UNIT 5 CHARACTERISTICS OF MEAT-p^H, TENDERNESS, COLOUR, WATER HOLDING CAPACITY AND TEXTURE

Structure

5.0 OBJECTIVES

After reading this unit, you will be able to:

- describe different meat quality parameters like meat p^H, texture, tenderness, water holding capacity and colour;
- explain the influence of different meat quality parameters on the acceptability of meat to its users — processors and consumers, and
- illustrate the factors which affect the meat qualities - colour, texture, tenderness etc.

5.1 INTRODUCTION

The p^H, colour and water holding capacity of meat are interrelated. We have already introduced you to the concepts of meat p^H, colour, water holding capacity and tenderness of meat. In this unit you will learn more about all these important meat quality parameters, how they are related to each other and their influence on final meat quality.

5.2 p^H OF MEAT

The p^H is defined as the negative logarithm of hydrogen ion concentration in a substrate/ solution and it denotes the alkalinity or acidity of the solution/substrate. You have already studied that after death, muscle p^H comes down from normal physiological p^H of around 7.2 to 5.5 - 5.6 and this is mainly due to the conversion of muscle glycogen to lactic acid and its accumulation in the muscle. This happens due to lack of oxygen in the muscle tissues. This anaerobic condition prevails in animal body after exsanguinations. As the accumulated lactic acid is not removed by the circulatory system which is no longer in operation, the muscle gradually acidifies. The final p^H reached (5.5-5.6.) is known as ultimate p^H. This p^H fall is achieved in the muscles of well-fed and unstressed animal. The ultimate p^H varies between muscles within the same carcass depending upon the glycogen reserve, temperature, glycolytic enzyme activity etc. in the muscle. Depending upon the pre-slaughter conditions of the animals and stresses during slaughter, the fall of p^H can follow any of the three patterns as described below. It should be noted that the rate and extent of fall of muscle p^H in the first two hours have considerable influence on the colour, texture, water holding capacity and tenderness of meat.

5.2.1 Normal

A normal p^H decline pattern is characterized by a gradual decrease from approximately 7.2 in living muscles to a p^H of about 5.6 to 5.7 within 6 to 8 hours after slaughter and then to an ultimate p^H of around 5.4 to 5.6 within 24 hours after slaughter. This generally occurs in healthy, well-fed, rested animals.

5.2.2 DFD (Dark, Firm and Dry) Meat

In some animals the p^H fall is very negligible (only few units drop in p^H) during the first hour after slaughter and then p^H remains stable at a relatively high level, resulting in an ultimate pH in the range of 6.5 to 6.8. This results in very dark, firm and dry meat (DFD) which has poor keeping quality. This condition occurs in animals which are physically exhausted or stressed some way during slaughter and have low glycogen reserve in the muscles.

5.2.3 PSE (Pale, Soft and Exudative) Meat

In other animals, the p^H may drop very rapidly to about 5.4 to 5.5 within one hour or so of slaughter while the temperature of the muscle is still above 35°C. Under these conditions, changes occur in the properties of the muscle proteins and the meat becomes watery and assumes a pale, unattractive colour, becomes soft in consistency and lacks flavour. This type of meat ultimately develops a p^H of about 5.2 to 5.3 (<5.5) and known as pale, soft, exudative meat (PSE).

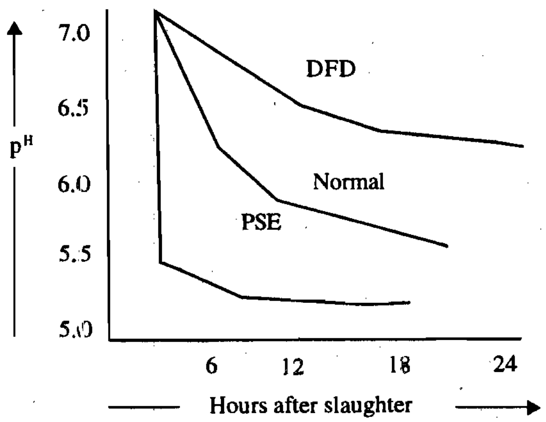

Fig. 5.1: Post-mortem p^H decline pattern

Factors responsible for development of PSE condition in meat include high environmental temperature, rough ante-mortem handling, fighting, physiological differences between breeds and individual muscles, inefficient slaughtering techniques and handling of carcasses.

Table 5.1: Differences between PSE and DFD meat

	PSE	DFD
1.	It occurs in case of acute stress.	It occurs in case of chronic stress.
2.	Initial acidification is very rapid.	Acidification is very slow due to reduced glycogen.
3.	Initial p^H is very low when the temperature of carcass is still high.	Ultimate p^H is high.
4.	Meat proteins denature.	Meat proteins do not denature.
5.	Water holding capacity becomes low.	Water holding capacity is high.
6.	Muscle fibres separate.	Muscle fibres remain tightly packed.
7.	High scattering of light.	Low scattering of light.
8.	Surface of the meat becomes pale.	Meat surface appears dark.
9.	Meat becomes soft and exudates fluid.	Meat is firm and dry.

Check Your Progress 1

1) What is meant by ultimate p^H of meat?

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2) What are the major differences between PSE and DFD meat?

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5.3 WATER HOLDING CAPACITY (WHC)

Water holding capacity is defined as the ability of meat to retain its water during application of external forces such as cutting, grinding, pressing and heating. Many physical properties of meat *viz*., colour, texture, juiciness, tenderness are partly influenced by WHC of meat. WHC is manifested by exudation of fluid known as "weep" in fresh meat, as "drip" in thawed uncooked meat and as "shrink" in cooked and stored meat. Meat with poor WHC loses more moisture from its surface during storage. WHC is of special importance while meats are further processed into comminuted products because during processing they are subjected to combinations of grinding, heating and other processes. Yield of manufactured products is the function of water loss from the product during processing.

Water in muscles remains in bound, immobilized and free from. Around 4-5% of water in muscle is hold in muscles by electrically charged reactive groups of muscle protein and they form a tightly bound layer of water in muscle. Immobilized water is held by weaker bonds and its amount depends on the amount of physical forces exerted on the muscle whereas free water is held only by capillary forces between thick and thin filaments. Water holding capacity of muscle is lowest when it reaches ultimate p^H (5.5) which is isoelectric point of muscle proteins. Drop in p^H in post-mortem period is responsible for an overall reduction of reactive groups on proteins. At isoelectric p^H, number of positively and negatively charged group is equal. Consequently, these groups tend to be attached to each other and only those "left over" are available to attract water. This influence of p^H is called the 'net charge effect'. Higher the p^H of muscle, higher is the WHC probably due to availability of more reactive groups in muscle proteins which help to retain more bound and immobilized water. WHC of muscle is also greatly reduced due to actomyosin formation during rigor mortis. This happens because of lack of space for water molecules within protein structure which is called "steric effect" on water binding. Pre-rigor meat has better water holding capacity and yields higher quantity of products while converted into products. Degree of WHC has large scale effect on firmness, structure and texture of meat. Muscles with extremely high proportion of bound water are firm, have a dry or sticky texture. Alternately, tissues, with poor WHC are soft, have a loose structure and have wet or grainy texture.

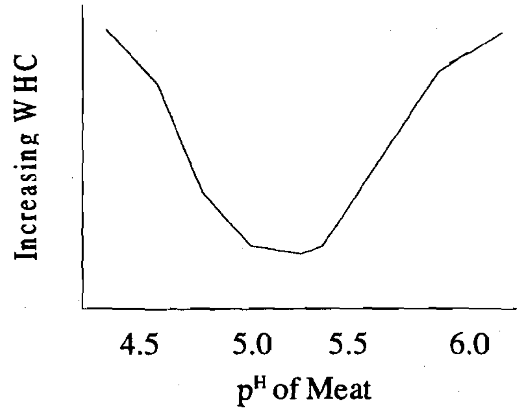

Fig. 5.2: Relation between WHC and p^H of meat

In comminuted meat products, salts of strong acids such as sodium chloride are incorporated and it enhances water holding capacity of meat mix. Similarly, alkaline polyphosphates such as tetra sodium pyrophosphate, sodium tripolyphosphate etc. also increase the water binding capacity of meat proteins in processed meat products. Addition of alkaline polyphosphates results in increase in ionic strength and p^H of the meat mix and splitting of actomyosin into actin and myosin and thereby increases the water binding capacity of meats.

5.4 COLOUR

A layman usually describes the colour of any meat as red, although there is vast difference in typical colour of meat obtained from different species. But any specific colour has three attributes, known as hue, chroma and value. Hue describes that which one normally thinks of a colour — yellow, blue, green or red. Chroma (purity or saturation) describes the intensity of a fundamental colour with respect to amount of white light that is mixed with it. The value of a colour is an indication of overall light reflectance (brightness) of the colour.

The major pigment responsible for meat colour is myoglobin (Mb). In well bled carcass, myoglobin constitutes 80 to 90 per cent of the total pigment followed by haemoglobin. Pigments namely catalase and cytochrome enzymes are also present in muscle, but their contribution to meat colour is very minor.

Table 5.2: Typical colour of meat from various species is listed below:

Meat	Colour
Beef	Bright cherry red
Veal (meat from calf)	Brownish pink
Poultry	Gray white to dull red
Pork	Grayish pink
Mutton	Light red to brick red
Chevon (meat from goat)	Light red to brick red
Horse	Dark red

The appearance of meat surface depends not only on the quantity of myoglobin present but also on the type of myoglobin molecule, its chemical state and the chemical and physical condition of other components in the meat.

5.4.1 Oxidation Status of Myoglobin and Colour Development

Myoglobin consists of a globular protein portion (globin) and a non protein portion called haeme ring. The haeme ring portion contains iron and the oxidation state of iron within this haeme ring partially determines the colour of meat and hence, haeme portion of myoglobin is of special interest to the meat technologists.

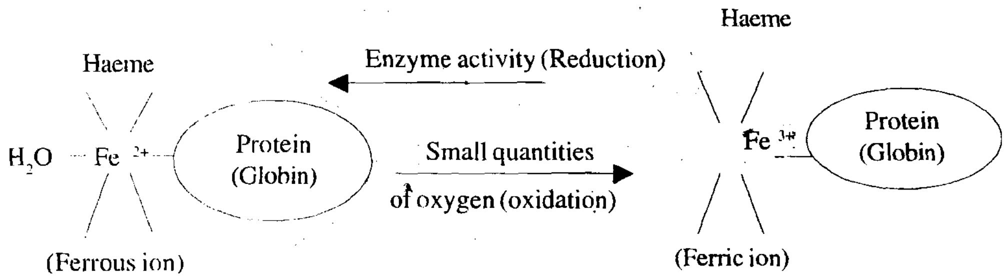

Fig. 5.3: Oxidation-Reduction of Iron in Haeme Ring

(Source: Hedric *et al.*, 1994)

Myoglobin can react with different compounds and ions including water and oxygen when the iron within the haeme ring is in reduced state (ferrous state); when the iron is in oxidized state (ferric state) it can not combine with other molecules including oxygen. So, it is important to maintain the reducing conditions of the pigment in fresh meat because oxygen reacts with reduced iron of myoglobin to provide desirable red colour of fresh meat.

When freshly cut meat is exposed to air, the reduced pigments will react with oxygen and form relatively stable pigment called oxymyoglobin. Formation of oxymyoglobin in fresh meat is responsible for its bright red colour which is otherwise termed as 'bloom'. Oxidized form of myoglobin is known as metmyoglobin and imparts brown colour to meat. Metmyoglobin is formed when small quantities of oxygen are present as in case of partial vacuum or a sealed semi-permeable package.

Formation of metmyoglobin (brown colour) in fresh meat must be avoided because consumers generally relate brown coloured meat with long stored meat and often reject such meat. However, under normal atmospheric conditions, oxymyoglobin (oxygenated pigment) is stable and not easily oxidized to metmyoglobin.

Formation of oxymyoglobin in meat is spontaneous when it is exposed to air. But its stability depends on continuous supply of oxygen because enzymes involved in oxidative metabolism rapidly use the available oxygen in the muscle tissue. As the pH and temperature of the tissues increase, these enzymes become more active and oxygen content is reduced. Hence, maintaining the temperature of meat near freezing point minimizes the rate of enzyme activity and oxygen utilization and thus helps to maintain a bright red colour for the maximum possible time.

Unusual colour development in fresh meat include pale (pale soft exudative meat) and dark (dark firm dry meat) coloured meat about which you have already learned in details.

5.4.2 Factors Affecting Myoglobin Quantity in Meat

Various factors which affect the quantity of myoglobin in meat are listed below:

(a) **Species:** The myoglobin quantity of meat varies in different species.

Species	Quantity of myoglobin
Pork	0.06 - 0.40%
Poultry	0.02 - 0.18%
Lamb	0.20 - 0.60%
Beef	0.3. - 1.00%

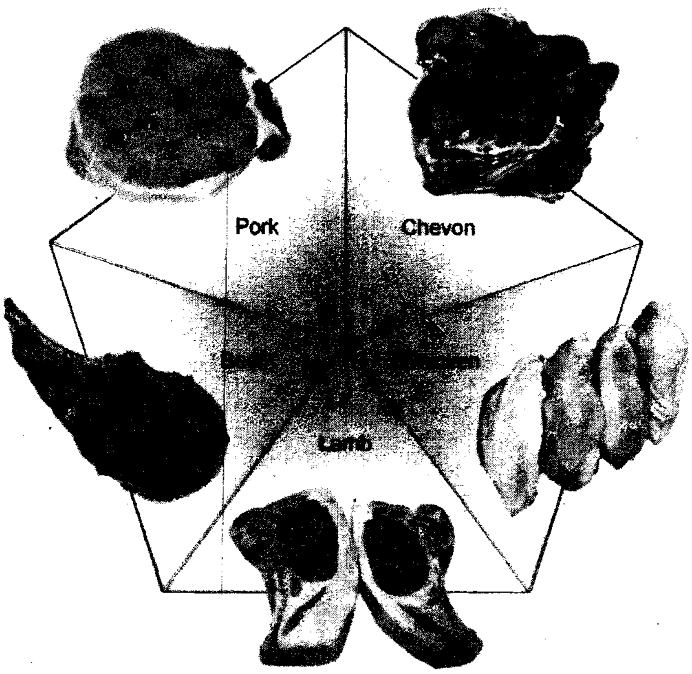

Fig. 5.4: Showing colour of different species me..

(b) **Sex:** Sex of the animal also influences the quantity of myoglobin in the meat. For example, bull has more myoglobin than the cow.

(c) **Age:** Myoglobin content of the meat is changed with the change in age of the animal. It increases with the age, that's why veal (meat of calf) is lighter in colour than the beef.

(d) **Type of muscle:** Muscle to muscle differences in quantity of myoglobin are due to type of muscle fibres present and operation of the muscles. The muscles which are having high proportion of red fibres, appear dark red and the constantly operating muscles like, diaphragm, have more myoglobin content than others.

(e) **Exercise:** Exercise increases the myoglobin content, therefore, the myoglobin content in free ranged animals are higher than that of the confined animals.

Check Your Progress 2

1) What are the colours of meats of different species?

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2) What do you mean by 'bloom' of meat?

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3) Enlist the factors which affect the myoglobin content of meat.

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5.5 TEXTURE

Among all the attributes of eating quality, texture and tenderness are rated most important in all the developed countries where meat items are eaten as a main dish of a meal rather than as a side dish as prevalent in our country including many other developing countries. As described in literatures, texture, as seen by the eye, is a function of the size of the bundles of muscle fibres which are covered and separated from each other by perimysium. Generally, coarse grained muscles have large bundles and fine grained muscles have small bundles. Besides the size of muscle fibre bundles, the amount of perimysium around each bundle is also important in determining texture because perimysial layer is thicker in coarse muscles. There is no direct correlation between coarseness of grain and toughness after cooking. However, an indirect correlation between muscle fibre diameter and tenderness exists which explain the complexity of texture and tenderness as attributes of eating quality.

5.5.1 Factors Affecting Texture of Meat

The texture of meat varies with the following factors:

(a) **Species:** Texture of meat varies with species of the meat animals. For example, meat of cattle has coarser texture than sheep and pig.

(b) **Breed:** Breed also influences the meat texture to a varying degree. Meat from Hampshire, Duroc and Landrace pig is coarser than that from Berkshire or Tamworth.

(c) **Age:** Coarseness of the texture increases with the advancement of the age of the animal.

(d) **Sex:** Muscles of the male animal has greater coarseness as compared to muscles of female animal.

(e) **Frame size of the animal:** Frame size of the animal also affects the texture of the meat. The coarseness of texture is greater in the muscles from the animals of large frame.

(f) **Type of muscle:** The muscles such as biceps femoris or semitendinosus of the hind leg, which perform vigorously in live animal, are coarser in texture than the infrequently used muscles such as Psoas major of the loin.

5.6 TENDERNESS

Now we know that tenderness is rated most important as a meat quality along with texture in all developed countries.

The overall impression of tenderness to the palate includes texture and involves three aspects such as – (i) the initial ease of penetration of meat by the teeth, (ii) the ease with which meat breaks into fragments, and (iii) the amount of residue remaining after chewing.

The sensation of tenderness has several components of varying importance and perception of tenderness by human is very difficult to duplicate by scientific instrumentation. Major components of meat that contribute to tenderness are: (i) connective tissue, (ii) muscle fibre structure and (iii) adipose tissue. Amount and nature of connective tissue protein *viz.*, collagen in muscle tissue determine the toughness of meat. Background toughness of meat is contributed by connective tissue present in endomysium, perimysium and epimysium of muscle tissue. In young animal, although amount of connective tissue is comparatively more than that of mature animal, background toughness is less in meat from young animal compared to that of old animal. This is attributed to the formation of heat stable cross links in chemically mature collagen in old animals. Collagen in young animals and in rapidly grown animals are more heat labile and easily converted into gelatin during cooking imparting tenderness to meat.

Degree of tenderness of muscles is determined partially by post rigor contraction state. Loss of tenderness occurring in the first few hours postmortem has been known as actomyosin toughening. During this shortening and cross bridge formation period, the tenderness and WHC are minimum due to protein to protein interactions making binding sites unavailable for water binding. Thus tenderness and WHC are well correlated. This situation changes during postmortem ageing process. Due to enzyme action there is progressive degradation and increased fragmentation of myofibrillar proteins and Z-discs resulting in redistribution of ions and shifts in water binding activity causing an improvement in tenderness and water holding capacity.

Intramuscular fat (marbling) makes meat tender. This is mainly because of some which lipids act as lubricant during mastication of meat, thus improving apparent tenderness and easing the process of swallowing.

5.6.1 Factors Affecting Tenderness of Meat

a. *Pre-slaughter factors*:

(i) **Species:** Tenderness is heritable to an extent of over 60% and different species meat has different degree of tenderness. For example, pork is more tender than beef.

(ii) **Age:** Tenderness of meat decreases with the advancement of the age of the animal.

(iii) **Sex:** Tenderness of meat from female animal differs from that of male animal.

(iv) **Muscle:** Tenderness of meat varies from muscle to muscle. Psoas major is more tender than longissimus dorsi. Muscle which contains more elastin, is tougher and which contains intramuscular fat, is more tender.

b. *Post-slaughter factors:-*

(i) **Post-mortem changes:** When post-mortem p^H falls slowly, tenderness increases. Toughness of the meat increases with the greater degree of interdigitation of actomyosin during rigor mortis.

(ii) **Conditioning:** When the meat is conditioned i.e., stored at chill temperature for several days, tenderness of the meat increases.

(iii) **Chilling:** If the meat is chilled pre-rigor, then cold-shortening i.e., pre-rigor shortening decreases the tenderness of the meat. When the meat is frozen pre-rigor and thawed rapidly, it undergoes thaw-rigor which makes the meat tougher.

(iv) **Cooking:** Cooking helps in increasing the tenderness by converting the collagen of meat into gelatin. On the other hand, cooking coagulates the myofibrillar protein and results into toughening of the meat.

(v) **Artificial tenderizing:** Different types of proteolytic enzymes, mineral, salts, acids etc. also increase the tenderness of meat artificially.

(vi) **Electrical stimulation** and **application of pressure** after slaughter of the animal enhance the tenderness of meat.

Check Your Progress 3

1) Discuss the relationship between WHC and tenderness of meat.

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2) Name the factors that affect the texture of the meat.

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3) Justify the statement — "Background toughness is less in meat from young animal than that from old animal".

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5.7 LET US SUM UP

Major fresh meat quality attributes are p^H, water holding capacity, colour, texture and tenderness. Most of these parameters are interrelated. Due to postmortem conversion of muscle glycogen to lactic acid, meat p^H reaches to an ultimate p^H of 5.4 to 5.6 in meat from a healthy, well-fed, rested animal. The rate and extent of p^H

fall and pre-slaughter glycogen reserve in animals may affect the p^H of meat. Depending upon the rate and extent of p^H fall, there may be production of PSE (pale soft exudative) or DFD (dark firm dry) meats which are of inferior quality both from consumer and technological view points. WHC partially influences the other physical properties of meat namely colour, juiciness, texture and tenderness. WHC of meat is minimum at ultimate pH of 5.5 which is also the isoelectric point of muscle proteins. WHC affects the processed meat both quantitatively and qualitatively. Alkaline phosphates are used to increase water binding capacity of muscle proteins in comminuted meat products. Fresh meat colour depends on the state of major meat pigment, myoglobin. Oxymyoglobin is the oxygenated state of myoglobin and is responsible for bright red colour of fresh meat which is also known as bloom. Oxidized state of myoglobin produces metmyoglobin which results in brown colour of fresh meat, usually associated with long stored meat and disliked by most of the consumers. Most important attributes of eating quality of meat in developed countries are the texture and tenderness. Texture is the function of the size of the bundles of muscle fibres. Generally, coarse grained muscles have large bundles and fine grained muscles have small bundles. Three major meat components affecting texture and tenderness of meat are connective tissue, muscle fibre structure including muscle bundles and adipose tissue. Colour, texture and tenderness of meat are affected by several factors such as, species, breed, age, sex, size of the animal and type of the muscle.

5.8 KEY WORDS

Bloom : Development of bright red colour in fresh meat due to exposure to air and consequent formation of oxymyoglobin.

Drip : Exudation of fluid from thawed uncooked meat.

Shrink : Exudation of fluid from cooked meat.

Ultimate p^H : It is the p^H value of meat after conversion of muscle glycogen to lactic acid during postmortem holding of meat. This value is 5.4 — 5.6 in meat obtained from a healthy, well-fed, rested animal.

WHC : Ability of meat to retain its water during application of external forces such as cutting, grinding, pressing and cooking.

Weep : Exudation of fluid from fresh meat.

5.9 SOME USEFUL BOOKS

Biswas, S. (2005). *Meat and Egg Technology.* 1st ed., University Publication, WBUAFS, Kolkata. West Bengal.

Forrest, J.C, Aberle, E.D., Hedrick, H.B., Judge, M.D. and Markel, R.A. (1975). *Principle of Meat Science*, W.H. Freeman and Company, San Francisco.

Lawrie, R.A. (1998). *Lawrie's Meat Science*, 6th ed., Woodhead Publishing Limited, London.

Sharma, B.D. (1999). *Meat and Meat Products Technology.* 1st ed., JAYPEE Brothers, New Delhi.

5.10 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Due to postmortem conversion of muscle glycogen to lactic acid, meat p^H reaches to 5.4 — 5.6 in meat from a healthy, well-fed, rested animal. This p^H is known as ultimate p^H.

2) Major differences between PSE and DFD meat are given below:

	PSE	DFD
(i)	Colour of meat is pale	Colour of meat is dark
(ii)	Meat is soft and exudative	Meat is dry and firm
(iii)	WHC of meat is low	WHC of the meat is high
(iv)	This condition occurs in case of acute stress	This occurs in case of chronic stress
(v)	Meat protein denatures and fibres separate	Meat proteins do not denature and fibres remain tightly packed
(vi)	Initial acidification rate is very fast	Acidification rate is very slow.

Check Your Progress 2

1) A layman usually describes the colour of any meat as red but there is vast difference in colours of meat obtained from different species.

	Meat	Colour
(i)	Beef	- bright cherry red
(ii)	Pork	- grayish pink
(iii)	Mutton and Chevon	- light red to brick red.
(iv)	Poultry	- gray white to dull red
(v)	Horse	- dark red
(vi)	Veal	- brownish pink

2) When fresh meat is exposed to air, myoglobin of meat is oxygenated to oxymyoglobin which results in bright red colour of meat and this is called as bloom of meat.

3) Factors affecting the myoglobin content of the meat are as follows:

- Species of the animal
- Sex of the animal
- Age of the animal
- Type of muscle
- Exercise/training of the animal.

Check Your Progress 3

1) Degree of tenderness of muscles is determined partially by post rigor contraction state. Loss of tenderness occurring in the first few hours post-mortem has been known as actomyosin toughening. During this shortening and cross bridge formation period, the tenderness and WHC are minimum due to protein — protein interactions, making binding sites unavailable for water binding. Thus, WHC and tenderness are well correlated. This situation changes during postmortem ageing process. Due to enzyme actions there is progressive degradation and increased fragmentation of myofibrillar proteins and Z- discs

resulting in redistribution of ions and shifts in water binding activity causing an improvement in tenderness and water holding capacity.

2) Name of the factors that affect the texture of the meat are given below:
   - Species of the animal
   - Breed of the animal
   - Age of the animal
   - Sex of the animal
   - Frame size of the animal
   - Type of muscle.

3) Background toughness is less in meat from young animal than that from old animal because cross links in collagen of young animals are heat labile whereas those in old animals are heat stable. During cooking collagen with heat labile cross links in young animals converted easily into gelatin which imparts tenderness to meat of young animal.