Meat technology update

00/2 – April 2000
Reprinted November 2006

MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Prevention of fresh meat colour defects

Consumers usually assess meat quality in terms of colour, tenderness, juiciness, flavour, fat cover and marbling. However, at retail level, customers are most influenced by meat colour in their decision to buy. Colour is perceived to be a valuable guide to the overall quality of meat; if a visual appraisal raises any doubts it is unlikely that purchase of that particular item will be considered further.

Although there are conflicting scientific studies about colour relevant to eating quality, it is the colour of meat that first influences the potential customer and also affects the judgement of wholesale and institutional purchasers. It is therefore necessary to have an understanding of the variations in meat colour and how it is affected by various conditions and handling practices.

The basis of fresh chilled-meat colour

In the absence of oxygen (O_2), fresh meat is purplish-red. This colour is caused by the presence of a pigment called myoglobin, which, on exposure to air, absorbs oxygen and becomes bright red. Since this occurs progressively, colour appraisal of the meat should be carried out after it has been exposed to air for approximately 30 minutes. The oxygenated form of the pigment, called oxymyoglobin, causes the bright red meat colour expected by the consumer. The red meat layer occurs to a depth of only 3-4 mm at 0°C (Figure 1A).

After the meat's prolonged exposure to air, the pigment turns grey or brown just under the surface. This brown pigment is known as metmyoglobin (Figure 1B).

Systems in the meat and environmental factors control the rate at which the pigments change from one state to another. Generally speaking, pigment changes are caused by factors that reduce the O_2 tension at the meat surface or cause dissociation of the O_2 from oxymyoglobin. With this in mind, conditions of primary importance to meat colour are temperature, pH and the amount of available oxygen.

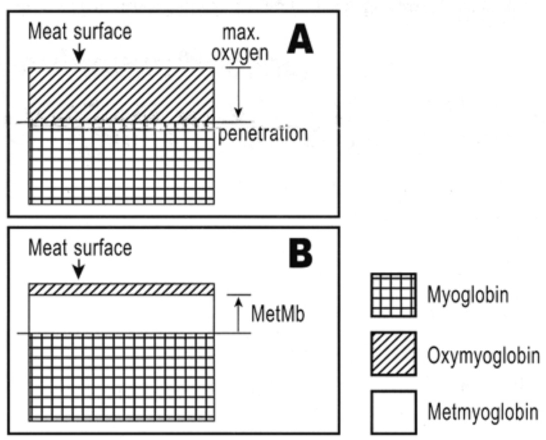

FIGURE 1 A simplified representation of the formation of pigments at the surface of meat

FOOD SCIENCE AUSTRALIA
A joint venture of CSIRO & the Victorian Government

AMPC
mla MEAT & LIVESTOCK AUSTRALIA

General points

- The rate of metmyoglobin formation is related to the balance between systems in the meat that promote metmyoglobin formation and those that slow it, as well as the oxygen content of the atmosphere around the meat.
- At extremely low concentrations of oxygen (such as in vacuum packs), the development of the brown pigment is prevented. However, at medium to low oxygen levels (about 1%, such as in poorly prepared vacuum packs), metmyoglobin development is greatest. There can be increased browning when unwrapped cuts are stacked in contact with each other and this browning occurs because of the low oxygen levels at the points of contact.
- Low temperatures slow the rate of the chemical and enzymic reaction leading to brown metmyoglobin pigment formation.
- The red colour of meat is brighter and deeper at low storage temperatures because oxygen is able to penetrate the meat more easily. The layer of oxymyoglobin at the surface of the meat is thicker at 0°C than at 15°C.
- Differences in the chemical and enzyme activities of different muscles cause colour stability variations from cut to cut and also within a cut. It is not uncommon to see red and brown parts within one cut. Some cuts, such as rumps and tenderloins, are more susceptible to browning than others such as striploins.
- pH (acidity) has an influence on retail display life in air. High-pH meat (dark cutting) discolours at a slower rate than low-pH meat. Meat discolours at a slower rate as its pH increases above normal pH (5.5).
- Beef from grass-fed cattle contains high levels of natural antioxidants, such as vitamin E and beta-carotene, which slow down the browning discolouration. Beef from cattle raised on good-quality pasture has Vitamin E content and lipid stability equivalent to that from grain-fed cattle supplemented with over 2500 international units (I.U.) of Vitamin E per day for four months.
- Exposure of meat to intense light, as in display cases in supermarkets, also increases the discolouration rate. It does this mainly by increasing the surface temperature of the meat.
- Contamination of meat with multivalent ions such as copper, iron and aluminium and oxidising agents such as peroxide, hypochlorite and common salt (NaCl) also greatly accelerates the rate at which meat discolours.
- Localised areas of discolouration on the surface of meat, sometimes referred to as ‘spot’ discolouration, may result on fresh meat surfaces from bacteria, contaminating substances, partial contact with other meat or packaging surfaces or from by-products of fat oxidation (which lead to fat rancidity).
- Lighting will influence the colour appearance of meat. Adequate quantity of light (or illuminance) is only one of the necessary elements of a satisfactory lighting system, particularly for such tasks as inspection for meat colour. Failure to achieve adequate light quality can reduce the efficiency of assessment and thereby increase the likelihood of customer complaint. In chiller assessment AUS-MEAT require that the exposed meat be evaluated after at least 20 minutes of cutting (provided blooming is complete) using a light with 1400-3000 lux (recommended 1800-2600 lux) and a colour temperature of 3000 degrees Kelvin (K).

Other aspects of fresh chilled-meat colour

Pigment concentration

For meat at any particular pH level, the greater the concentration of myoglobin, the darker the colour of the meat. Its concentration varies from species to species. Beef contains about nine times as much myoglobin as pork and this partly explains why beef is red and pork is pink. Meat colour is also affected by the sex and age of the animal, with older animals having a higher concentration of pigment. Within a carcase, different muscles contain varying concentrations of myoglobin, and so vary in darkness of colour. Meat from bulls typically has a higher myoglobin (muscle pigment) content than that from steers, heifers or cows at the same age. Similarly, meat from rams has a higher myoglobin content than that from wethers and ewes.

Drying out

Drying of the meat surface affects the way that light is reflected and absorbed. The drier the meat surface, the greater the reduction in reflected light. During drying, the concentration of meat pigment increases at the surface and produces a darkening effect. Drying out also leads to increased brown pigment formation. This darkening, due to dehydration, can often be seen on the cut surface of the topside on sides of chilled beef.

'Dark cutting' meat

Stress prior to slaughtering also plays a significant role since it affects meat pH, which in turn affects colour. High-pH meat is dark because, with low acid levels in the meat, there is less oxymyoglobin formation at the surface. The reduced myoglobin under the surface gives a dark appearance to the meat. As a result, there is less light reflected from the surface. This, coupled with the fact that there is a light scattering effect, causes the eye to perceive the colour differently.

Meat colour gradually darkens with an increase in ultimate pH right through the pH range 5.4 to 7.0. If beef has a pH of 6.0 or more it is usually classified as 'dark cutting' or 'high-pH' beef. However, meat with an ultimate pH of 5.8 may be regarded as dark by some consumers but would not be classed technically as 'dark cutting' meat. Dark cutting meat has a shorter shelf-life than meat of 'normal' pH.

Two-toned (pale and 'dark') meat

In two-toned meat there are undesirable gradations in meat colour within a cut, with the deep meat tissue being paler than the normal red meat closer to the surface. Pale-coloured meat will discolour more quickly than normal-coloured meat in the presence of oxygen because of the effect on its enzyme system and the faster progression of the metmyoglobin reaction.

The two-tone effect is sometimes evident in beef (particularly heavy carcases), but is not seen in smallstock carcases to any extent because of their more even chilling rate. The paleness causes a ring effect in the meat, sometimes called a 'heat ring and is due to the comparatively slow cooling of the deep meat compared to that of the surface meat.

The undesirable paleness leading to two toning is due to denaturation of meat proteins at relatively high temperatures (30-40°C) and acidity resulting from the natural development of lactic acid during the early stages of rigor mortis (acid production is also faster at higher temperatures). The paleness normally occurs in the deep muscle where slower chilling conditions are experienced.

Electrical stimulation tends to even up the colour, making it more uniform, and lighter. However, it is important not to overstimulate and measuring muscle pH and temperature as the beef side enters the chiller will indicate the effect of the combined electrical inputs. As a guide, if the pH is at or below 6.0 while the temperature is at or above 35° C, then the electrical inputs have been excessive, and there may be undesirable paleness of the slow cooling muscles and heat shortening. Subsequent pH and temperature measurements will indicate whether cold shortening is a possibility. If at any time the pH is at or above 6.0 when the temperature is at or below 12°C, it is likely that the combined electrical inputs are insufficient, and there may be cold shortening. These pH and temperature values are currently those incorporated in the Meat Standards Australia 'window of eating quality', which is currently under review.

Fast chilling of hot, heavy beef sides after slaughter gives more evenly coloured meat, and firmer muscles. It also minimises the subsequent unsightly weep (drip) in display or vacuum packs that might lead to customer complaints. However, where rapid chilling conditions are applied and no electrical stimulation is utilised, the rate of pH decline can be quite slow. As a result, at 24 hours after slaughter, the ultimate pH has not been attained; therefore, it is incorrectly assessed as dark cutting. Effective electrical stimulation will overcome this effect by accelerating the rate of pH decline.

Normal colour of vacuum-packaged and 100% CO_2 flushed chilled meat

The removal of oxygen during vacuum packing leads to changes in the colour of meat. Inside a vacuum package, residual oxygen is consumed and carbon dioxide (CO_2) is produced as a result of metabolism by the muscle tissue. The resultant atmosphere contains less than 0.5 per cent oxygen, some 20-40 per cent CO_2 with nitrogen making up the remainder.

The bright red (oxymyoglobin) colour of fresh meat disappears in the vacuum pack and in the CO_2 flushed pack as the pigment reverts to its purplish-red form. This is the normal and desirable colour of vacuum-packed meat. Within a short time of the pack being opened the surface purple myoglobin changes to bright red oxymyoglobin and the meat blooms to a bright red colour. The relationship between pigments is shown in

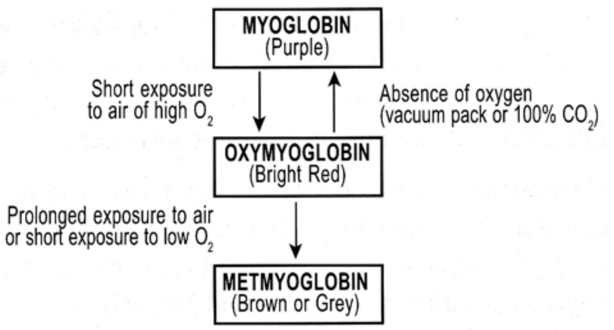

Figure 2.

FIGURE 2 Some colour relationships found in fresh and vacuum-packaged meats

Browning

Browning of meat stored in a vacuum package indicates that there is too much oxygen in the pack. This occurs fastest at moderate (1%) level. If there are poor seals, punctures, or poor air evacuation at the time of packing and sealing, the meat will turn brown during storage.

The oxygen permeability of the films used for vacuum packing is also very important and is a matter to which the packer should pay close attention. To prevent oxygen from gaining access to the meat surface, care is needed to ensure that the appropriate degree of impermeability is chosen. If the permeability is a little too high, or if there are pinholes or poor seals, a small amount of oxygen will gain access to the meat surface and its concentration could very easily reach the critical (low) level at which metmyoglobin formation is most rapid.

It is difficult to evacuate all the air from a vacuum pack but residual oxygen should be used up by respiration of the meat and microbial activity. The speed at which this residual oxygen is used up is dependent on the age of the meat when packed. If the meat is not fresh (i.e. is older than 48 hours post-slaughter) at the time of packing, insufficient meat respiration to consume the residual oxygen can cause a problem.

In addition, if there is residual oxygen in the pack due to any of these factors, the browning problem will be exacerbated by high temperatures.

Colour problems with beef stored in high concentrations of carbon dioxide will not occur *provided oxygen is excluded from the pack.* If only 0.5-1 per cent of oxygen is present, the rate of formation of metmyoglobin is higher than in air, and browning occurs more rapidly. In addition to discolouration of the lean surface, problems with the appearance of fat surfaces may occur (brown-grey discolouration). With lamb, a brownish discolouration of the fell surfaces may develop after several weeks storage at 0°C if there is too much oxygen present and, if this occurs, the appearance is inferior to that of fresh primals.

From a colour point of view the aim of vacuum or gas packing is to prevent the production of undesirable brown metmyoglobin by *reducing the concentration* *of oxygen in the pack to below 0.2%.* To achieve this, the meat should be packed and sealed as quickly as possible after boning or cutting the carcase, provided that the carcase deep muscle temperature is adequately reduced.

This type of browning should not be confused with cooked meat browning (grey-brown), which can be caused by excessive heat during shrinkage of the packaging film.

Retail storage of chilled meat in air or in air-permeable film

Because the bright red colour is enhanced by high concentrations of oxygen, most displayed meat is either open to air or sealed in an oxygen-permeable wrap. The wrap allows passage of oxygen but prevents undesirable drying of the meat surface.

Meat displayed in this fashion usually becomes discoloured owing to the development of brown colour (metmyoglobin) before bacteria have grown sufficiently to cause spoilage. Incorrect storage or handling at any stage of the chain will reduce retail storage life.

The principal factor affecting the shelf life of wrapped meat on display is its temperature. This is mainly because the oxidation of myoglobin to metmyoglobin is extremely temperature dependent. However, it is also partly because higher temperatures increase bacterial growth on the meat, and the result is that bacterial metabolites contribute to the increased oxidation rate.

In order to obtain the longest possible shelf life for meat on display, the storage temperature should be as close to 0°C as possible. This will keep microbial growth to a minimum and prolong the retention of the attractive red meat colour. As it is impossible to maintain a steady 0°C in open meat display cabinets, a realistic optimum temperature range is 0-5°C.

Meat should be cooled to below 5°C before cutting and it should be cut immediately prior to display.

Storage after ageing

After three weeks ageing, aged meat exposed to air discolours in the retail situation faster than fresh meat because of a diminished ability of any brown colour that has formed to revert to the desired red colour. The longer meat is aged, the faster it will discolour after opening to air because the enzyme system becomes less effective with ageing.

Table 1 indicates the relative retail display life of consumer cuts of beef (stored at about 5°C) in conventionally overwrapped and oxygen-enriched modified-atmosphere packs (as a function of the meat storage time in the vacuum pack at 0°C). The longer the period of storage in the vacuum pack the shorter the display life of the consumer portions, because of the more rapid conversion of oxymyoglobin to the brown metmyoglobin.

TABLE 1 The relative retail display life of consumer cuts of beef as a functionof the time the meat was stored vacuum packaged

Storage time in the vacuum pack (weeks at 0°C)	0	2	4	6	8
Retail display life (days) *Overwraped trays	3	3	2	2	1

Beef and lamb stored in high levels of CO_2 appear to retain their retail display life better than vacuum-packed lamb. Retail shelf life of product prepared from lamb primals or carcases stored in a CO_2 atmosphere should be three days after 12 weeks chilled storage.

Summary

The delay of adverse colour changes involves efficient refrigeration during chilling, holding, transportation, storage, preparation and display; and proper hygiene, packaging and selection of meat. Attention to the above is necessary, but in particular, if fresh meat is to be maintained in good condition with minimum colour deterioration for an adequate commercial display period, the temperature of the meat must be kept close to 0°C.

Further Reading

Meat Technology Update Newsletter 99/6 ‘ Pre-slaughter aspects of beef eating quality’

Meat Technology Update Newsletter 99/4 ‘Post-slaughter aspects of beef eating quality’

Meat Technology Update No. 97/3 (AMT) ‘Lighting in Meat Processing Areas’

CSIRO *Meat Research Newsletter* 93/5 ‘Displaying Meat for Maximum Return’

Contact us for additional information

Meat Industry Services is supported by the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA).

Brisbane:
Food Science Australia
PO Box 3312
Tingalpa DC QLD 4173

Ian Eustace
T +61 7 3214 2117
F +61 7 3214 2103
M 0414 336 724

Neil McPhail
T +61 7 3214 211
F +61 7 3214 2103
M 0414 336 907

Alison Small
T +61 7 3214 2109
F +61 7 3214 2103
M 0409 819 998

Sydney:
Bill Spooncer
PO Box 181
KURMOND NSW 2757
T +61 2 4567 7952
F +61 2 4567 8952
M 0414 648 387

Adelaide:
Chris Sentance
PO Box 178
FLAGSTAFF HILL SA 5159
T +61 8 370 7466
F +61 8 8370 7566
M 0419 944 022