanguination.
- An early accumulation of lactic acid is linked with rise in carcass temperature which leads to denaturation of proteins. The level of denaturation of proteins is species specific with pork being more susceptible than beef.
- Denaturation will cause –

  i) Loss of protein solubility

  ii) Loss of water holding capacity

  iii) Loss in the intensity of muscle`s pigment coloration.

  ***i+ii + iii* = pale muscle**

with highly wet surfaces which in pork is PSE All above needs to be monitored so that conversion of muscle is guided through regulated values to become meat. This can be done by understanding the status of the animal subjected to slaughter and by proper handling and cooling of the carcasses.

Rigor mortis

- Rigor mortis is a latin word which means "stiffness to death".
- The contraction and relaxation of muscle constantly requires ATP i.e. to release the actin and myosin filaments from strong binding ATP is required.
- In absence of ATP (which happens postmortem) the actin and myosin remain bound together as an actomyosin complex.
- The above conditions lead to rigor mortis.
- All possible measure should be adopted to ensure that minimum of actomyosin complexes are formed.
- One of the common practices in the meat industry of hanging carcasses helps the muscles stretch by help of gravitational force.
- The period before rigor mortis during which muscle is relatively extensible and elastic is called the delay phase.
- Completion of rigor mortis is signalled by total depletion of creatine phosphate and other sources of rephosphorylation.

Postmortem changes in Color

- The color of muscle in living animal is bright red due to abundance of oxygen.
- postmortem there is shortage of oxygen and color becomes dark purplish red.
- Fresh meat when cut has dark red color but on exposure to atmospheric air within few minutes changes to brighter red color. This happens due to oxygenation of myoglobin.

Factors affecting post-mortem changes

1. Stress

Any external or internal stress activates the homeostatic mechanism which generates variable physiological responses so as to tide over the stress symptoms. These are executed through hormones. Most important are –

- Epinephrine – breaks down glycogen stored in liver & muscles, also breaks down fat.
- Epinephrine & norepinephrine – maintains the blood circulation
- Adrenal hormones – provide stress resistance.
- Thyroid hormones - increase metabolic rate.

2. Environmental effects

- Temperature – Too low a temperature to which an animal is not acclimitized will lead to all such changes which generate and conserve heat like shivering, higher rate of metabolism etc. Too high a temperature will not allow an animal to dissipate body heat leading to ATP splitting and glycolysis.
- Humidity – High levels of humidity add to discomfirt stress in a cold environment it increases heat loss and in a hot one it makes heat losses difficult.
- Light , sound, and space – Darkness – stresses the animal through the efforts made by it to go towards light.Less space – not providing an animal free mobility causes stress. Unfamiliar sounds – frighten the animal and cause stress.

Abnormal Post mortem changes

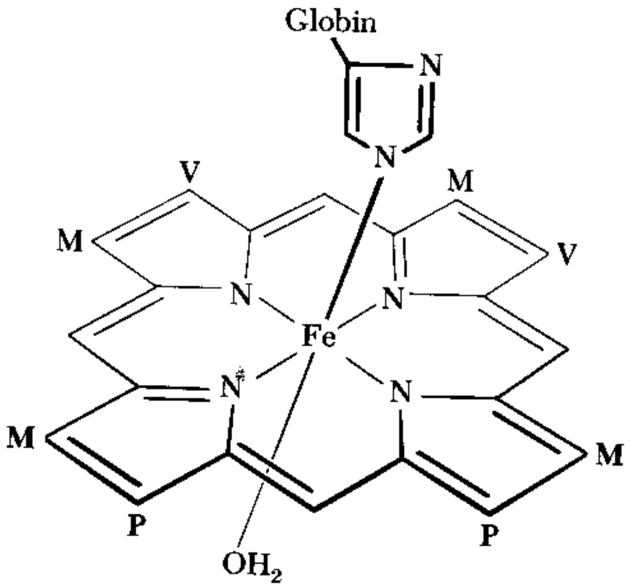
- Different types of stresses cause different of effects on the animal.
- Some of the stresses demand more from activity the muscle requiring more energy use which aerobic metabolism can`t meet fast enough.
- As a result the anaerobic metabolic pathway may also be activated.
- This may lead to generation of lactic acid and if the build is too large it may cause acidosis.
- In pork it is called "porcine stress syndrome" which may lead to death.

1. **PSE (Pale, soft, exudative meat)**
   - Results from low pH at high temperature. pH decreases twice as fast as normal causing PSE. PSE does not result from a low ultimate pH.
   - Pale because light is reflected by denatured sarcoplasmic proteins.
   - Softness and exudation from structural damage (areas of super contraction and Z- line loss, increased denaturation of protein.
   - PSE can be decreased by rapid post-mortem cooling.
   - PSE is common in pigs with defective ryanodiine receptors. The occurrence reflects susceptibility and triggering, not all susceptible pigs will exhibit PSE pork.
   - It must have increased ATP use for glycolysis to occur rapidly causing pH to fall abnormally fast
   - Ca++ leakage ⟶ contraction ⟶ ATP hydrolysis
   - PSE can be caused in normal pigs by improper handling.
2. **DFD (dark, firm and dry)**
   - The DFD condition can be found both in beef and pork.
   - Muscle appears dark and may be so dry as to be "sticky" just like pre- rigor muscle.
   - It is caused due to glycogen depletion pre -slaughter resulting in little or no lactic acid production post slaughter.
   - As a result post rigor muscle pH remains high > 6.0
   - Myosin and actin are far removed from isoelectric point.
   - The glycogen depletion pre-slaughter have already been discussed above.

Color of meat

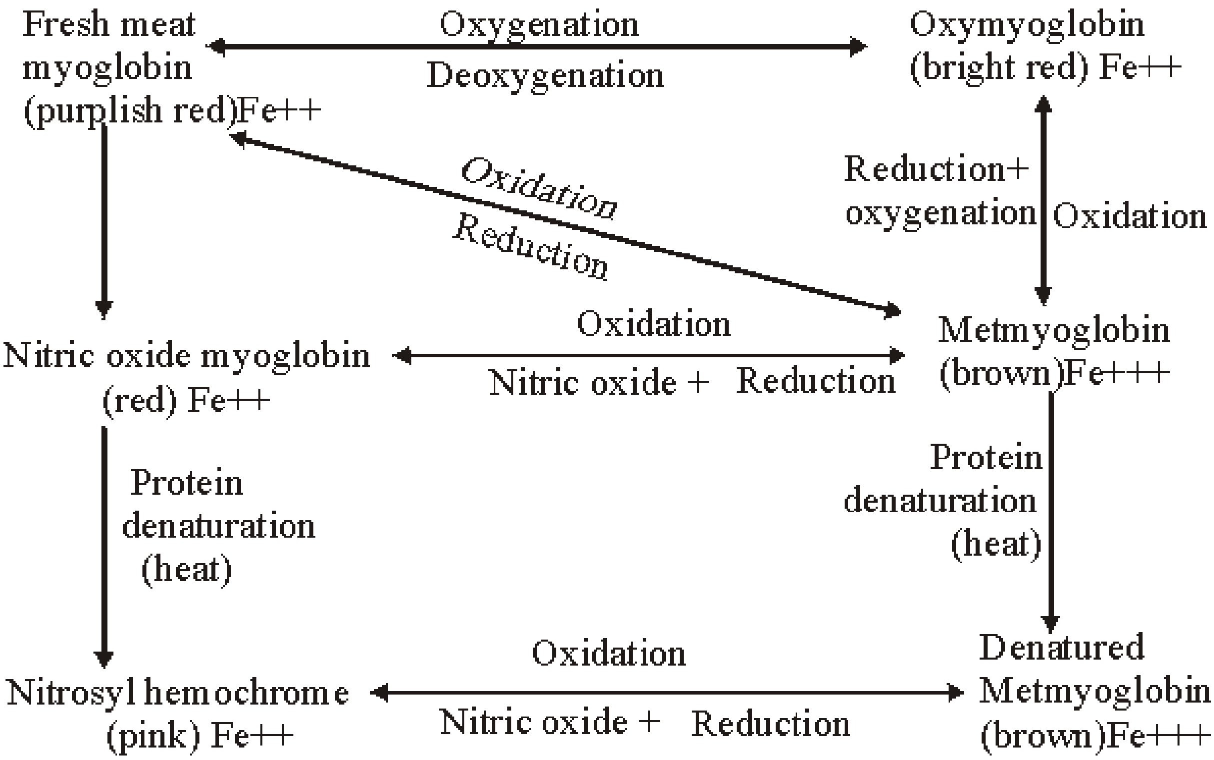
1.Meat is one of the most important factors affecting the consumer`s decision to purchase fresh and processed meat products.

2.**Myoglobin** is the predominant meat pigment and accounts for 80% of the meat pigment.



- Myoglobin consists of a protein called a globin and the non protein portion as heme ring.
- The heme portion is important as color of meat predominantly depends on the chemical state of the iron present in the heme ring.
- The heme group of myoglobin is planar structure with iron atom centrally located.
- Iron atom is a transition metal capable of existing as ferric (oxidized) and ferrous (reduced) forms. It has 6 coordination sites.
- These sites are available for chemical bonds.
- Out of 6 the 4 of these have iron atom attached with heme, the fifth connects iron atom to amino acid chain of globin protein and sixth to coordination site.
- The coordination site is available for binding of a variety of chemical groups.
- The chemical group bound to sixth site (i.e. known as ligand) the oxidation state of heme iron determines the color of meat.
- The oxidation state of heme iron affects the color of meat.
- The oxidation state determines which molecule will bind at sixth site of heme iron.
- The ferrous myoglobin or deoxymyoglobin 9 purplish red 0 bind O2 at the sixth site and form oxymyoglobin (cherry red). This is oxygenation and not oxidation (loss of electrons).
- The oxidation occurs in myoglobin when ferrous form is converted to ferric form and leads to formation of metmyoglobin (brownish red 0 in fresh meat. But the ligand in this case is water molecule.

Therefore there could be variable colors depending upon the oxidation state of central; iron atom and some of the **probable ones could be**. When meat is subjected to curing treatments the color reactions could be like **these.**



3. The myoglobin content varies with species, age, sex muscle and physical activity.

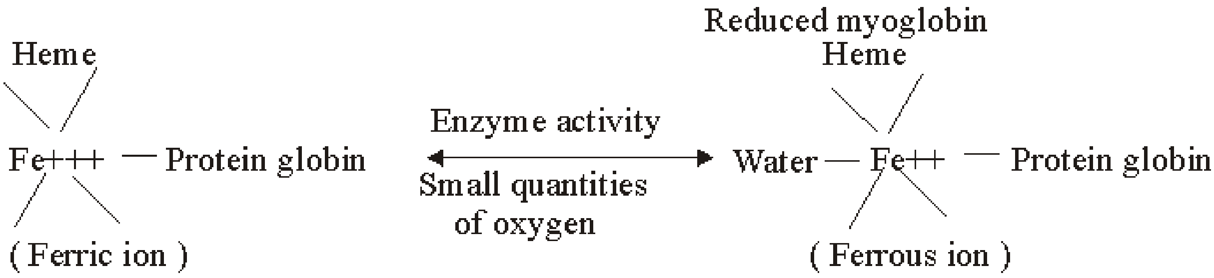
- ***Beef –*** bright , cherry red
- ***Fish –*** gray- white to dark red
- ***Horse –*** dark red
- ***Lamb and mutton –*** light red to brick red
- ***Pork –*** grayish pink
- ***Poultry*** – gray – white to dull red
- ***Veal–*** brownish pink

4. Approximately 20 % of the pigment in meat is hemoglobin. However, the bulk of hemoglobin is found in the arteries, veins and capillaries.

5. The normal color of the surface of fresh meats in an oxygen environment is bright red/pink due to oxymyoglobin. As oxygen penetrates into muscle, it is utilized to oxidize reduced compounds (co-enzymes). This results in an oxygen gradient ranging from saturation on the surface to zero a few centimeters in the muscle. At low partial pressures of oxygen metmyoglobin is formed. The effect of oxygen is shown in the figure below —

6. The **chemical state** of myoglobin affects the color– Oxidized myoglobin Reduced myoglobin Heme

Chemical state of myoglobin affects the color



Enzyme activity.
7. There are certain factors that affect the color of pigments

Discoloration of meat–

- Apart from the reasons discussed above there could be certain other reasons which could lead to discoloration of meat.
- PSE meat has a pale color due to presence of more water in the on the surface of the meat and the low pH causes denaturation of proteins.
- The DFD meat appears to be more darker . This is due to increased bound water in meat which minimizes the white light reflection and color absorption is enhanced. The dark cutting meat also has a high rate of oxygen using enzyme activity. due to high pH this in turn reduces the proportion of the pigment in the oxymyoglobin.
- The color of the meat also serves as an indicator of the quality of the meat. The color is to an extent indicator of physical, chemical and bacterial contamination.
- The microbes change the physiological environment by changing the pH and by producing amino acids and amines. They may also produce compounds which may react with the heme pigments to produce other colors. Catalase negative bacteria produce hydrogen peroxide that results in a green color.
- Microorganisms change the color also by producing pigments themselves.
- Salt works as a prooxidant for heme pigment oxidation and thereby also influences the color.
- Light can cause the dissociation of oxygen from the heme which may result in the fading of fresh meat color.
- Cooking causes protein denaturation and the browning reactions. During cooking the heme pigment protein denatures and the iron undergoes oxidation to the ferric state and ability of the pigment to complex oxygen is lost.

FROZEN MEAT

Freezing has long be recognized as an excellent method for the preservation of meat. It results in less undasirable changes in the qualitative and organoleptic properties of meat than other methods of preservation. In addition to that most of the nutritive value of meat is retained during freezing, and through period of frozen

storage. The only loss can be occur only water soluble nutrients are lost in the drip during thaving and the amount of drip varies with freezing and thawing condition. Nutrients found in drip are –salt, amino acids, some proteins and peptides, and water soluble vitaminc. When proper freezing and storage methods are used there is little change in color, flovor, odor and juiciness of cooked meat product.
Quality of frozen meat is influenced by the freezing rate , length of freezer storage, and freezer storage condition. And these conditions include such important factors; temperature, humidity, and the packaging material.
Changes which can occurs during frozen storage are the development of rancidity and discoloration, with the latter change being due to surface dehydration as well as microbial activity.

Slow freezing: During slow freezing , the temperature of the meat product being frozen remains initial freezing point for long time. As a result, a continuous freezing boundary forms and proceeds slowly fom the outside of the product inward. Extracellular water freze more rapidly than intracellular water becouse it has a lower solute concentration.
During the slow freezing process , the long period of crystallization before freezing occurs, produces numerous large extracellular masses of ice crystals that are easy lost as drip during thawing.As shown on figure when freezing temperature getting higher the cristalization period will be longer .

Fast freezing : During fast freezing the temperature of meat product being frozen rapidly falls below the initial freezing point. Numerous small ice crystals tend to form uniformly throughout all of the meat tissues. These small ice crystals are formed with aproximately same speed , both intra and extracellularly. Since most of the water inside the muscle fibers freezes intracellularly , drip loosing during thawing are lower than thawing of slow frozen meat. In addition muscle fiber shrinkage and distortion effects are minimized during fast freezing, resulting in a near normal ultrastructural and strieded appearancein the frozen state, volume changes are less , and the period of crystalization are shorter than slow frozen.

Freezing Methods

Commercially several methods are used to freeze meat products incluiding :

1)Stil air : In this methods air is the heat trasfer medium. This methods of freezing is entirely dependent upon convection , and meat freze very slowly. Commercial temperatures commonly used in stil air freezing range from about -10 to -30 ^{o}C .

2)Plate freezing : the heat transfering medium in this freezing metal, rather than air. Trays containing the products, or the flat surfaces of meat products are placed directly in contact with the metal freezing plates or shelves. Plate freezer temperatures usually range from about -10 to -30 ^{o}C in commercial practise, and the methods is generally limited to thin pieces of meat . conduction is important rather than convection in this method and the freezing rate is slightly faster than it would be in stil air. Although plate freezing is stil slow it can be speeded up by circulating cold air ower the product.

3)Blast freezing: the most commonly used method for freezing meat product is cold air blast freezing in rooms or tunnels that are equipped fans to provide rapid air movement. Air is the medium of heat transfer, but because of it s rapid air movement the rate of freezing is markedly increased. High air velocity increases both the cost of freezing and the severity of freezer burn in unpacked meat product. Commercially air velocity range from 30-1070 meters/minute and temperatures range from about -10 to -40 ^{o}C in the blast freezing. However, an air velocity of about 760mpm and temperature of -30 ^{o}C are the most practical and economical now being used in the meat industry.

4)Liquid immersion and liquid sprays: liquid immersion or spray is the most widely used commercial method for freezing paultry. However some red meat product and fish are also frozen also by this method. Because of the rapid heat transfer , higher temp. are generally used than in blast freezing.
The products to be frozen are placed in plastic bags, stacked on pallets or in shelved racks, and then either immersed into the freezing liquid by fork lift trucks , or moved through the cold liquid by a conveyor. In other application, the product is conveyed through an enclosed freezing cabient while the cold liquid is continuously sprayed on its surface. After the product is removed from the immersion tank the freezing liquid is rinsed from its surfaces with cold water. The length of time that the product is immesed or sprayed determines extent of freezing. When the surface of product is frozen the product is generally transferred to a freezer room for completion of the freezing process and subsequent storage.
The liquid used for freezing must be non toxic, relatively inexpensive, shuld have a high viscosity , low freezing point, and high heat conductivity. Sodium chloride brine has been commonly used but glycerol and glycols are currently achieving wide usage.

5)Cryogenic freezing: Any one of the three systems may be used for cryogenic freezing.these are direct immersion, liquid spray, or the circulation of the cryogenic agent vapor over the product to be froozen. The most commonly used cryogenic agents are nitrogen(liquid or vapor), carbon dioxide (liquid, vapor or snow).
Large pieces of meat are rarely immersed directly into liquid nitrogen because of extensive shattering or cracking that might occur. Therefore , present systems generally evaporated liquid nitrogen in the freezing chamber and utilize its termendous cooling capacity as it changes into nitrogen gas in order to freeze the meat product. Lquid nitrogen spray or liquid carbon dioxide spray combined with a conveyor belt system , are used to rapidly freze meat products of relatively small size.

Some freezer photo used in meat industry:

Tunnel freezer

Super contact freezer

Cabinet freezer