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Lecture title: **Meat Hygiene: Conversion of Muscle to Meat**

Lecturer Affiliation: *Professor, Dr.* ***Muntaha Ghazi Hasan***
Department of Public Health,College of Veterinary Medicine, University of Mosul, Mosul, Iraq
https://orcid.org/ 0000-0001-7250-0117

Summary:
In the fed animal the circulating levels of free fatty acids are low, and glucose is mostly used. In the fasting state, free fatty acids derived from the breakdown of triglyceride stores in the fat depots of the body are metabolized. Glycogen is mobilized only when the rates of breakdown of fatty acids and glucose cannot provide energy at a sufficient rate to meet the demands of contracting muscle.
Glycogen and glucose are broken down essentially by three interrelated processes:

- glycolysis
- oxidative decarboxylation
- oxidative phosphorylation.

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O.$$

Glucose having six carbon atoms is broken down into two pyruvate molecules each containing three carbon atoms. The process generates either two or three
ATP molecules and four hydrogen atoms.

Table 1: The production of ATP from the oxidation of glucose

Glycolysis	1 Glucose	2ATP +4H + 2 Pyruvate
Oxidative Decarboxylation	2 Pyruvate	20 H + 6 CO_2
Oxidative Phosphorylation	24 H +6O_2	36ATP +6H_2O

Post-mortem Acidification of meat:
After animal slaughter and bleeding the supply of oxygen to the muscles ceases when the blood circulatory system fails. Any subsequent metabolism must be anaerobic, and ATP can only be regenerated through breakdown of glycogen by glycolysis since oxidative decarboxylation and phosphorylation will no longer operate. As glycogen is broken down so lactic acid accumulates**.** The lowering of pH in muscle due to the accumulation of lactic acid is one of the most significant postmortem changes, pH in living muscles 7.4, at postmortem the ultimate pH reaches to about 5.5. Thus, the pHu is inversely proportional

to the concentration of lactate. The process of acidification normally takes 12–24 h in sheep and 15–36 h in cattle. In poultry meat the initial pH fall may be relatively rapid. For example, in turkeys the pH in the breast muscle can have fallen to 6.

Importance of acidification to the characteristics of meat:

Both the rate and the extent of the postmortem decrease in pH determine the palatability of meat by affecting several meat quality properties including:

-Drip Loss,
- Color Development
-Shelf Life
-Water-Holding Capacity
-Texture
- Tenderness
-Feeding quality

- **(PSE) pale soft exudate**

Is abnormal condition, The pH will drop rapidly to around 5.4- 5.5 during the first hours after bleeding. Meat is characterized by its pale color, lack of firmness and exudate dripping from its cut surfaces, Low PH and high temperature causes denaturation of some muscle proteins leading to reduction in their power to bind water. Also, the myofibrillar proteins, myosin and actin, reach their isoelectric point. The large amount of exudate reflects the poorer water holding capacity, eventually this exudate may produce drip,The shrinkage of myofilaments increases the amount of light reflected from the meat. The low PH tend to promote oxidation of the haem pigments from purple red myoglobin Mb and oxymyoglobin MbO_2 to the brown metmyoglobin.

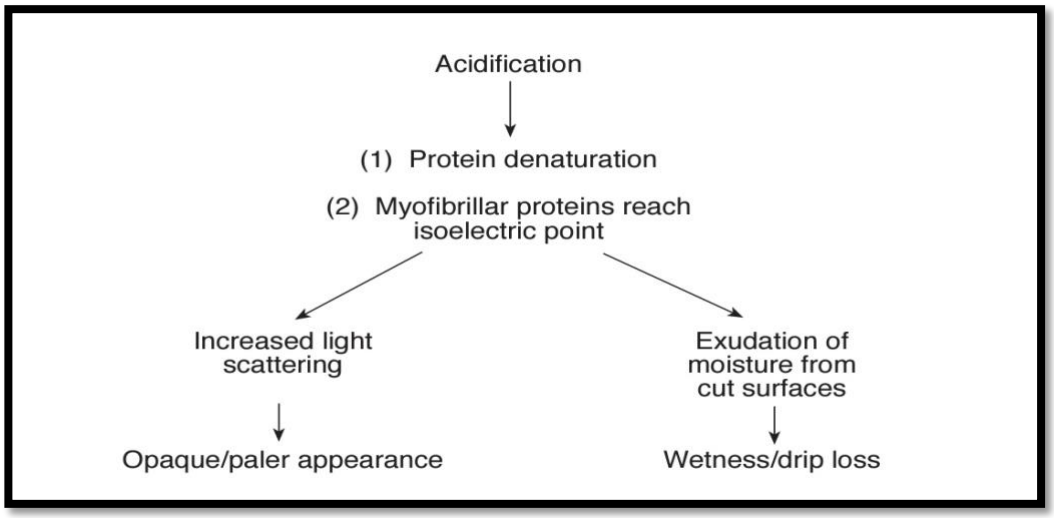
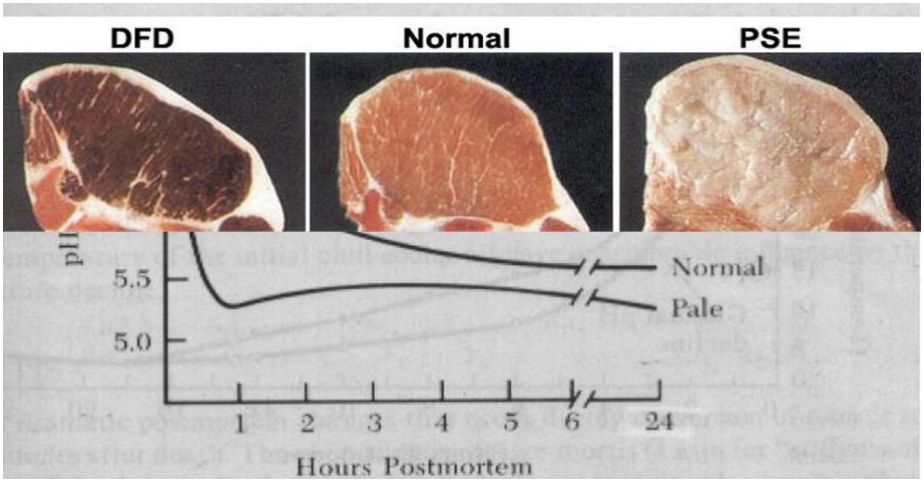


Figure 1: The consequences of muscle acidification for the appearance and water holding of meat.

- **(DFD) Dark Firm Dry:**

The pH drops very slowly during the first hour after slaughter and then stays stable, at a high level. The ultimate pH in the range of 6.5-6.8.

In DFD meat has extremely low shelf life because: DFD meat is caused by glycogen depletion at antemortem, low levels of CHO in muscle restrict the growth of lactic acid producing bacteria and encourage the growth of bacteria that metabolize amino acids and proteins. the high PH of the meat promote this bacterial growth, Meat with high PH is a problem in vacuum packed meat. A green coloration may develop due to formation of sulphmyoglobin which is caused by haem pigment reacting with hydrogen sulphide produced by bacteria under anaerobic conditions.



PSE	DFD
Acute stress	Chronic stress
Rapid initial acidification	Reduced glycogen
Low initial pH at high carcass temperature	High ultimate pH
Proteins denature	Proteins don't denature
Low water holding capacity	High water holding capacity
Bound water lost	Water held by proteins
Muscle fibers separate	Fibers tightly packed
Large extra cellular space	Small extra cellular space
Surface appear pale	Surface dark
Low pH promotes Mb oxidation	O_2 diffusion inhibited
Meat looks less red	Mb O_2 layer thin and underlying Mb purple

Factors affect rate of postmortem metabolism and development of rigor mortis include:

1. The size of the carcass,
2. The amount of fat cover,
3. The temperature of the chiller
4. In addition, the use of electrical stimulation to speed postmortem glycogen and high energy metabolite depletion will also have a profound effect on the time course of muscle metabolism.

The development of Rigor mortis

The first and most considerable post-mortem change which occurs in muscle is rigor mortis. Rigor mortis occurs when the ATP level falls below the low level (~ 5 mmol /kg) needed to keep relaxation. When this happens, the actin and myosin molecules of the thin and thick filaments combine irreversibly to form actomyosin and extensibility of the muscle is lost. Cross-bridges form permanently. rigor mortis takes several times to develop in the different species, ranging from about 4 h in the chicken to over 24 h in excised beef muscles. Rigor mortis has phases:

- **The onset of rigor mortis**
  Characterized by loss of elasticity and extensibility as well as shortening and tension.
  development
- **Resolution of rigor mortis**
  The myofibrils become more easily fragmented by controlled homogenization of the muscle in aqueous solutions, Alteration in ultra-structure of myofilaments, Changes of neutral protease enzymes is related directly to tenderization in meat.

Rigor mortis is characterized by:

- a hardening and contraction of all the voluntary muscles
- a loss in transparency of the surface of muscle which becomes dull.
- It is accompanied by a slight rise in temperature of the carcass to 1.5^{o}c or more above normal in the case of beef carcass, the temperature then gradually Dropping to that of the surrounding atmosphere.
- The heart is affected early, usually within an hour of slaughter.

Tenderization results from the activities of proteolytic enzymes present in the muscles. There are two main sorts of enzyme involved, cathepsins and calpains, As the pH of the muscle drop(pH<5.6), cathepsins enzymes are released and begin to degrade protein structure of the

muscle. Cathepsins occur in the lysosomes in the sarcoplasm. They are known to degrade troponin T, some collagen cross-links and mucopolysaccharides of the connective tissue ground substance. They only appear to degrade actin and myosin below a pH of 5. The calpains are activated by calcium ions They occur in two forms:

- m-calpain activated by high (millimolar) concentrations of calcium ions (1–2 mM)
- μ-calpain activated by low (micromolar) concentrations (50–100 μM).

Calpain promoting breakdown of other proteins such as tropomyosin and titin (connectin). The calpains are inhibited by calpastatin. High calpastatin activity reduces the extent of proteolysis in muscles.