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A REVIEW OF MUSCLE BIOCHEMISTRY AS MEAT

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Abstract.- The review is about the latest development in the field of meat chemistry and biophysics as they relate to the quality parameters-like tenderness, water holding capacity (WHC), flavour and colour. The importance of pH value in meat has been given in somewhat detail. Preservation techniques in the light of modern day knowledge has been given.

INTRODUCTION

Webster (1960) defines meat as "The flesh of animals, as distinguished from fish and fowl's used as food usually. Lawrie (1975) considered that meat is in general regarded scientifically as the postmortem flesh derived from the 300 or so anatomically distinct muscles of an animals's body including connective tissue in which the muscle fibres are encased and such inter and intra-muscular lipids or fat that can not be removed without destruction of the muscle structure. Hanson (1975) states that any definition of meat must be based on the flesh, including fat, skin, rind, gristle and sinew amounts naturally associated with the flesh of any animal or bird normally used for human consumption. From these definitions it becomes clear that the term "meat" normally refers to the edible portion of animals, that is, the tissue associated with the skeletal muscle, but also includes fat, connective tissue, blood vessels, residual blood and sometimes bone, ligaments, tendons and skin.

The Composition of Muscle

Skeletal muscle forms the main part of the meat we eat and contributes more than 50% to the animal's weight. Lawrie (1965) approximated composition of adult mammalian muscle to 75.5% water, 18% fat and 3.5 non-protein substances. Since a large variation exists in composition, severage values should serve only a general guide. Goll *et al.* (1977) reported that the skeletal muscle from all animals used by humans for food was composed of protein (15-20%), moisture (60-85%), lipids (1-12%) and small amount of carbohydrates and organic compounds (1-12%). Muscle protein can be divided into 3 fractions based upon their solubility characteristic. Those soluble in water or dilute salt solutions are known as sarcoplasmic proteins and those soluble only in concentrated salt solutions as myofibrillar proteins. The third fraction comprises the proteins of the connective tissue and other formed structure, which are not soluble in salt

solutions, at least in cold state. The approximately distribution of protein nitrogen amongst muscle proteins fractions is as:- sarcoplasmic proteins 36% myofibriller proteins 58% and connective tissue proteins 6%.

Sarcoplesmic Proteins

Myogens and globulins are dissolved in the sarcoplasma of the muscle cell and represent a complex mixture of some 50 components, many of which are enzymes of the glycolytic cycle. Myofibrillar proteins form the A and I bands. Brief but forceful exercise is known to increase sarcoplasmic and decrease myofibrillar fractions of muslce proteins (Gordon and Kowalski, 1966; Gordon, Kowalski and Fritts, 1967). For the purposes of meat hygiene the composition of striated muscle tissue has considerable more significance since meat consists of this class of muscle tissue. Approximately 4/5 of the solids in the muscle consists of protein with the remainder being made up of "extractives" and inorganic solids. According to Mitchell, the protein content tends to be higher in smooth muscle than in striated muscle. The major components of muscle proteins are myosin 67-68% globulin x 21% myogen 10% omyoalumin 1% muscle hemoglobin (in real muscle) less than 1%.

Myosin

Myosin is the most thoroughly studied of all the muscle proteins. It is the major, if not the only protein of the myofibril and is therefore, considered to play a major role in muscle contraction. It has been found to possess enzymatic properties which are linked to that part of metabolism of muscle tissue which supplies part of the energy for contraction. Gobulin x, myogen and myaolbumin appear to be proteins of the sarcoplasm.

Myoglobin

Myoglobin is one of the respiratory pigments. The respiratory pigments are primarily responsible for the red colour of fresh meat. Changes in the colour of the pigment which may be brought about by the addition of chemical compounds, heat, or enzyme action result in the colour changes in meat produced by curing, cooking and aging. The compounds involved are hemoglobin myoglobin and to a slight extent, cytochromes and the enzymes catalase and cytochrome oxidase.

Myoglobin, like blood hemoglobin as a combination of globin with reduced heme, the iron in the myoglobin molecule being in the ferrous state. Myoglobin contains only one hoeme group per molecule and like blood haemoglobin takes oxygen in two distinctly different pways.

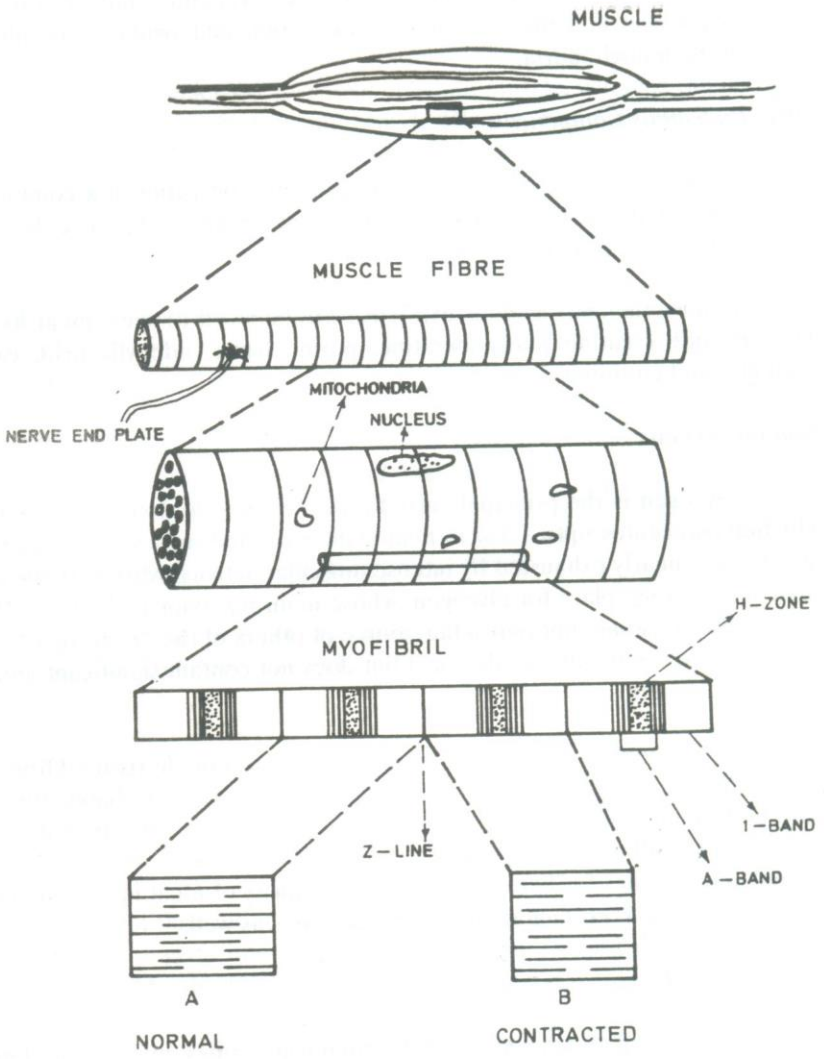

Fig. 1. STRUCTURE OF NORMAL AND CONTRACTED MUSCLE.

The insoluble proteins are the collegen, reticulin and elastin fibers of connective tissue and the enzymes of respiration and oxidative posphorylation found in the mitochondria.

Other Proteinous Components

Cytochromes are iron prophyring proteins consisting of a combination of globin and reduced heme. Three cytochromes with a, b, or c heme, been identified by their distinct absorption bands.

Come other nitrogenous extractive are believed to sgive meat its flavour. They include creatine phosphocratine, purine bases, adenylic acid, carnosine, acid, uric and cretinine.

Non-nitrogenous

Glycogen is the principal carbohydrate of muscle tissue and according to Mitchell constitutes upto 1.5% in mammalian striated muscle. Glycogen content may be very nearly exhausted by intense muscular activity, Muscle tissue does not serve as a storage place for glycogen, whose main reservior is the liver. Meat is a good source of some, but only a fair source of others of the, '8' group of vitamins. Meat is a fair source of ascorbic acid but does not contain significant amounts of fat soluble vitamins.

Potassiuum (K) is the predominent cation in muscle tissue. Other cations are Na, Mg, and Ca phosphate is the principal anion and is probably, for the most part, tied up in ADP, ATP and phosphocreatine. Other anions are chloride (Cl^-) and traces of sulfate. Their presence helps to maintain fluid balance in the living animal and provides for better water-holding capcity of meat in the carcass. Some metals can serve as co-factors for muscle enzymes as well.

Types of Muscle

Based upon histological and biochemical studies muscle has long been classifies as either red or white (Needham, 1926). The red muscle tends to have a majority of narrow myoglobin-rich fibres and the white muscle to have a majority of broad myoglobin poor fibres (George and Naik, 1958, George and Scaria, 1958). The red muscle is capable of activity for long periods of time, without rest, due to its relatively high concentration of mitochondria and myoglobin (Lawrie 1952). The white muscle is active for short quick bursts (Ranger and Keenen, 1952) and because of its low myoglobin and respiratory enzyme concentration, frequent periods of rest and restitution are necessary. The glycogen reservior of

white muscle is higher than that of red muscle and this is thought to be related to difference in oxidative metabolism of the two muscles. The activity of lactic dehydrogenase is very high in white muscle (Dubowity and Pearson, 1961) suggesting the use of anaerobic glycolysis in white muscle, whereas the activity of succinic dehydrogenase is high in red muscle (Beatly, Basinger and Beck, 1967) indicating that perhaps aerobic glycolysis is the main metabolic pathway for energy production.

Tenderness

Tenderness continues to be one of the most important component of meat quality which is sought by consumer (Yeats, 1965 and Jeremish, 1978). Meat is a complex animal product that is composed primarily of skeletal muscle tissue in varying proportions. Species differences in tenderness are associated mainly with the large size of cattle, coarser nature of their muscular tissue and tougher meat as compared with that from sheep and pigs (Hammond, 1932, Hill 1962a,b). Tenderness has been divided into three organoleptic components, firstly intial ease of penetration, secondly ease of fragmentation of muscle fibre and thirdly the amount of residue left after chewing (Weir, 1961).

The major components of meat that contribute tenderness or lack of it can be divided into the following categories:

i) Muscle protein
ii) Muscle fibre characteristic-state of rigor (March and Leet, 1961).
iii) Intramuscular lipids (Wellington and Staugger, 1959 Cover and Hostetler, 1966, Walter, *et al*., 1965; Alvi, 1972).

Postmortem time influences tenderness of meat. Shortly after killing, meat is tender but as it goes into rigor the actomyosin formed during contraction makes it less so. Marsh (1963) has indicated a direct relationship between time before rigomortis and tenderness on cooking. Schilling (1966) observed tht lean muscles with wide corss-striations produced tender meat. The rate and extent of shortening during rigor mortis is subject to rate of fall of muscle pH which in turn is a function of temperature (Cassens and Newbold, 1967) and glycogen reserves. Higher ultimate muscle pH increases tenderness, but pH values above 6.5 make the meat too tender and jelly-like to be acceptable, conditioning of meat makes it more tneder and also increases other organoleptic values. This is not due to dissociation of actomyosin or hydrolysis of connective tissue (Weirbicki, *et al*., 1954) although a possibility of band detachment from the Z-line has been suggested (Davey and Gilbert, 1967).

The time, temperatue and method of cooking are known to influence tenderness. Marion (1967) reviewed the work done on tenderness of poultry meat and concluded that the greatest signle factor that influence tenderness of turkey is the time postmortam after which they are frozen. Rhodes and Shephard (1966) reported that ionising radiation at the sterilisation level have caused no change in organoleptic qualities including tenderness by a trained taste-panelist.

More frequently used muscles has more elastin fibers which account for their toughness (Hiner, Anderson and Fellers 1955). The quality of connective tissue is associated more with tenderness than its quantity (Bate-Smith, 1948; Baskey, Toril and Angrist, 1967), since younger animals given tender meat, although they are known to have more connective tissue. Both Swanson *et al.* (1965), and Smith *et al.* (1969) documented significant anatomical tenderness differences with and a tenderness gradient across the cross sectional surface of the the longissimus dorsi muscle; and Martin *et al.* (1970, 1971) reported anatomical tenderness differences along the longitudianl axis of longissimus dorsi muscle.

Major bovine muscle have been classified histochemically into three types by Ashmore and Doerr (1971) as B.R (Red), R. (intermediate) and W (White), Melton *et al.* (1974, 1975) and May *et al.* (1977). However, they found no correlation between tenderness and the muscle content of these fiber types.

Cooking influences on tenderness

It is a well-accepted fact that many changes occur during the cooking process that affect the quality of meat in general and tenderness in particular. Changes in tenderness of meat that occur during cooking are generally considered to be influenced by heat included changes in the primary structural components of muscle tissue collagenous and myofibrillar proteins. Several investigators (Paul, 1963, Laakkonen *et al* 1970a; Draudt, 1969) have suggested that heat serves to solubalize connective tissue, providing a tenderizing effect, while hardening and therefore toughening, myofibriller proteins. In order to maximize tenderness, many workers have investigated the effects of low-temperature/long-time cooking processes on the quality of cooked meat and reported that samples are more tender and cooking losses are decreased when lower cooking temperature are used (Bramblett *et al.*, 1959; Marshall *et al.*, 1960; Woolsey and Paul, 1969; Bayne *et al.*, 1969; Bonton and Harris, 1972; Harrison, 1975; Loander *et al.*, 1980; Bonton and Harris, 1981). Dinardo *et al.* (1984) prepared beef muscle in a 60°C water bath and 94°C conventional oven, with some samples held in the water bath for 2-4 additional hours after reaching internal end-point temperature. Extended cooking times increased collogen

solubilization and decreased yields, overall rareness, panel scores for juiciness and flavour and Warner-Bratzler shear values.

Davies *et al.* (1975a) observed that shear force values obtained on raw pork muscle were not related to cooked tenderness while Alexander and Fox (1975) reported that cooked beef was more tender than raw beef, exceptin prerigor samples. Bouton *et al.* (1974), found that the adverse effects of cold shortening on muscle tenderness could be overcome by cooking (1-3 h or to an internal temperature of 90°C). However, Hostetler *et al.* (1976) reported that higher internal tempratures in meat after cooking were associated with lower tenderness values and that such relationships were greater in muscles that were allowed to shortern. Vollmax *et al.* (1976) observed that the longer internal temperature of beef was held within the range 55-70°C during cooking, the less tender and mealy the cut was. Williams and Harrison (1978) found that the length of time that the internal temperature of beef remained between 55 and 60°C was significantly related to the amount of collagen solubilized ($r=0.70$, $P < 0.05$) and to panel tenderness ($r=0.86$, $P<0.01$) and panel softness cores ($r=0.73$, $P<0.05$). Cross *et al.* (1975-1976) reported that tenderness and juiciness decreased with internal temperature regarless of oven temperature and that such tenderness raductions were more pronounced in mature beef. Dube *et al.* (1972) and Locker and Daines (1975) observed that the exposure of muscle to heat during cooking shortened the sarcomere and reduced the ultimate tenderness. It has been demonstrated that presurization of pre-rigor muscle significantly improves tenderness (MacFarlane, 1973; Elgasim, 1977; Kennick *et al.*, 1980). The usefulness of this technique is related to its possible effect upon the protein quality of meat as measured by better protein efficiency ratio (PER).

The tenderness of beef is an important palatability factor for consumer acceptance. There are a number of factors that influence meat tenderness (Szczesniak and Torgeson, 1965), one of the important being the aging. Usually ageing is allowed to be completed before freezing the meat. Marsh *et al.* (1968) found that freezing lamb meat during rigor, before completion of ageing leads to toughness. Locker *et al.* (1975) concluded that quick freezing of meat before ageing is responsible for pronounced toughness and therefore, they recommended conditioning and ageing the meat before freezing.

The pH also influences the tenderness of meat (Dodge and Stadelman *et al.*, 1960). It is believed that a slow rate of glycolysis results in tenderness of meat whereas with a rapid drop of pH from physiological value (about 7.32 to 6.0) within 20 min and a verylow ultimate pH (5.3), tenderness appears to decrease.

Water holding capacity

The water holding capacity (bound water) of muscle is closely related to tenderness and is influenced by the treatment of animal before slaughter (Hamm, 1963). Deatherage (1963) also indicated that the capacity of muscle to hold water is a main factor in tenderness. All other factors which influenced the water holding capacity of meat contribute of its tenderness or toughness. Good water holding capacity in meat imparts good appearance before and juiciness after cooking. Drip on thawing of frozen uncocked meat is manifestation of diminution in its water holding capacity. Out of the 70-75% raw meat, water is only 4% is chemically-bound and linked up due to the hydrophillic forcess of proteins. The rest is chemically free water (Hamm, 1963). Chemically bound water is altered by the physiological and structural changes (Hamm, 1960) and its presence during dehydration and freezing can accelerate denaturation of muscle proteins (Greavers, 1960). The water holding capacity of meat increases with the muscle pH in a direct relationship but at very high pH-values the dark colour and mushy strcuture makes the meat unacceptable. Conditioning of meat has long been known (Cook *et al*., 1926) to improve its water holding capacity and although slightly increased pH-values after conditioning may be held responsible for the phenomenon, a substantial contribution comes from an "ion-protein relationship" (Arnold *et al*., 1956; Hamm, 1960). Apart from these general effects, the water holding capacity of meat is altered by species age and individuals muscle (Hamm, 1960; Schon and Stosiek, 1958; Topel *et al*., 1967; Urbin *et al*., 1962). Further there is a well established positive correlation between intracellular fat and water holding capacity (Bryce-Jones *et al*., 1963; Hamm, 1960; Pearson, 1966; Scaffle and Bratzler, 1959).

Much of the success of the comminuted meat depends upon the ability of the muscle to hold fat as well as water. This is because the processed and comminuted meat is liable to loose more fluid after destruction of its structural organisation. Various workers have improved water holding capacity by the addition of salts (Gerard, 1955) and phosphates (Hellendrom, 1962) which alter the ion-protein relationship in muscle (Arnold *et al*., 1956; Hamm, 1960). The loss of water on cooking depends upon such factors as time, method and temperature of cooking (Bramblett and Vail, 1964; Paul and Bratzler, 1955). It is interesting to note that a fast rate of postmortem fall in pH is significantly related increased moisture loss on cooking (Sayre *et al*., 1964) due possibly to irreversible changes in ion-protein relationships which occur due to protein denaturation under such conditions. All factors affecting water holding capacity apply equally well to frozen and non frozen meats. However, removal of w: .er from within the muscle cells facilitates loss in moisture which appears as drip on thawing. Rate of freezing influence the water holding capacity and it is known that slow freezing

results in a lower-water holding capacity than does quick freezing (Hamm, 1963).

Both Boutan *et al.* (1973) and Walter *et al.* (1965) also observed significant relationships between muscle pH and water binding capacity, and McClain and Mullins (1969) reported significant inverse relationships between water loss and pH and between water loss and moisture content. Elliott (1965) found that both muscle temperature and pH were important determinants of ultimate meat quality; and Wirth *et al.* (1976) reported that water binding capacity, flavour, keeping quality, formation of cured meat colour and capacity for cure absorption were all dependent on muscle pH. Martin and Fredeen (1974) found that in the absence of stress conditions pH was not a reliable indicator of either tenderness or water binding capacity.

Other workers have reported that acceleration of postmortem glycolysis, with consequent decrease in muscle pH, may reduce both tenderness and water binding capacity (Ma and Addis, 1973; and Wismer-Pedersen, 1976). Kastner and Pussel (1975) have found that prerigor beef and higher water binding capacity than postrigor beef and was organoleptically more acceptable. Water binding capacity and the solubility of muscle proteins have been reported to be grossly altered by both temperature and pH during the first few hours postmortem and and onset of rigor mortis (Sayre and Briskey, 1963). Wismer-Pedersen and Briskey (1961) reported that fast-glycolyzing porcine muscle had low water binding capacity and that the lean portion was pale in colour, as a result of partial denaturation of the meat proteins.

Importance of pH value in meat

The symbol 'pH' (the hydrogen ion concentration) is an expression of degree of acidity or alkalinity of a substance or medium. The neutral point is 7 (using chemically pure H_2O as a basis) and a pH below 7 indicates the degree of acidity whereas a pH above 7 indicates the degree of alkalinity. The postmortem pH of meat will be determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis. Since pH is an important determinant of microbial growth, it will be obvious that the ultimats pH of meat is significant for its residence to spoilage. It has been establ shed that CO_2 immobilization of hogs reduces loss of muscle glycogen, resulting in a high pH. The animals rested and fed before slaughter have a lower pH, and that the feeding of sucrose to cattle and hogs before slaughter gives a lower pH resulting in improved colour and keeping quality (Lawris, 1966). The biochemical condition of a given muscle is also a factor in determing flavour. In general the higher the ultimate pH the lower is the flavour as determined by tasts panel, possibly because the consequently swollen structure interferes with access to the palate of the

substances concerned. A similar effect has been noted with cured meats. It has also been observed that the bacon of relatively high ultimate pH appears less salty to the palate than that of low pH, even when the salt content is the same in both (Ingram, 1949). It is now almost well established fact that a high pH and low muscle glycogen have been shown to be characteristic of dark cutting beef. The high ultimate pH alters the absorption characteristics of the myoglobin the meat surfaces becoming a darker red (Winkler, 1934). Such meat will also appear dark because its surface will not scatter light to the same extent as will the more 'Open' surface of meat of lower ultimate pH. Hall *et al.* (1954) showed that the colour of beef muscle is closely associated normally bright white at pH 5.7 the muscle becomes shady and dull. Above pH 6.5 the muscle become dark. A dark color is often associated by the consumer with the lack of freshness, even though it usually indicates and old animal or one that was slaughtered it usually indicates and old animal or one that was slaughtered under stress. Dark cutting is, sometimes, considered to result from exposure to various forms of stress during the pre-slaughter period (Hedrick, 1959; Lawrie, 1958).

Meat of high ultimate pH, which as a high water holding capacity when fresh, has also a higher water holding capacity after heating than that of normal ultimate pH (Bendall, 1946, Hamm and Deatherage, 1960). This phenomenon is important in the production of frankfurters (Grau, 1952) and canned ham (Koeppe, 1954) wherein application of heat is involved.

Wismer-Pederson (1959) believed that the enhanced water holding capacity of the meat of low ultimate pH was to the greater ease of salt penetration made possible with its more open structure and greater formation of salt protein complex.

An increase of temperature causes increase in the precipitation of sarcoplasmic proteins at all pH values. But at all temperatures, maximum precipitation occures at a pH range of 4.8-5.2. However, at some temperature between 37° and 45°C, a high ultimate pH no longer protects this precipitation (Scopes, 1964). The ultimate pH of the muscle affects the changes in the myofibrillar proteins and their extractability. It is now known that a high ultimate pH tends towards greater extractability of proteins. The temperature postmortem is also important, a high temperature being associated with lower extractability (Wismer-Pedersen 1962). The chemical condition of a given muscle is also a factor in determining flavour. In general, the higher the ultimate pH the lower is the flavouring as determined by tast panel, possible because the consequently swollen structure interferes with the access to the palate of the substances concerned. A similar effect has been noted with cured meats. It has also been observed that high pH appears less salty to the palate than that of low pH, even

when the salt content is the same in both (Ingram, 1949). It is important to note that rehydration of freeze dried meat having originally a low ultimate pH, in a fluid of high ultimate pH, does not enhance its water holding capacity to the same extent as does the rehydration of freezing.

There is some indication that juiciness reaches a minimum when the pH level of meat is about 6 (Howard and Lawrie, 1956). This possibility reflects the greater ability of muscle protein to bind water in this region. The process such as freezing, thawing and freeze drying also effects the juiciness of meat. It has been shown that juiciness was highest in the fresh or frozen meat of high ultimate pH and less in corresponding dehydrated material (Bouton *et al.*, 1958, Hamm and Deatherage 1960). It is belived that a slow rate of glycolysis results in tender meat whereas in case of a rapid drop of pH from physiological value (about 7.3) to 6.0 within 20 minutes, and a very low ultimate pH (5.3), tenderness appears to decrease. Luckett *et al.* (1975) have concluded that even where absolute pH differences are small postmortem pH measurements may be of value for segregating beef carcasses into tenderness groups. Bouton *et al.*, 1973) reported that the bovine longissimus dorsi muscle was maximally tough within the pH range of 5.3-6.0 and that in most other bovine muscles, a positive relationship existed between pH and tenderness.

It has been observed that muscle shown on open structure is usually dark in colour, has a high pH and is firm and dry whereas muscle with a closed structure is light in colour, has lower pH and tends to show soft watery characteristics (Wismer-Pederson and Briskey, 1961). The pH value of fresh buffalo meat ranged from 6.67 to 6.30 at the age of 50 days and also of the bulls of 24 months. After chiling, the reduction in the pH value was 1.34 in the former and 0.23 in the latter age (Ragab, 1966). The slower reduction in pH of meat from 24 months bulls may be due to their natured and violent struggling during slaughter resulting in the depletion of glycogen reserves of the muscle. Ragab (1966) also indicated the darker colour of meat from buffaloes than that of cattle. Seasonal effects on postmortem pH value has been studied by Bem *et al.* (1976) and Tarratn (1976). They have reported that high pH muscle occurred in both bovine and porcin. Tarrant (1976) found that the greatest incidence of such muscle in beef carcasses occurred between August and December and that only certain muscles were usually affected. other workers have reported significant differences in the incidence of such muscle in porcin breeds (Wismer-Pederson 1976) and bovine sexes (Fredeen *et al.*, 1974). Some evidence also exists tht the incidence of high pH muscle differ significantly among bovine breeds (Martin A.H., 1979).

High ultiamte pH in beef (Munns and Burrell, 1966) and fast rate of fall in

pigs, when the postmortem temperature is still high (Briskey and Sayere, 1929), (Sayere and Briskey, 1963) are known to be associated with dark cutting beef and pale, soft and exudative (PSE) pork. Porcin (Mcloughlin, 1970) and bovine (Bodwell *et al.*, 1965) muscle pH has been reported to decline from approximately 7.0 to approx. 5.5 during the first 49 hrs postmortem and then to increase slightly to approx. 5.6. However, Elliott (1965) reported that muscle from pigs susceptible to stress often reached an ultimate pH 4.7-5.4 in 45-60 minutes while Falk *et al.* (1975) observed that normally there is more rapid and greater decline in muscle pH during the first 3 hrs postmortem than during the subsequent four hours. Martin and Fredeen (1974) reported that with absence of stress conditions, pH was not a reliable indicator of either tenderness of water binding capacity. Bouton *et al.* (1972) reported that postmortem pH exerted the most influence on the mechanical properties of the muscle fibre and the adhesion between fibres.

Various workers have implied that high pH of meat and products made from it have a greatly reduced self life and a greater tendency to spoil (Bem *et al.*, 1976, and Hood, 1976) thus requiring optimum sanitation and refrigeration during processing and handling. Bem *et al.* (1976) and Ingram (1972) reported that the relatively high pH (about 6.2) of such muscle facilitated the growth of clostridia organism and other undesirable microorganisms which putrified the meat and subsequent product made from it. Bem *et al.* (1976) have recommended, therefore, that high pH muscle should not be used in raw meat products to be stored in vacuum packages or in the manufacture of frankfurter-type sausage or raw cured products.

Flavour

Historically flavour has been considered an important quality characteristic of meat. It seems from the reviews by Patterson (1975) and Dwired (1975) that the chemistry of meat flavour is not fully developed unless and until meat is thoroughly cooked.

Flavour precursors are distributed between the lean and fat in the spaces-specific elements probably present in the fat. Flavour profiles of meat have been defined chemically (Chang and Peterson, 1977; Persson and Vonsydow, 1973), but differences in flavour between high and low quantity of beef steak have not been conclusively developed. Over 100 compounds of at least ten different chemical classes were identified by Patterson (1975). Major studies on meat Flavour have been carried out on volatile aroma compounds which may be misleading as a sensation of juice in the mouth, playing an important part in the appreciation of meat flavour (Patterson, 1975). The isoation of various volatile

compounds, developed during the cooking process of beef, have been shown to be involved in the flavour of cooked beef (Kramlich and Pearson, 1960).

Over 500 compounds have been mentioned in the literature as components identified as the volatiles of cooked beef (Macleod and Seyydain-Ardebil, 1981). Heterocyclic compounds play an important role particularly in roasted flavours and in meat products (Ohloff and Flament 1978). Hartman *et al.* (1983) reported the identification of nitrogen containing heterocyclic compounds in the volatils flavour of roasted beef. Important non-volatile flavour components are produced with heating (Tonsbeek *et al.*, 1969) often with large flavour contribution (Tonsbeek *et al.*, 1971). The correlation of chemical composition with the flavour of beef remains elusive.

Lipids are important both as such and as a flavour precursors (Forss, 1969; Wasserman, 1972). Alabran (1982) isolated and identified the compounds, such as glutamic acid, lactic acid, phosphoethanolamine, glycerol, cretine and creatinine which represent 94% of the flavour fraction. Some minor cconstituents, amono-acids, were also identified. Reactions between proteins or amon-acids and carbohydrates have shown that the Millard-reaction is the principal factor by which known aroma compounds are formed.

Wilson and Katz (1972) reviewed the literature on chicken meat flavour and listed 178 compounds in the volatiles from cooked chicken. However, in another review by Ramaswamy and Richards (1982) more than 250 compounds have been identified in the volatiles of poultry meat. Tang *et al.* (1983) have reported the isolation and systematic characterization of the volatiles flavour constituents of fried chicken.

Colour

One of the major factor affecting fresh meat colour is the concentration and nature of the haemoproteins and thus it may not be surprising that the response of these pigments to meat is important in determining the colour of cooked meats. Retail acceptability of meat and meat products is largely dependent on the colour of the fresh meat Hood (1976) reported that the colour of fresh meat was dependent on microbial contamination, temperature, time postmortem, intrinsic muscle properties and exposure to light and ultraviolet radiations. He further reported that increase in temperature above freezing point accelerates meat discolouration, and therefore, the storage at 0 °C was considered essential for prolonged colour preservation. Lanier *et al.* (1977) noted an increase of oxidation of meat pigments at high temperature, high realtive humidity and low air velocity. The colour of lean meat is largely determined by the chemical state

of the meat pigments, primarily myoglobin. Myoglobin in uncut muscle given the meat a purplish red colour. However, when the cut surface of meat is exposed to oxygen for a short time (upto 20 min) the myoglobin becomes oxygenated and colour becomes more red (Price and Schweigert, 1978). However, if exposed for prolonged periods the myoglobin becomes oxidized (metmyoglobin) and muscle colour becomes brownish which markedly reduces the consumer appeal, acceptability and saleability.

Almost as important as Leanness, is the colour characteristics of meat, more so in beef (Landrock and Wallace, 1955; Jeremiah *et al.*, 1972). The oxymyoglobin metmyoglobin and reduced myoglobin are affected by packaging, length of dispaly time (Prike and Ayres, 1957; Pierson *et al.*, 1970; Livingston and Brown, 1981) and processing. Hall *et al.* (1980) found no differenes between muscle from ES and non-ES carcasses in colour, surface discolouration, or overall appearance for ground beef upto 3 days of display.

The dark coloured muscle is generally associated with high muscle pH (Romans and Ziegler, 1977; Price and Schweigert, 1978). There is apparently no direct pH effect on muscle colour, since there is little change in the affinity of myoglobin for oxygen over a broad pH-range (Stryer, 1981). Actively respiring mitochondria in pre-rigor muscle deplete oxymyoglobin reserves, preventing bloom on surface exposed to air, and this phenomenon affects colour. A chemical, votenon, blocks mitochondrial respiration by inhibiting transfer of electrons to the flavin-mononucleotide prosthetic group of NADH-Q reductase (Stryer,, 1981; Zubay, 1983) and hence colour remains good. Cornforth and Edbert (1985) determined the effect of mitochondrial inhibition by rotenone and low pH on pre-rigor muscle colour by the use of the Hunter Colour Difference Meter and by visula appraisal. They found that it led to the development of the bright red colour in the beef muscle homogenates, probably due to the fact that the myoglobin remained oxygenated.

Meat Preservation

The dictionary defines 'Preserve' in the sense of preserving meat is 'to save from decompostion' since the only known natural agents causing rapid decomposition of meat and other foods are microorganisms, the art and science of meat preservation must involve processes that prevent the growth and action of microorganisms (molds, yeats and bacteria). Any method of food preservation must depend basically on killing all spoilage microorganisms and then keeping the product under sterile conditions or on holding the product under conditions that do not permit spoilage microorganisms to grow. Naturally any acceptable method of preservation must be such that the food remains edible after the preservation process and subsequent storage.

Spoilage microorganisms will grow only if , proper nutrients are furnished and adequate amounts of water are present. The temperature is within the proper range and no lethal (antiseptic) compounds are present.

We might preserve meats by removing moisture (drying), holding at a temperature above or below that needed for microbial growth, freezing of chilling, and salting are the generally used preservation preocesses.

Dehydration

During the second World War considerable interest was shown all over world in the dehydration of meat (Sharp, 1953; Lea, 1944; Bartlett, 1943). High class dehydrated meat products have been developed by British workers (Rolfe, 1950; Gooding and Rolfe, 1957) using an elegant though expensive technique of accelerated freeze drying.

The drying of meat for preservation is based on the fact that microoganisms and enzymes need water in order to be active. The removal of water (moisture) from meat by heat is the main process of dehydration. The preservation by dehydration is due to the reduction of water activity to such a low level that microbial growth is inhibited.

The dehydration of uncooked meat containing a cure of salt sugar, nitrates etc. was investigated by Ritchell *et al.* (1943). Such meats (e.g. communited pork and beef mixture) have long been dehydrated in casings to produce what is known as dry or summer sausage. It is not a great fact or in the current dehydration programme, because of the length of time required for the drying process (30-90 days).

Australian workers have devoted lot of attention to the preparation of dehydrated pre-cooked mutton mince, employing the simple air-drying technique (Howard *et al.*, 1956; Howard and Prater, 1960; Howard *et al.*, 1960; Howard and Prater, 1961; Prater and Coote, 1960 and Prater and Eliott, 1959). Dehydration using a through flow dryer with wire mesh trays gave good result and with cross flow dryer also gave satisfactory product but the drying time was longer. Dehydrated mince with 3-4% moisture content and fat content less than 25%, packed under nitrogen has been found to keep well for 6 months at 37°C (Iyenger *et al.*, 1962).

The meat is usually cooked prior to dehydration. However, proper degree of pre-cooking is an important factor, over cooked meat's concentrative tissue will be changed to gelatin. It will give dry granuless and break down under

compression. During cooking extract obtained from the meat contains soluble substance and should be returned to maintain the nutritive value. Once dried, the meat must be stored in moisture proof bags or cotainers to prevent uptake of moisture from the atmosphere. The main advantages of drying as a method of preservation are the savings in weight and space and consequently packing methods include:-

1. Sun drying
2. Hot air drying
3. Freeze drying

Curing

Curing is processing method used to increase the keeping qualities of meat, fix the colour and alter and improve the flavour. Meats are cured by bringing them into intimate contact with the curing agent "(Dry cure or Picke)". Although a variety of compounds can be used in curing meat, the basic curing ingredients are salt, sugar or some other sweetener, and nitrite and/or nitrate. In addition, phosphates are commonly added to pickle cures in commercial operations to enhance water holding capacity.

Salt acts by dehydration and altering of the osmotic pressure so tht it inhibits bacterial growth and subsequent spoilage. But the use of salt along results in a dark, undesirable colored lean that is unattractive and objectionable to consumer. Sugar softens the products by counteracting the harsh hardening effects of salt by preventing some of the moisture removal and by a direct moderating action on flavour.

The function of nitrite in meat curing is four fold (1) to stabilize the colour of the lean tissues, (2) to contribute to the characteristics flavour of cured meat, (3) to nihibit growth of a number of food poisoning and spoilage organisms, and (4) to retard development of rancidity. Nitrite is effective in nitrite in cured canned meat products, that are thermally procesed, aids in destroying the spores of anaerobic bacteria and inhibits germination of the surviving spores. Infact, the addition of 150-200 ppm of nitrite to canned or vacuum packaged processed meat products prevents the formation of butulinum toxin that may occur at lower nitrite levels, or in its absence.

Freezing

Freezing of meat has long recognized been as an excellent method for the preservation of meat. It results in less undesirable changes in the qualitative and

organoleptic properties of meat than other methods of preservatin. Most of the nutritive value of meat is retained during freezing, only some of the water soluble nutrients are lost in the drip during thawing. The nutrients found in the drip include salts, amino acids, some proteins and water soluble vitamins (Howard *et al.*, 1960). Quick freezing, produces a large No. of small crystalls both outside and inside the cells resulting in a near normal ultrastructure and striated appearance in the frozen state. The form of freezing is ideal for meat because when the meat is thawed the better distributed water can be better reabsorbed by proteins.

According to the Deatherage and Hamm, 1960, Freezing and thawing caused only minor changes in the water holding capacity of meat, while quick freezing (-55°C) of both ground and cut meat results in a small but significant increase of water holding capacity. It is known that slow freezing results in more 'drip' than quick freezing (Bysstrone, 1940). Callow, 1952; Drozdov and Yanuschkin, 1954; Hiner *et al.*, 1945; Smorodintser, 1953). The more slowly the tissue is frozen the larger are the crystals of ice and more cell walls are destroyed (Kuprianoff, 1952) and large crystals of ice are found between the muscle fibre.

From the nutritive point of view freeze drying does not alter the biological value of the meat proteins (Hanson, 1961 and indeed, may enhance it (Adachi, Sheffer and Spector, 1958). Although there is a loss of about 30% of the the thiamin content of the meat during freeze drying, this would occur on cooking in any case. It is also interesting to note that freezing is an excellent way of excluding animal parasite from meat (Trichines, tap warms, toxoplasms, Wirth, 1979). Recent work (unpublished data of Anila Qaisara and H. Ahmed) on the domestic freezing practices of about 2-4 weeks on fresh meat and meat products has indicated no detectable changes in their organoleptic appreciation.

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