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Foreword

Why is muscle metabolism important for red meat quality? An industry perspective

Introduction

In the 1990s, the beef and sheep industry in Australia recognised that an eating quality assurance scheme was needed in order to describe and differentiate the eating qualities of different types of beef and sheep meat and to ensure the descriptions were credible (Meat Research Corporation 1996). This was in response to the falling per capita consumption of both beef and sheep meat in Australia (Williams and Droulez 2010) and evidence that the inconsistency in tenderness was causing major problems for both sheep (Safari *et al*. 2002) and beef (Meat Research Corporation 1996) meat. Furthermore, the recommendations for the proposed grading scheme were that it should encompass whole of chain, from genetics and animal age, through pre- and post-slaughter treatment of the carcass, to the consumer, where cooking technique based on cut and quality were recommended (Meat Research Corporation 1996). The development of the Meat Standards Australia (MSA) grading system, the consumer testing protocols, and the underpinning research for assuring quality to the consumer is summarised for beef by Polkinghorne *et al*. (2008) and Smith *et al*. (2008) and for sheep by (Thompson *et al*. (2005*a*) and Young *et al*. (2005).

Why is muscle metabolism important for eating quality assurance?

Importantly, although research had shown that muscle metabolism post-mortem, as measured by the rate of pH and temperature fall, influences eating quality (Marsh *et al*. 1987; see Kim *et al*. 2014), the grading schemes for assuring beef and lamb quality, from major meat producing countries such as Japan, USA and Canada, did not include this parameter (Webster *et al*. 1999; Polkinghorne and Thompson 2010). Early MSA trials showed reduced beef eating quality with inducement of rapid metabolism post-mortem using electrical stimulation (ES) (Polkinghorne *et al*. 2008) and this was confirmed in studies by Hwang and Thompson (2001*b*) and Hwang and Thompson (2001*a*) when ES was applied to specific types of carcasses. The negative effect of high pre-rigor temperature on the ageing potential of excised beef muscles under controlled conditions was demonstrated by Thomson *et al*. (2008). Although there has not generally been a detrimental effect of rapid metabolism induced by ES on tenderness in most experiments using sheep carcasses, there have been some instances where ES produced detrimental effects. Shaw *et al*. (2005) demonstrated that high voltage ES of sheep carcasses increased the percentage of 4-day-aged lamb loins rated as unsatisfactory. Warner *et al*. (2005) showed that low voltage ES of lamb carcasses resulted in lower consumer scores for smell, tenderness and overall liking, and attributed this to the 'heat toughening' (viz. higher rigor temperature). Finally, Thompson *et al*. (2005*b*) showed the curvilinear relationship between consumer scores for sheep meat for overall liking and rigor temperature, with the optimum rigor temperature being ~20°C.

In 1999, the Meat Standards Australia Pathways Committee recommended the inclusion of a 'pH–temperature window' in the Australian eating quality scheme for assuring quality to the consumer (Webster *et al*. 1999). The Meat Standards Pathways Team focussed on identifying an abattoir window which could avoid damage and reduced eating quality resulting from either hot- or cold-shortening (Webster *et al*. 1999). The prescribed pH–temperature window for beef carcasses stated that the muscle (striploin, *longissimus lumborum*) should commence rigor (defined as pH < 6.0) between 12°C and 30°C to avoid cold-shortening (≤12°C) and 'high rigor temperature' (≥30°C) respectively (Ferguson *et al*. 1999). This was later revised to between 10°C and 35°C (Thompson 2002) (see Fig. 1). The effect of high rigor temperature on the visual colour and water-holding capacity of beef striploin is shown in Fig. 2. For lamb carcasses, an optimal pH–temperature window for eating quality has been defined as 18−35°C for product aged for 5 days and 8−18°C for product aged for 10 days (Food Science Australia 2007).

As a consequence of the inclusion of the pH–temperature window in MSA grading, the registration of beef processing plants for accreditation for MSA includes an initial audit to establish the pH–temperature decline post-mortem of a typically slaughtered sample of carcasses (Meat Standards Australia 2013). If the beef carcasses are outside the window, the MSA graders assist the processing plant to achieve a pH–temperature decline to fit within the window. Furthermore, in order for a beef abattoir to maintain MSA accreditation, their procedures are audited within a QA system to ensure pH and temperature relationships are within the prescribed window to achieve optimal palatability (Thompson 2002). In the case of sheep carcasses, Meat Standards Australia requires sheep meat processors to measure and control systems to fall within the pH–temperature window (Food Science Australia 2007). Four times per year, processors are required to select four consignments of sheep per day and 25 carcasses per consignment to determine the number of carcasses 'hitting' the window. pH needs to be recorded 20–30 min post slaughter and again when the carcass is close to 18°C (Food Science Australia 2007).

Definition and explanation of high rigor temperature

As described above, a high rigor temperature carcass is defined as a carcass in which the *longissimus lumborum* has a pH < 6.0 while the temperature is ≥35°C (Thompson 2002; Fig. 1). MSA has previously described this as 'heat-shortening' or 'heat-toughening'. For reasons described in papers in this special issue (Jacob and Hopkins 2014; Kim *et al*. 2014; Warner *et al*. 2014), these terms are not recommended and the use of the term 'high rigor temperature' has been adopted in most of the papers in the special issue.

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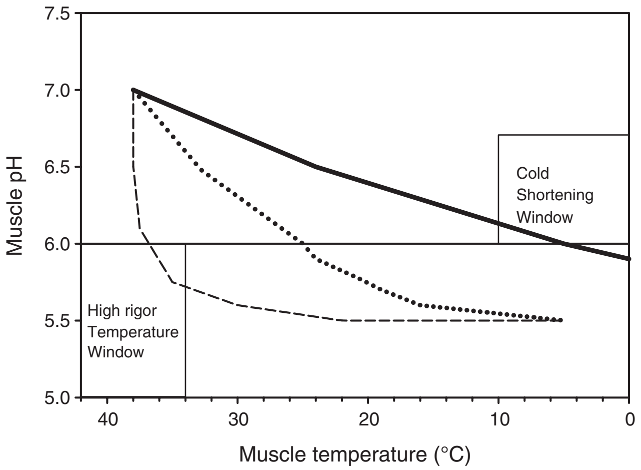

Fig. 1. The pH–temperature window used by Meat Standards Australia to optimise the decline in pH relative to the temperature of the muscle in beef. The dotted line represents an optimal rate of decline, the solid line a cold shortening, and the dashed line, a high rigor temperature scenario. The regions to avoid for assurance of quality meat are the cold-shortening region and the high rigor temperature region.

Fig. 2. An exposed striploin (*longissimus thoracis*) at grading (quartered between 11th and 12th rib) showing the pale colour and beads of moisture exuding from the surface, both of which are associated with high rigor temperature beef carcasses. Credit: Robert Strachan, formerly Meat Standards Australia, Brisbane, Australia.

Why a project?

After MSA had been grading beef carcasses for 10 years in Australia, the processing industry reported that the incidence of 'heat-shortening' in beef carcasses was high, particularly in carcasses from grain-fed cattle. The processing industry requested the development of a 'pH decline program' to assist in controlling yield-, quality- and efficiency-related issues associated with fast pH decline. It was recognised by industry that these quality and yield problems had impacts on the acceptability of the product on domestic and export markets. Thus, it was proposed to undertake a series of case studies with beef supply chain companies experiencing associated quality and yield problems due to non-ideal pH and temperature declines. The proposed project was designed to focus on the development of industry guidelines, processing solutions and interventions and on a strategic research program to address the issues. The project involved collaboration between seven beef processing plants and seven research organisations and was supported by investment from all organisations and companies and funding from Meat and Livestock Australia.

Contents of the special issue and dissemination to industry

This special issue of *Animal Production Science* ('Muscle metabolism in sheep & cattle in relation to meat quality') provides the research outcomes and recommendations arising from a project which had the aim of addressing quality problems associated with high rigor temperature in beef and sheep carcasses. The first paper quantifies the occurrence of high rigor temperature in beef processing plants in Australia and identifies some of the causative factors. Section 1 contains a review and four research papers quantifying the influence of high rigor temperature on the visual, objective and sensory quality traits of muscles from beef and lamb carcasses. Section 2 has a review and three research papers which focus on the *in vivo* metabolic conditions that contribute to high rigor temperature post-slaughter and potential strategies to apply to the live animal to ameliorate or prevent the occurrence of high rigor temperature. Post-mortem muscle metabolism and potential industry solutions are presented in two reviews and two papers in Section 3. Finally, an overview is presented, in which the results are reviewed and summarised by overseas researchers external to the research and the project.

The research program also involved close collaboration with commercial meat processing companies. Outcomes were disseminated (and implemented) by site visits to each commercial processing plant involved in the project and the publication of industry fact sheets. The effects of heat-toughening on beef quality and the incidence in Australia is described in Meat and Livestock Australia (2011*a*) and the strategies for reducing the incidence in beef carcasses are described in Meat and Livestock Australia (2011*b*). Food Science Australia (2007) describes the procedures for managing electrical inputs in sheep carcasses in order to meet the pH–temperature window.

D. A. Gutzke
Meat and Livestock Australia

P. Franks
Meat and Livestock Australia

D. L. Hopkins
NSW Department of Primary Industries
Centre for Red Meat and Sheep Development

R. D. Warner
CSIRO Animal, Food and Health Sciences

References

CSIRO (2011*a*) Heat toughening – Part 1: Effects of heat toughening on quality of beef, and the incidence in Australia. Meat technology update 2/11 – March 2011. Available at http://www.meatupdate.csiro.au/data/MEAT_TECHNOLOGY_UPDATE_11-2.pdf [Verified 20 February 2014]

CSIRO (2011*b*) Heat toughening – Part 2: Strategies for reducing the incidence of heat toughening in beef carcases. Meat technology update 3/11 – May 2011. Available at http://www.meatupdate.csiro.au/data/MEAT_TECHNOLOGY_UPDATE_11-3.pdf [Verified 20 February 2014]

Ferguson DM, Thompson JM, Polkinghorne R (1999) Meat Standards Australia. A 'PACCP' based beef grading scheme for consumers. 3) PACCP requirements which apply to carcass processing. *International Congress of Meat Science and Technology, Yokohama, Japan* **45,** 18–19.

Food Science Australia (2007) Producing quality sheep meat. Meat technology update 6/07 – December 2007. Available at http://www.meatupdate.csiro.au/data/MEAT_TECHNOLOGY_UPDATE_07-6.pdf [Verified 27 February 2014]

Hwang IH, Thompson JM (2001*a*) The effect of time and type of electrical stimulation on the calpain system and meat tenderness in beef longissimus dorsi muscle. *Meat Science* **58**, 135–144. doi:10.1016/S0309-1740(00)00141-8

Hwang IH, Thompson JM (2001*b*) The interaction between pH and temperature decline early postmortem on the calpain system and objective tenderness in electrically stimulated beef longissimus dorsi muscle. *Meat Science* **58**, 167–174. doi:10.1016/S0309-1740(00)00147-9

Jacob RH, Hopkins DL (2014) Techniques to reduce the temperature of beef muscle early in the post mortem period – a review. *Animal Production Science* **54**, 482–493. doi:10.1071/AN12338

Kim YHB, Warner RD, Rosenvold K (2014) Influence of high pre-rigor temperature and fast pH fall on muscle proteins and meat quality: a review. *Animal Production Science* **54**, 375–395. doi:10.1071/AN13329

Marsh BB, Ringkob TP, Russell RL, Swartz DR, Pagel LA (1987) Effects of early postmortem glycolytic rate on beef tenderness. *Meat Science* **21**, 241–248. doi:10.1016/0309-1740(87)90061-1

Meat Research Corporation (1996) 'Eating quality assurance. Implementation of a National Scheme. MRC beef and lamb eating quality key program. Project report M.944.' (Meat Research Corporation: Sydney)

Meat Standards Australia (2013) The effect of the pH–temperature decline on beef eating quality. (Meat and Livestock Australia: Sydney) Available at http://www.mla.com.au/files/97917c3d-7cd3-427f-b2d7-a20d00dde382/MSA_BeefInfoKit_TT8_Jul13.pdf [Verified 27 February 2014]

Polkinghorne RJ, Thompson JM (2010) Meat standards and grading: A world view. *Meat Science* **86**, 227–235. doi:10.1016/j.meatsci.2010.05.010

Polkinghorne R, Thompson JM, Watson R, Gee A, Porter M (2008) Evolution of the Meat Standards Australia (MSA) beef grading system. *Australian Journal of Experimental Agriculture* **48**, 1351–1359. doi:10.1071/EA07177

Safari E, Channon HA, Hopkins DL, Hall DG, van de Ven R (2002) A national audit of retail lamb loin quality in Australia. *Meat Science* **61**, 267–273. doi:10.1016/S0309-1740(01)00192-9

Shaw FD, Baud SR, Richards I, Pethick DW, Walker PJ, Thompson JM (2005) New electrical stimulation technologies for sheep carcasses. *Australian Journal of Experimental Agriculture* **45**, 575–583. doi:10.1071/EA03257

Smith GC, Tatum JD, Belk KE (2008) International perspective: characterisation of United States Department of Agriculture and Meat Standards Australia systems for assessing beef quality. *Australian Journal of Experimental Agriculture* **48**, 1465–1480. doi:10.1071/EA08198

Thompson JM (2002) Managing meat tenderness. *Meat Science* **62**, 295–308. doi:10.1016/S0309-1740(02)00126-2

Thompson JM, Gee AM, Hopkins DL, Pethick DW, Baud SR, O'Halloran GR (2005*a*) Development of a sensory protocol for testing palatability of sheep meats. *Australian Journal of Experimental Agriculture* **45**, 469–476. doi:10.1071/EA03174

Thompson JM, Hopkins DL, D'Souza DN, Walker PJ, Baud SR, Pethick DW (2005*b*) The impact of processing on sensory and objective measurements of sheep meat eating quality. *Australian Journal of Experimental Agriculture* **45**, 561–573. doi:10.1071/EA03195

Thomson KL, Gardner GE, Simmons N, Thompson JM (2008) Length of exposure to high post-rigor temperatures affects the tenderisation of the beef M. longissmus dorsi. *Australian Journal of Experimental Agriculture* **48**, 1442–1450. doi:10.1071/EA07132

Warner RD, Ferguson DM, McDonagh MB, Channon HA, Cottrell JJ, Dunshea FR (2005) Acute exercise stress and electrical stimulation influence the consumer perception of sheep meat eating quality and objective quality traits. *Australian Journal of Experimental Agriculture* **45**, 553–560. doi:10.1071/EA03270

Warner RD, Thompson JM, Polkinghorne R, Gutzke D, Kearney GA (2014) A consumer sensory study of the influence of rigor temperature on eating quality and ageing potential of beef striploin and rump. *Animal Production Science* **54**, 396–406. doi:10.1071/AN12226

Webster J, Gee A, Porter M, Philpott J, Thompson J, Ferguson D, Warner R, Trout G, Watson R, Shaw F, Scott J, Chappell G, Strong J (1999) 'Meat Standards Australia. Grading for eating quality. Development of the Meat Standards Australia grading system – Volume 1.' (Meat and Livestock Australia: Sydney)

Williams PG, Droulez V (2010) Australian red meat consumption - predominantly lean in response to public health and consumer demand. *Food Australia* **62**(3), 87–94.

Young OA, Hopkins DL, Pethick DW (2005) Critical control points for meat quality in the Australian meat supply chain. *Australian Journal of Experimental Agriculture* **45**, 593–601. doi:10.1071/EA04006