

# CHEMISTRY IN THE MEAT INDUSTRY

The meat industry is concerned with turning an animal carcass into many different end-products. These end-products are derived from all parts of the animal (muscle, bone, fat, cartilage, skin, fluids and glands), and are produced through a range of physical, chemical and biological processes.

## **The Composition of Meat**

Meat is composed of, in descending order, water, protein, fat, other water-soluble organic material and water-soluble minerals. The fat portion includes some fat-soluble substances, including some vitamins. Meat is an important source of amino acids (the building blocks of proteins), minerals and vitamins, as well as being a good source of energy.

## **Biochemical Changes: From Muscle to Meat**

The most significant change occurring on death is that circulation stops, with the result that oxygen is no longer sent to the animal cells. This means that reactions begin to take place there under anaerobic conditions. One of the major consequences of this is that the pH decreases, because in the absence of oxygen glucose is converted to lactic acid rather than  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . This tenderises the meat, so research is being done into ways to maximise this effect.

## **The Importance of Myoglobin**

Myoglobin is the major pigment in meat. In different environments it has different forms, each with a slightly different colour, e.g. in cured meat it is pink, in very fresh meat it is purplish-red, and in meat that has been exposed to the air it is bright red. By changing the environment in which meat is stored and packaged, the colour of the meat can be controlled.

Three components of an animal carcass with specialty value are the fat, collagen and glands.

## **Fat**

The fat (lipids) is an important source of energy. The lipids can be used as is for animal feed, or processed to make tallow for margarine manufacture or free fatty acids and glycerol for soap manufacture. Anti-oxidants (e.g. vitamin E) prevent the fat from going rancid.

## **Collagen**

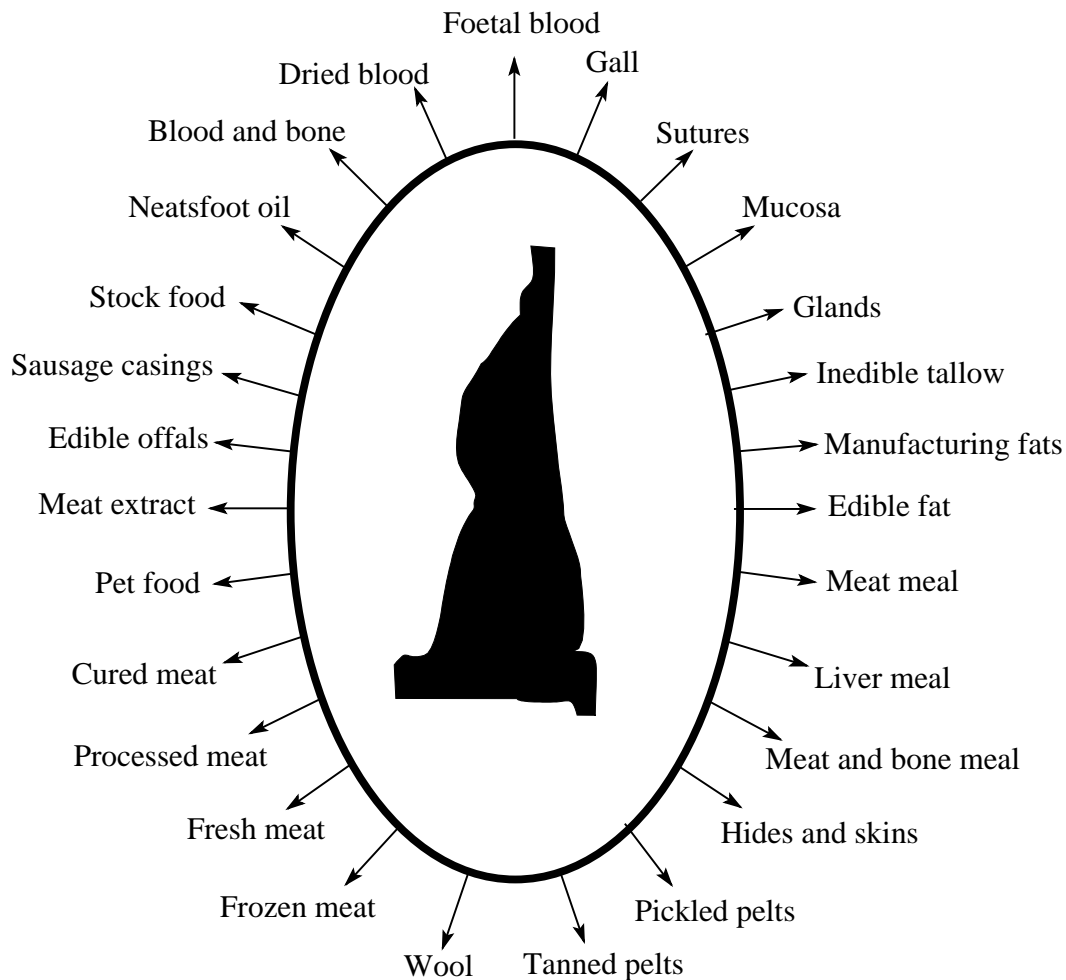
Collagen is a fibrous protein found in the bones, teeth, skin and connective tissue of animals. It is the portion of skin used to make leather, and also the portion of the intestines used to make sausage casings. If it is reacted first with alkali and then with hot aqueous acid its structure breaks down to form gelatin.

## **Glands**

Many animal glands can be processed to make pharmaceuticals, e.g. adrenalin, a heart stimulant, is commonly extracted from the adrenals of cows.

## INTRODUCTION

The meat industry is involved in the processing of meat from slaughter to edible and inedible end-products. The task can be likened to "biochemical disassembly", in which a small number of raw materials are biochemically altered to produce a huge range of different products. To accomplish this, a wide variety of different skills are needed, including those of chemists, microbiologists, food technologists and engineers.



**Figure 1 - Meat processing end products**

### Meat products

The main meat end products are given in **Figure 1**. From this it can be seen that the products fall into four main categories: skin products (leather, wool etc.), pharmaceuticals, blood products and edible meat-based products, as well as various other products such as sausage casings, sutures and oils.

## THE COMPOSITION OF MEAT

The various constituents of meat are listed in **Table 1**, and discussed in more detail below. Each of these broad categories consists of many different chemical entities which are modified to obtain the wide variety of products listed above.

**Table 1 - The composition of meat**

Substance	Composition	Proportion / %		
		Lean (average)	Beef	Lamb
Water		75	73	71
Protein		18	22	21
Fat	Includes phospholipids, cholesterol and fat-soluble vitamins.	3	3.9	7.4
Other soluble organics	Amino acids, vitamins, carbohydrates.	3	1.1	1.0
Soluble minerals	Mostly K and P. Small amounts of Na, Mg, Ca and Zn.	1		

**Water**

Water content can be decreased (e.g. dried or dehydrated meat), and it varies in many processed meats such as sausages, salamis, bacon and ham. During these processes, care must be taken to protect the nutritional and organoleptic (taste, smell, texture and appearance) properties of the meat.

**Protein**

Protein is the source of the essential amino acids necessary for life. It is the building block of the muscular tissue.

**Fat**

Fat itself consists of triglycerides (see below), and is the main energy reserve for the animal. Other important substances (e.g. some vitamins) are dissolved in this fat.

**Soluble non-protein organic substances**

These substances fall into two categories: nitrogen-based substances such as free amino acids and vitamins, and carbohydrates such as lactic acid and glucose.

**Inorganic substances**

The major minerals consist of phosphorous and potassium together with small amounts of sodium, magnesium, calcium, zinc, and other trace metals.

Thus meat is a good source of essential amino acids, minerals and vitamins, and a good source of energy (on average, beef yields 510 kJ and lamb yields 630 kJ per 100 g). All the essential amino acids required for life are present and highly bioavailable in raw muscle tissue. Iron, phosphorous and potassium (together with the sodium present in cured meats) are important minerals. Pork has a high vitamin B content, while liver is rich in a considerable number of vitamins, particularly vitamin A. Meat is an important dietary source of both vitamins B1 (thiamin) and B2 (riboflavin).

## BIOCHEMICAL CHANGES: CONVERTING MUSCLE INTO MEAT

After slaughter, the various regulatory processes which prevent living meat from decomposing cease to function. The most significant of these occur as a result of circulatory failure, which causes the oxidation of muscle glycogen<sup>1</sup> to cease and glycolysis to proceed. Changes in key properties of the meat are outlined below.

In life: 
$$\text{Glycogen} + \text{O}_2 \xrightarrow{\text{aerobic conditions}} \text{CO}_2 + \text{H}_2\text{O} + \text{ATP(energy)}$$

But in death: 
$$\text{Glycogen} \xrightarrow{\text{anaerobic conditions}} \text{C H}_3 \overset{\text{O H}}{\underset{\text{O}}{\text{C}}} \text{H C O H}$$

**Figure 2** shows some of the changes which occur after slaughter.

### Acidity

With the accumulation of lactic acid the pH falls from 7 to 5.5, and at the same time the energy rich ATP<sup>2</sup> reserve is depleted. The drop in pH is a desirable feature as a low pH slows down growth of micro-organisms and enhances flavour, juiciness and colour of the meat to give an attractive saleable product. As the above equations show, the more glycogen in the muscles, the more lactic acid formed. Consequently, animals are held at rest at the works before slaughter to make sure that they are not stressed prior to slaughter, as stress causes them to burn up their glycogen reserves. Meat from stressed animals has a high pH, causing it to be dark in colour, firm in texture and dry in taste (known as DFD meat).

### Protein fibre

After slaughter, shortening of the muscle protein fibre causes the meat to become tough, a process that is accentuated by freezing immediately after slaughter. To produce meat of maximum tenderness the carcass is allowed to hang for at least 24 hours before freezing. In addition, carcasses are electrically stimulated, as chemists at the Meat Industry Research Institute in Hamilton have found that this increases the rate of *post mortem* glycolysis and thus helps to prevent cold induced toughening.

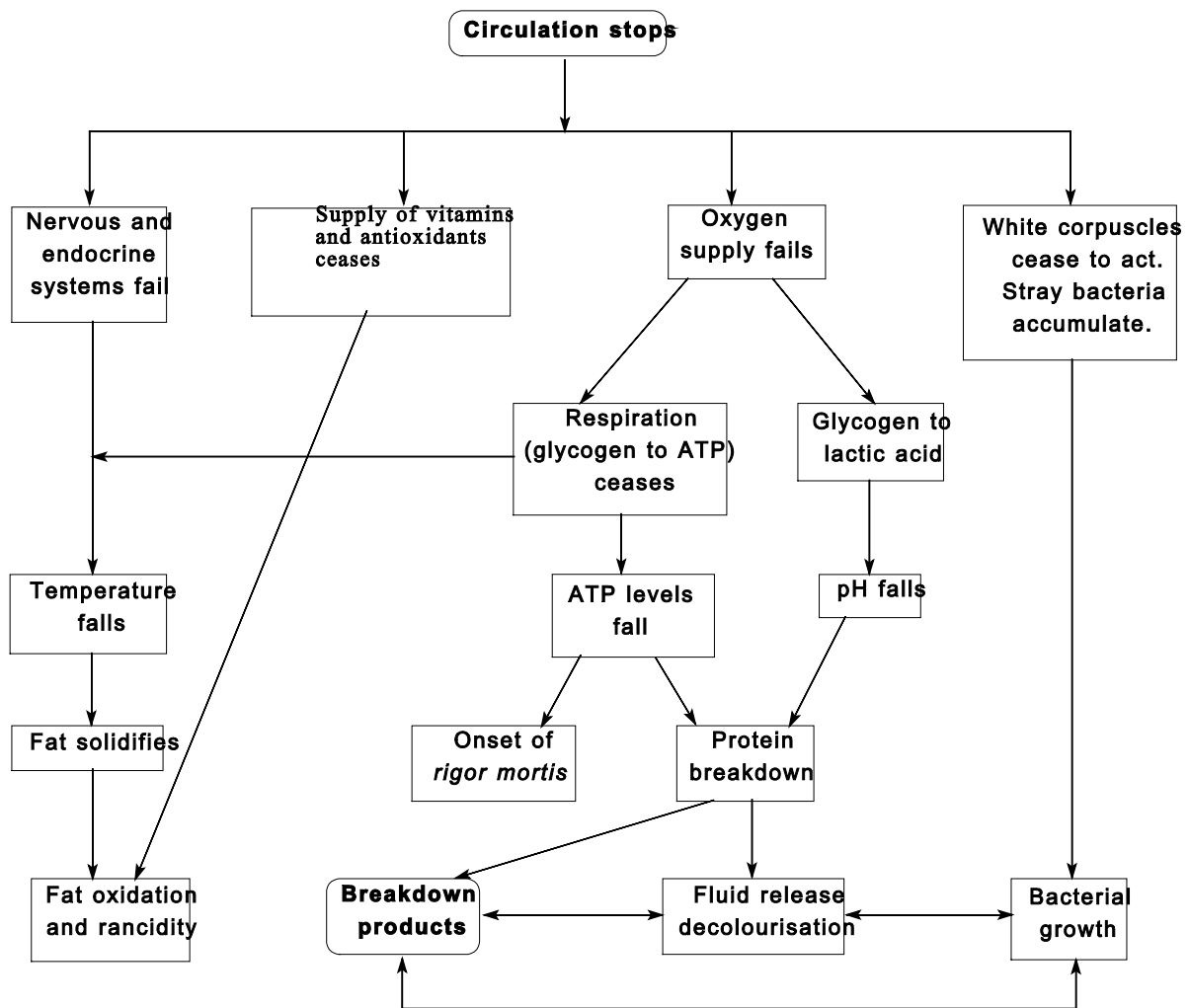
### Factors affecting the tenderness of meat

As has already been noted, pH, temperature and time are all of crucial importance in ensuring that the end product is as tender as possible. Current research is focussing on the inter-relationships between these factors and the action of calcium dependant proteases (enzymes

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<sup>1</sup>A starch-like polymer used in animal muscle and liver cells for glucose storage. Under anaerobic conditions (absence of O<sub>2</sub>) glycogen breaks down to finally form lactic acid in a process known as "glycolysis". In the presence of oxygen, the glucose is oxidised to CO<sub>2</sub> and water with the concurrent formation of ATP (the source of energy in many biochemical reactions).

<sup>2</sup>ATP (adenosine triphosphate) is a complex organic molecule that provides the energy to drive many biological reactions. It is converted to ADP (adenosine diphosphate), releasing energy which is then used to carry out an oxidation reaction within the cell.



**Figure 2 - The changes in meat after slaughter**

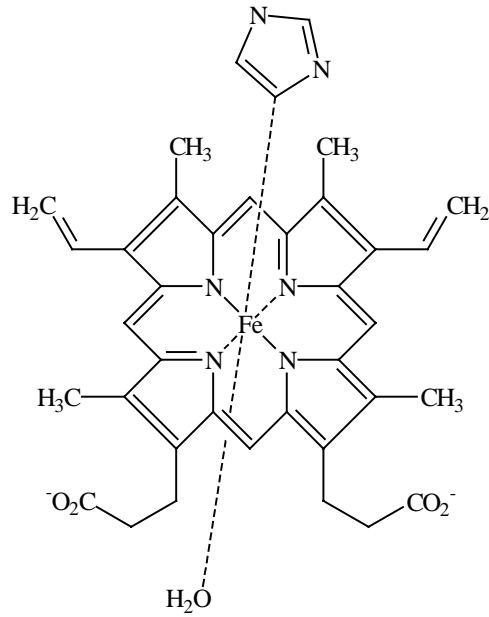
requiring calcium ions to activate them). Predictive computer models are being developed to assist the export meat industry in producing more tender meats for the supermarkets of the world.

## THE IMPORTANCE OF MYOGLOBIN

Myoglobin (shown below) is a haemoglobin-related substance that is found in animal cells. Where haemoglobin is used in blood as an oxygen carrier, myoglobin is used within cells (especially muscle cells) for oxygen storage. Depending on the oxidation state of the iron and whether the ligands are ionically or covalently bonded to it, the myoglobin changes colour. Because of the high concentration of myoglobin in muscle cells, these colour changes correspond to colour changes of the meat as a whole. These changes are summarised below in **Figure 3**. As the colour of meat is a very important attribute in the eyes of the consumer, it is important to control these interconversions as much as is possible to give an end product of the desired colour.

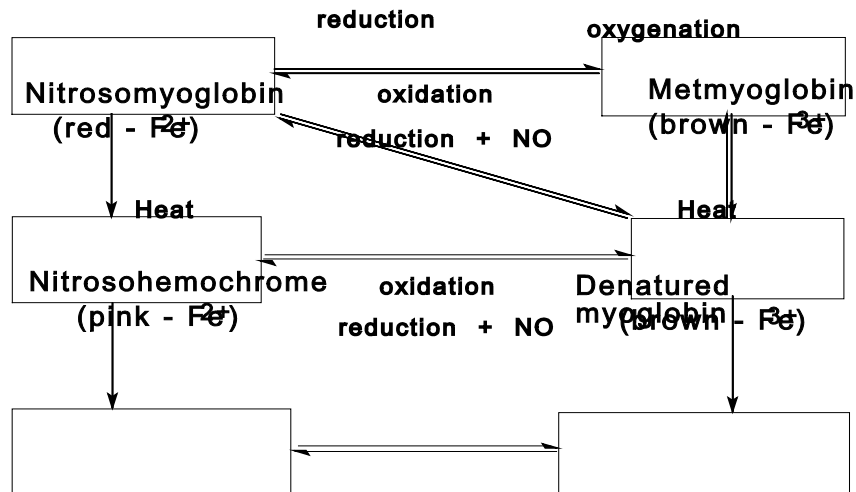
### The Forms of Myoglobin

Myoglobin is responsible for the purplish red muscle colour, observed in the depth of the



**Myoglobin**

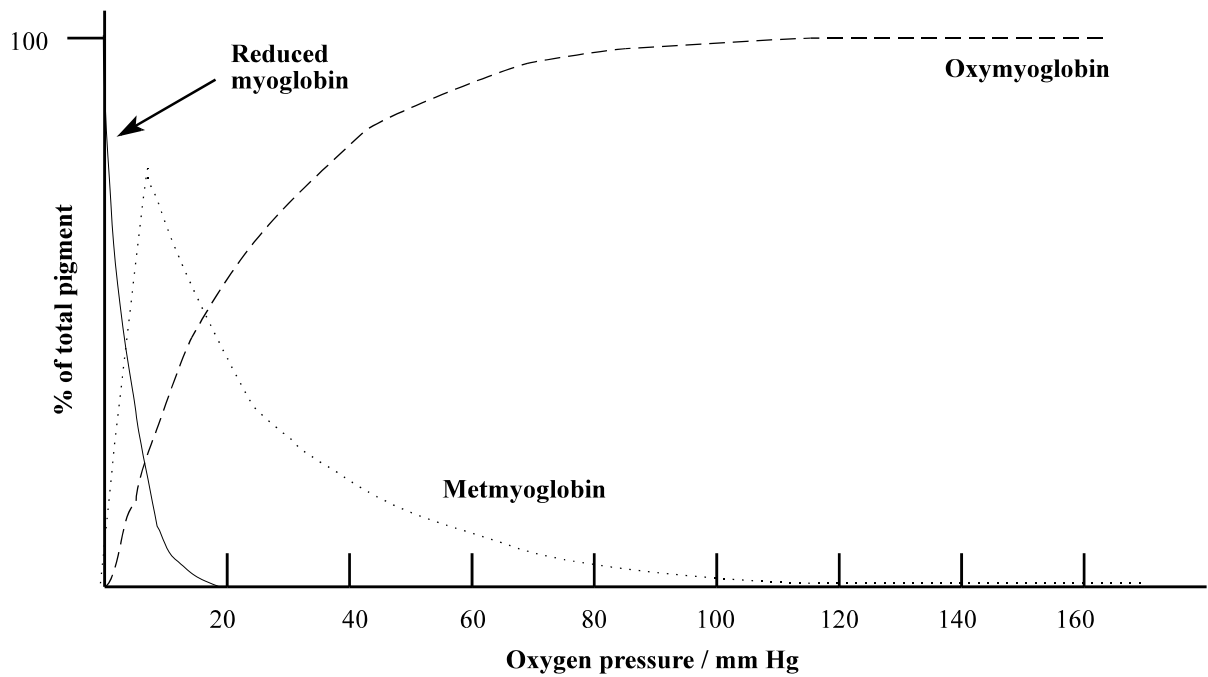
muscle when meat is freshly cut. This quickly changes to the bright red oxymyoglobin, due to oxygenation when the muscle surface is exposed to air. With time this slowly reverts to the unattractive, dull brown, metmyoglobin associated with stale and spoiled meat. The colour of cooked meat is due to denaturing the metmyoglobin.



**Figure 3 - The reactions of myoglobin**

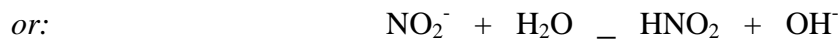
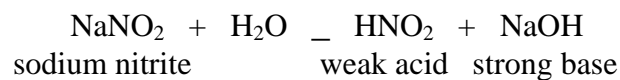
Under conditions of low oxygen partial pressure formation of metmyoglobin is favoured is shown in **Figure 4**. The formation of unattractive brown metmyoglobin is maximised at an oxygen partial pressure of about 10 mm mercury, which has implications for vacuum packaging.

Modification of the myoglobin molecule takes place in the meat curing process where nitric oxide (NO), which originates from the sodium nitrite or potassium nitrite curing agent,

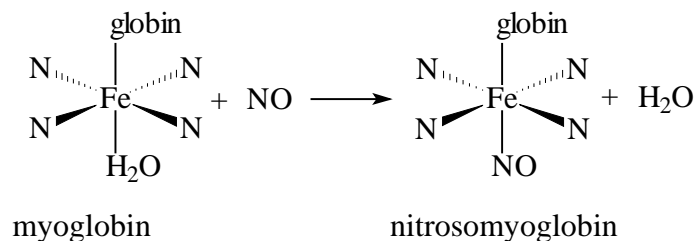


**Figure 4 - The changing forms of myoglobin with pressure**

combines to form nitrosomyoglobin.



Modern day meat curing has arisen from the historical practice of salting meat to preserve it. The impure salt that was used contained traces of sodium nitrate,  $\text{NaNO}_3$ , which was converted by bacteria in the meat to sodium nitrite,  $\text{NaNO}_2$ , thus providing nitric oxide,  $\text{NO}$ , by the reactions above, which resulted in the typical pinkish cured meat colour being formed. Today, cured meats have become products in their own right and are now desired because of their particular organoleptic characteristics such as flavour, texture and appearance. Examples are ham, corned beef, bacon, salami, sausage etc.



This is a good example showing the use of basic chemistry in a meat processing operation.

## Implications for packaging

The chemistry of meat pigments is an important factor in determining the correct packaging material for meat and meat products.

- *Vacuum-packed meat* must have very low oxygen pressure (i.e. below 10mm Hg) so that metmyoglobin levels are minimised. Vacuum-packed conditions prevent oxidation (important in chilled and cured meats), and also inhibit bacterial growth.
- *Fresh chilled meat and frozen meat.* These are packaged covered in plastic film. The film must have high oxygen permeability to promote oxymyoglobin formation, but low moisture permeability so that the meat does not dry out.
- *Modified atmosphere packaged meat.* If meat is to be stored for a long time, oxygen levels must be kept extremely low to prevent bacterial growth. This is done by storing the meat in metallised or metal laminated film with no permeability, and injecting this with an inert gas.

Other than meat itself, three of the most economically important constituents of an animal carcass are lipids (i.e. fat), collagen (derived from connective tissue and the skin) and glands. The processing of these components is outlined below.

## LIPIDS

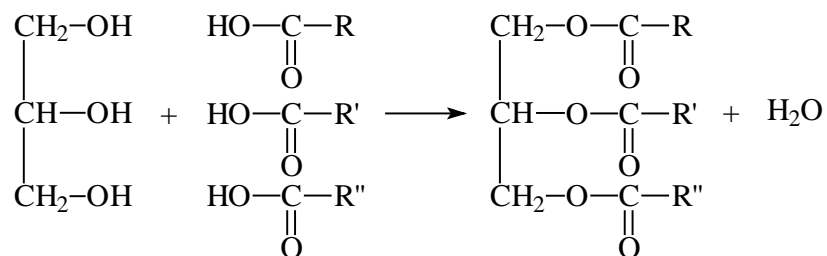
Large quantities of fat in the form of edible fat or inedible tallow are produced by the Meat Industry and used as a raw material for:

- shortening and margarine manufacture
- soap making and fat splitting
- animal feedstuffs

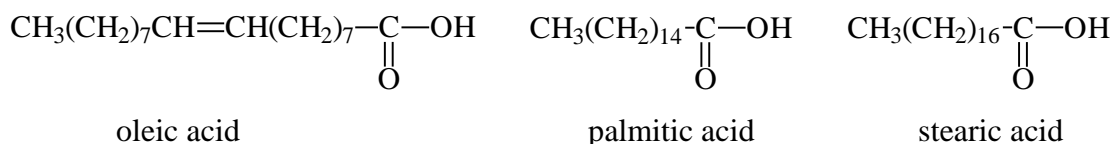
Animal fat has been criticised on health grounds, but is still an important constituent in the diet, providing energy, essential fatty acids and interaction effects with other nutrients.

### Structure

Any lipid, whether derived from plant, animal or synthetic sources, consists of triglycerides, i.e. can be formed in accordance with the following equation:



Thus a triglyceride is a glycerol joined to three fatty acids. The three major fatty acids occurring in animal fats are oleic, palmitic and stearic acids.





In addition to the lipids, small quantities of fat-soluble substances such as fat-soluble vitamins are also found in animal fat.

### **Lipid reactions occurring in meat processing**

The two most important reactions are the oxidation and hydrolysis reactions of fat. In fat oxidation, the carboxylic acid group of the fatty acid chain is oxidised, making the fat rancid.

This reaction goes slower in the presence of antioxidants such as the naturally-occurring vitamin E, and goes faster at higher temperatures, with more unsaturated fats (i.e. fats with fewer double bonds) and with trace amounts of metals to act as catalysts.

Fat hydrolysis, the other important reaction, is the reverse of the reaction for fat oxidation given above, i.e. one mole of fat reacts with one mole of water to give one mole of glycerol and three moles of fatty acids. The rate of this reaction increases with temperature up to 70°C, and is catalysed by the enzyme lipase.

### **Lipid processing**

Fat is used as is in animal feeds. For all other uses it has to be converted to tallow. Tallow manufacture consists of freeing the fat from its associated tissues by heat rendering and then refining it to separate it from the solids and water which would lead to its deterioration. The major source of deterioration is oxidation (as outlined above), although this is inhibited by the vitamin E (a fat-soluble vitamin) naturally occurring in the fat.

This tallow is then either sent to various other industries such as the edible fats and oils industry for processing into saleable goods, or processed further on site. The tallow that is sold on the export market has to meet precise chemical specifications in terms of:

- colour (originating from the pigments carotene and chlorophyll derived from feedstuffs)
- bleached colour (indicates the degree of colour removal for soap making purposes)
- titre (solidification point of the fatty acids which indicates the hardness of the resulting soap)
- free fatty acid proportion (measures fat deterioration)
- moisture and impurities (indicates the efficiency of the refining)
- stability (indicates the freedom from rancidity)

If the tallow is further processed on site, this processing consists of fat hydrolysis to produce free fatty acids and glycerol as outlined above. The fatty acids are used in soap and detergent manufacture, and the glycerol is used by many industries, including the confectionery and cosmetic industries.

## **COLLAGEN**

Collagen is the most widely occurring protein in the animal body, being the basic component of the intestines and the dermal portion of the skin, and serving as connective tissue in almost every organ of major importance in bone, tendons, teeth and connective tissue of muscle.

### **Structure**

Collagen is a triple helix of peptide chains coiled about one another to form fibre. The tissue is strong and contains very few cells - a structure which leads to remarkable strength and versatility.

### **Reactions**

The hydrolysis of collagen yields gelatin. The process consists of conditioning with alkali (hydrated lime) which serves to break cross linkages between peptide chains, followed by hot aqueous extraction under acid conditions.

### **Processing**

The most important use of collagen is in fellmongery and the production of leather. However, this process is too complicated to be covered here, and instead is covered in the next article.

The two other major uses of collagen are in gelatin and in sausage casings. As outlined above, collagen can be hydrolysed with alkali and then hot acid to form gelatin. This is done using waste material that is rich in collagen (e.g. skin pieces, bones, trotters). In addition, animal intestines (which are largely collagen) are used to make the casings for sausages.

### **GLANDS**

A wide number of pharmaceuticals are potentially available from animal glandular material. This is covered in the article "Pharmaceuticals from Animal and Plant Products".

### **ROLE OF THE LABORATORY**

The laboratory is primarily involved in analysis of the more processed products, such as tallow, gelatin and the various pharmaceutical products.

Revised by R.C. Rendle (Kaiapoi High School) from an article written for volume one of the first edition by R.C. Rendle and G. Keeley (Canterbury Frozen Meat Co. Ltd.), with editing by Heather Wansbrough.