

Meat Technology Update

Newsletter 2/04

April 2004

Visual assessment of marbling and meat colour

The grade, or suitability of a beef carcass for a particular market, is primarily determined by the visual assessment of quality-indicating characteristics such as marbling, meat colour and fat colour. This is normally performed in chillers once the carcasses have cooled sufficiently. Chiller assessment of beef carcasses relies on the evaluation of quality characteristics by making comparisons to reference standards under controlled conditions. Even though assessors are trained and go through correlation procedures at regular intervals, the subjective nature of chiller assessment means that there can be variability in grading scores between assessors. To ensure that carcasses are graded to gain the best possible scores, it is important that they are assessed under standardised conditions that do not detract from the appearance of quality characteristics.

This newsletter discusses factors that can affect the visual appearance of meat characteristics and contribute to variations in grading scores of marbling and meat colour.

Visual assessment techniques

The visual assessment of beef carcasses is performed under standardised conditions using approved assessment techniques as stated in the AUS-MEAT chiller assessment requirements. Assessment is carried out with the aid of light from a torch held at an angle of 30–50° and at a distance from the meat surface so that a light intensity between 1400 and 3000 lux is achieved.

Marbling

Marbling has a positive impact on eating quality and is an important characteristic of beef. Carcasses with higher marbling scores attract premium prices, as product with good marbling is perceived as being of



better quality by certain markets e.g. Japan; but the accurate assessment of marbling score can be influenced by a number of factors.

Temperature and time

The current AUS-MEAT standards state that chiller assessment should proceed only when the temperature of the eye muscle, *M. longissimus dorsi*, is 12°C or below, with the recommended temperature being 4–8°C. Marbling score can be influenced by the carcass-chilling regime, chiller temperature and carcass temperature at the time of assessment.

In the live animal, marbling fat is in a semi-fluid state. After slaughter, when the carcass is chilled, this fat solidifies and becomes opaque. As marbling fat solidifies, it goes through a series of temperature- and time-dependent transformations. The whiteness of marbling depends on the proportion of fat that has undergone the phase transition to a solid state. In marbling fat that is more unsaturated, and where there is incomplete phase transition, fat will be less white and the visibility of marbling to the chiller assessor may be reduced (Tume, 2001).

The chilling regime can have an impact on the amount of marbling perceived at the time of grading. There is evidence to suggest that rapid chilling can improve marbling scores by causing the intramuscular fat to solidify and separate more from adjacent muscle tissue by the time assessment occurs; however, the manipulation of chilling rate to improve marbling scores could have a detrimental effect on the tenderness of meat and adjustments to electrical inputs should be considered to avoid toughening.

US researchers (Johnson et al., 1985) investigated the effects of several postmortem factors on marbling score, including chill time before quartering, and the interval between quartering and evaluation. An improvement in marbling score was observed when the period of chill time before quartering increased from 24 hours to 72 hours. This is because the longer the time a carcass is exposed to low temperatures, the more time for the fat to go through the phase transition—to solidify and become more opaque—and, therefore, the higher the visual marbling score.

After quartering, the US researchers found that the marbling score increased slightly as the time between quartering and assessment increased. To optimise marbling scores, they recommended that beef carcasses should be further chilled after quartering for more than 30 minutes prior to assessment of marbling; however, it has also been found that marbling can be more evident immediately after quartering due to the greater contrast between the white-coloured marbling and the unbloomed meat.

The US researchers also found that the visual marbling score after shipment was significantly higher than the assigned marbling score, when assessed after 24 hours of chill time. This was partly attributed to the differences in temperature. The average loin temperature at the 24-hour assessment was 3.8°C and, after shipment (a further 70 h), it was 1°C. A significant correlation was found between loin temperature prior to shipment and the changes in the visual marbling score during shipment.

Re-warming beef carcasses slightly is a common practice used in Australia to reduce the OH&S problem of hard fat in the boning room; however, this re-warming cycle could be detrimental to marbling score. Warming carcasses that have been quartered with air at a temperature of 20°C can increase the surface temperature of exposed muscle by 5°C or more within a few minutes. If assessment cannot be completed before re-warming commences, it is probably better to delay quartering and assessment until after re-warming has ceased and the air has cooled again.

Quartering site

One of the major difficulties associated with the assessment of marbling score is the uneven distribution of marbling. The fat deposits that are measured as marbling are irregularly shaped, branching structures that occur within the muscle. Marbling is measured on a small, straight-cut surface of muscle and the underlying fat deposits

are unable to be seen. Individual cells of marbling deposits can be very small (40–60 µm) and are not visible to the human eye unless in clusters. Because of this, the quartering site can have a significant impact on marbling assessment. The distribution of marbling varies throughout the *M. longissimus dorsi*. Various studies have reported that the amount of marbling tends to be greater at the extremities of the muscle between the 5th and 6th ribs, and the 2nd and 5th lumbar vertebrae, than between the 9th to 12th ribs.

Intramuscular fat (IMF%)

IMF% is estimated by determining the amount of chemically extractable fat from muscle tissue; whereas marbling score is assigned to a carcass by assessing the amount of visible intramuscular fat. There are major limitations with measuring IMF%. The process involved with chemical analysis is labour intensive and expensive. Also, it doesn't give a good indication of the quality aspects of the marbling such as the size and distribution of the marbling pieces within the eye muscle. In terms of eating quality, and for some export markets, it is more desirable to have fine, evenly distributed marbling rather than coarse marbling unevenly distributed throughout the eye muscle.

Generally, an increase in IMF% is observed as visual marbling score increases; however, results from a number of studies show that the relationship between IMF% and visual marbling score can be highly variable. The main factor that contributes to the variability is that visual assessment of marbling score is carried out on a two-dimensional surface; whereas IMF% gives a three-dimensional measurement of marbling fat. In addition, IMF% measurements include microscopic portions of marbling fat that are not detected at visual assessment. Overseas studies show stronger correlations than those in Australia. This has been attributed to their use of a wider range of marbling scores, as well as greater ranges of IMF% in the trials.

Fatty acid composition

The visual appearance of marbling at the time of chiller assessment can depend on the composition of the marbling fat and the melting points of the associated fatty acids. Stearic acid is a fatty acid component of marbling fat that has a high melting point and, therefore, contributes to a dense, opaque appearance at chiller temperatures. The content of stearic acid in marbling fat can vary widely (from 5 to 30%) and affects the physical properties and appearance of the marbling fat. Consequently, for meat with identical fat contents (IMF%), there may be slight differences in the visual appearance of marbling and therefore marbling score.

Recommendations

Marbling score can be a critical specification for supplying beef to a particular market. The following recommendations should be followed to give carcasses every chance of meeting specification.

- Assess marbling when muscle surface temperature is as low as possible (preferably 4–5°C).

- Assess marbling score prior to any chiller re-warming cycle to ensure that rib-eye surface temperature is as low as possible.
- If it is practical to do so, hold over any carcasses that just fail to meet the specifications and re-assess the marbling later. Chilling them for a further 24 hours has been shown to improve marbling scores in some carcasses.

Meat colour

Meat colour is also an important specification that is used in conjunction with other characteristics to determine the grade or suitability of meat for a particular market. Meat colour has a huge influence on the consumer appeal of a product. There are a number of interacting factors that occur during processing that can have a significant impact on meat colour, including electrical stimulation, chilling rate, bloom time and dark cutting meat.

Electrical stimulation

Electrical stimulation causes a decrease in muscle pH and, therefore, a stimulated carcass is likely to reach its ultimate pH sooner after slaughter than a non-stimulated carcass. For this reason chiller assessment can be done earlier with stimulated carcasses. The AUS-MEAT chiller assessment requirements state that a non-stimulated carcass cannot be assessed until 18 hours post-slaughter; while a carcass that has received full stimulation can be assessed at 8 hours post-slaughter. For carcasses that have received less than full electrical stimulation, the permissible time for assessment can be determined by the ultimate pH, which has been validated under a controlled pH decline program.

In comparison with non-stimulated carcasses, the meat from electrically stimulated carcasses tends to bloom more rapidly and the meat colour appears brighter. The improvement in meat colour is believed to be partly due to the tissue disruption caused by electrical stimulation, which allows oxygen to penetrate deeper into the muscle and form a thicker layer of oxymyoglobin.

Chilling rate

The rate of cooling and the temperature at which a carcass enters rigor has been found to affect meat colour at chiller assessment. If chilling is slow, a combination of low meat pH and high temperature can lead to protein denaturation which causes the meat to have increased light-scattering properties and a pale meat colour due to deeper oxygen penetration into the muscle; however, it is important to realise that if muscles reach low pH at high temperatures, the effect can be detrimental to the colour stability—reducing retail shelf life and also increasing the amount of drip. Such muscles are also predisposed to a condition called 'heat toughening'.

The meat colour of rapidly chilled carcasses may be affected by cold shortening where high pH (>6.0) is combined with low temperatures (<15°C). The meat tends to have a darker appearance due to

compaction of the muscle fibres. The ability of electrical stimulation to prevent cold shortening is mentioned above.

Bloom time

The colour of meat is dependent on the chemical state of the muscle pigment, myoglobin. The desirable red colour of beef occurs upon exposure to oxygen when deoxymyoglobin is converted to oxymyoglobin. Bloom time refers to the amount of time necessary for the freshly cut surface of the meat to oxygenate and form the bright red layer of oxymyoglobin.

The amount of time required for good meat-colour development can be dependent on both time from slaughter and time from quartering to assessment. There is also evidence that shows carcasses entering rigor at a lower temperature, can take longer for meat colour to fully develop due to a higher oxygen consumption rate and the inhibition of the formation of oxymyoglobin.

The AUS-MEAT chiller assessment requirements state that meat colour should be assessed at least 20 minutes after quartering or re-facing or after a period of time which allows for the completion of bloom (at least an hour is recommended). The time between quartering and assessment should not extend beyond 3 hours.

Surface abnormalities

Visual assessment of meat colour can be influenced by a number of conditions at the cut surface of the quartering site. The surface should be inspected prior to assessment for abnormalities such as blood splash, large seams of connective tissue, excessive moisture, bone dust or an unevenly cut surface. These defects can affect the light scattering properties of the meat surface and may affect assessment scores. Excessive dryness of the meat surface can also have an effect on the way light is reflected from the meat surface. As the surface of the meat dries out, the concentration of myoglobin increases at the surface and produces a darkening effect.

Two-toned meat

Meat colour is scored on the area of the eye muscle that displays the predominant colour and, in the case where there is no predominant colour, the darkest colour score is assigned to the carcass.

In two-toned meat there is undesirable variation in meat colour within a muscle or cut of beef. This type of discolouration, also sometimes referred to as 'heat ring', is more likely to occur within muscles where there are differences in cooling rates. The outer portion of the muscle appears darker in comparison with the inner part of the muscle because rapid chilling can cause a delay in the outer portion of the muscle reaching ultimate pH. Therefore it could still be in pre-rigor condition at high pH and may shrink due to cold shortening and exhibit a dark colour after quartering.

In some large carcasses, the inner portion of the muscle that cools slowly may appear lighter in colour compared with the outer part due to

the combination of low pH and high temperature that leads to protein denaturation. The major problem with two-toned meat is the colour stability of pale-coloured meat. This meat discolours more quickly in the presence of oxygen due to the formation of metmyoglobin.

Dark-cutting meat

The dark-cutting condition in beef is associated with a high ultimate pH. High ultimate pH occurs when glycogen levels are depleted due to stress endured by an animal prior to slaughter. If glycogen levels are below 50 µmol/g at the time of slaughter, the ultimate pH will be high and the meat colour will be adversely affected.

The dark, undesirable appearance of dark cutting meat is due to the high water-holding capacity of the muscle, resulting in less light being reflected from the surface of the meat. In addition, the oxygen consumption rate of the meat is increased—which inhibits the formation of the red-coloured oxymyoglobin.

Recommendations

In order to ensure that carcasses are assessed as close to their 'true' meat colour score as possible:

- manipulate electrical inputs and chilling rate to allow carcasses to enter rigor at a temperature between 15 and 35°C;
- extend the minimum amount of bloom time to 1 hour, but do not exceed 3 hours;
- ensure that the meat surface is not affected by abnormalities and re-face if necessary;

- ensure that the light intensity from the grader's torch is between 1400 and 3000 lux at the meat surface. The higher the light intensity, the lighter the meat colour will appear.

Further reading

AUS-MEAT National Accreditation Standards Manual & the Australian Industry Classification System Manual.

Baud, S., Wade, C.M. & Goddard, M.E. (1998) *Relationships among carcass quality characteristics between and within carcass quartering sites*, Australian Journal of Agricultural Research, 49:285–291.

Johnson, D.D., Savell, J.W., Murphey, C.E., Stiffler, D.M. & Cross, H.R. (1985) *Postmortem environmental factors affecting beef carcass lean maturity and marbling evaluations*, Journal of Food Quality, 8:253–264.

Murray, A.C. (1989) *Factors affecting beef color at time of grading*, Canadian Journal of Animal Science, 69: 347–355.

Renner, M. (1990) *Review: Factors involved in the discolouration of beef meat*, International Journal of Food Science and Technology, 25:613–630.

Taylor, D.G. & Johnson, E.R. (1992) *Visual marbling score and chemical fat content of M. longissimus in beef carcasses*, Proceedings of the Australian Society of Animal Production, 19:71–73.

Tume, R. (2001) *Environmental factors on fatty acid composition and its impact on assessment of marbling*, Marbling Symposium (Coffs Harbour).

Zembayashi, M. & Lunt, D.K. (1995) *Distribution of intramuscular lipid throughout M. longissimus thoracis et lumborum in Japanese Black, Japanese Shorthorn, Holstein and Japanese Black crossbreds*, Meat Science, 40:211–216.

The information contained herein is an outline only and should not be relied on in place of professional advice on any specific matter.

For more information, contact one of the Meat Industry Services staff listed below.

Food Science Australia Meat Industry Services Section

The Meat Industry Services (MIS) section of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia's meat industry.

Need additional help, information or advice? *Contact one of the following:*

BRISBANE:	Ian Eustace	Neil McPhail
Food Science Australia	Ph. 07 3214 2117	Ph. 07 3214 2119
PO Box 3312	Fax. 07 3214 2103	Fax. 07 3214 2103
TINGALPA DC Qld 4173	Mob. 0414 336 724	Mob. 0414 336 907
Cheryl Masson	Donna Knox	Frank Shaw
Ph. 07 3214 2101	Ph. 07 3214 2109	Ph. 07 3214 2001
Fax. 07 3214 2103	Fax. 07 3214 2103	Fax. 07 3214 2103
Mob. 0416 198 403	Mob. 0416 198 402	

SYDNEY:	MELBOURNE:	ADELAIDE:
Food Science Australia	Food Science Australia	PO Box 178
PO Box 181	Private Bag 16	FLAGSTAFF HILL
KURMOND NSW 2757	WERRIBEE Vic. 3030	SA 5159
Bill Spooncer	Jocelyn Midgley	Chris Sentance
Ph. 02 4567 7952	Ph. 03 9731 3424	Ph. 08 8370 7466
Fax. 02 4567 8952	Fax. 03 9731 3250	Fax. 08 8370 7566
Mob. 0414 648 387	Mob. 0414 647 231	Mob. 0419 944 022

Additional copies of this newsletter are available from: www.meatupdate.csiro.au