PE7.44 Rigor temperature influences objective and consumer quality traits of beef striploin.
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Abstract— Understanding the factors that contribute to variations in quality are important in helping to underpin grading systems for quality. This study was designed to investigate the effect of the temperature at which beef striploin (longissimus lumorum) goes into rigor (rigor temperature) on the consumers' assessment of eating quality. A data set containing consumer eating quality scores for 3,865 striploins including pH-temperature decline data, eating quality and grading data was obtained from Meat Standards Australia (MSA) and the temperature at pH 6 was calculated for each striploin, as an estimate of rigor temperature. Temperature at pH 6 (T at pH 6), hanging method, sex, estimated % bos indicus, carcass weight, US ossification score, US marbling score, days aged, fat depth over the P8 site, cooking method and ultimate pH or combinations of fitted parameters along with quadratic terms, adjustments for abattoir, day of kill, carcass and carcass side, were used to determine the effect of temperature at pH 6 on the CMQ4 (combined sensory meat quality = 0.4 x tenderness+0.1 x juiciness+0.2 x flavour+0.3 x overall liking) scores for the striploin. Muscle colour was analysed for the effect of T at pH 6 with an adjustment for kill day. For the striploin, aside from the factors in the MSA model already known to influence the CMQ4 score, the T at pH 6, Tat pH 6 x days aged and a quadratic term for T at pH 6, influenced the CMQ4 score (P<0.05 for all). As the rigor temperature (T at pH 6) in the striploin increased, the predicted CMQ4 score was initially higher for heat-toughened striploin (T at pH 6 = 40oC) after 0-7 days ageing. Beyond 14 days of ageing, the heat-toughened striploins failed to age any further and after 35 days of ageing, non-heat-toughened striploins were predicted to be 9 CMQ4 units higher then heat-toughened striploins. As the temperature at pH 6 increased from 15oC to 40oC, the AUSMEAT colour score changed (P<0.05) from scores red to dark red (scores 2, 3, 4&5) to pale red (scores 1B and 1C). In conclusion, carcasses where the striploin entered rigor at a high temperature and were heat-toughened showed a failure to age and improve in tenderness beyond 14 days.

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Index Terms— beef quality, colour, consumer, heat toughening, rigor temperature

I. INTRODUCTION

Tenderness, juiciness and flavour of beef meat are quality attributes not only important to the consumer but vital for continued sales in domestic and export markets. Understanding the factors that contribute to variations in these quality traits assists in determining strategies to optimise the quality traits. The concept of a pH/temperature window was one of the initial specifications for the MSA 'carcass pathways' grading scheme in Australia. This scheme is aimed at minimizing the meat tenderness variation in the beef carcass in Australia. The pH-temperature window was developed from the meat science literature available from around the world which generally shows that minimal shortening in muscles occurs at about 12–15 °C resulting in optimum tenderness [1][2]. The negative effects of fast pH fall at a high temperature on the water-holding capacity, colour and texture of pig muscle resulting in the pale, soft exudative (PSE) phenomenon have been well-documented [3]. Although PSE pork has been shown to be initially more tender then non-PSE pork, non-PSE pork is more tender then PSE pork after 5 days of ageing [4], suggesting that PSE pork may not age as well as normal pork. Fast glycolysing muscle is suggested to exhibit early inactivation of calpains [5] which would explain the reduced tenderisation during ageing observed in pork.

Muscle shortening and enzyme activity both affect tenderness and are highly affected by rigor temperatures with both shortening and reduced proteolysis occurring if the rigor temperature >15oC [6]. This study used rigor temperatures up to 35oC but did not go higher then this. Fast pH fall in beef carcasses has been described as 5.6 at 4-5h post-mortem and the ensuing meat is described as more tender, measured by Warner-Bratzler shear force at 24 h post-slaughter, relative to the meat from slower pH fall carcasses [7] Similarly, fast glycolysing beef muscle has been defined as about a loin pH of 6.6 at 1 h post-slaughter (estimated from graph in [8]) and by a loin pH of 5.9 to 6.2 at 3 h post-slaughter [9] and in each case the loin was more tender (sensory panel and Warner-bratzler shear force) for fast-glycolysing muscle. In Australia, beef processing plants report loin pH values of 5.5 at 1 h post-slaughter, while the muscle temperature can still be 400C (Janine Lau, unpublished results), thus the Australian meat industry reports much faster rates of pH fall then those historically reported for beef in different countries. Rapid glycolysis has been reported to have a negative effect on beef meat tenderness which appeared to be associated with an early reduction of u-calpain levels [10]. Higher rigor temperatures have also been reported to result in earlier activation of u-calpain with a trend for more tender meat (WBSF) but as ageing time increased, this advantage was eroded by early exhaustion of u-calpain [11], as suggested by [5]. There has been no large consumer studies examining the impact of temperature at pH 6 on eating quality, because of the difficulty and costs associated with conducting large-scale consumer taste panels. This paper reports an analysis of a large data base. The aim of this experiment was to investigate the effect of high rigor temperatures (temperature at pH 6) on the consumer eating quality and other quality traits of beef meat.

II. MATERIALS AND METHODS

A. Sample collection and preparation

A subset of data was obtained from the Meat Standards Australia data base which contained eating quality data on 15,581 samples collected from 1997 to 2006 from 36 abattoirs across Australia, Japan, Korea and Northern Ireland using consumers in Sydney, Osaka, Tokyo, Sowon and Belfast. The specifications for selecting the data set were that each carcass was required to have three or more pH and temperature readings on the longissimus lumborum. Only the data pertaining to the striploin and the cook methods roast and grill were included. Using these specifications, the data set contained 3,865 data points and temperature at pH 6 was calculated as an estimate of the temperature at which the striploin entered rigor. This was calculated by using the three pH and temperature readings recorded and the pH and temperature at grading.

After quartering of the carcass at about 20 hrs post-mortem, MSA graders made the following measurements: USDA ossification score; USDA marbling score, ultimate pH of the exposed M. longissimus thoracis, AUS-MEAT colour score (using AUS-MEAT standard meat colour chips in a range of 1A (very pale) to 7 (very dark purple)) and estimated % bos indicus.

Data on the hot carcass weight, hanging method (achilles tendon or tenderstretch, or other hanging method), sex (steer or female), days aged, fat depth over the P8 site and cooking method (grill or roast) used were also recorded.

The data set included grain and grass-fed cattle, cattle treated with growth promotants, vealers and cattle from saleyards. The majority of the carcasses were from cattle with zero permanent incisors although there was a small number of carcases included from cattle with eight permanent incisors. Consumer assessment of the palatability of LL samples was done by MSA. A detailed description of the preparation, cooking, and tasting protocols is available in [12]. As described by [13], briefly LL samples taken for sensory analysis were aged at 1°C for a specified period, and 6 steaks (25 mm thick) prepared from each sample. These were stored at –20°C until required.

Untrained consumers did the assessment and steaks were assessed for tenderness, juiciness, flavour and overall acceptability using 4 unstructured 100 mm lines anchored by the words very tough/very tender for tenderness, very dry/very juicy for juiciness and extremely dislike/extremely like for both flavour and overall acceptability. These 4 sensory dimensions were combined into a single palatability score (CMQ4) using weightings formulated from a discriminant analysis. The weightings were 0.4, 0.1, 0.2 and 0.3 for tenderness, juiciness, flavour and overall acceptability, respectively [12].

B. Statistical analysis For the analysis of the CMQ4 score, the method of restricted maximum likelihood (REML) was used with temperature at pH 6 (temp at pH 6), hanging method, sex, estimated % bos indicus (% bos indicus), carcass weight (kg), US Ossification score (ossification score), US marbling score (marbling score), days aged, fat depth over the rib site (rib fat, mm), cooking method (grill, roast) and ultimate pH (pHu) or combinations of fitted along with quadratic terms as fixed effects and abattoir, day of kill, carcass and carcass side fitted as random effects as the initial starting model.

All of these parameters are included in the MSA model [14]. Initial analysis started with a saturated model, all parameters present and up to 3 – way interactions. Further refining of models was done by selecting a parsimonious model by backward selection of terms using Wald tests. All statistical analyses were performed using GenStat. Grading data on the striploin was in the data set and only colour score is reported here.

Muscle colour (grades 4 & 5 were combined due to lack of grade 5 scores) was analysed for effect of temperature at pH 6 using the method of generalised linear model with a multinomial distribution and logit link function and adjustment for kill day.

III. RESULTS AND DISCUSSION

A. Description of population The carcasses ranged from being suitable for the domestic trade (< 180 kg carcass weight) to heavy carcasses (>420 kg carcass weight) suitable for the export market to Japan and Korea. The number of observations for each days aged range was 50, 990, 2553 and 251 carcasses for 1, 5-10, 13-21 and 26-35 days aged respectively. The number of observations for each temperature at pH 6 range was 117, 164, 379, 699, 1148, 1196 and 56 for the ranges <15, 15-20, 20-25, 25-30, 30-35, 35-40 and >40 respectively. This shows that there is good representation of observations across these categories. Thirty-three % of the carcasses had a high rigor temperature (temperature at pH 6 > 35oC), were outside the acceptable pH-temperature window and would be considered heat-toughened.

B. Effect of temperature at pH 6 and other factors on CMQ4 score for the striploin After extensive modelling, temperature at pH 6, days aged, temperature at pH6 x days aged, a quadratic term for days aged, ossification, marbling score, % Bos indicus rib fat, hang method, cook method x ossification, hang method x days aged, and a quadratic term for days aged were found to be significant predictors of the CMQ4 value (P<0.05 for all). Days aged, marbling score, rib fat and roast cooking have a positive effect on the CMQ4 score whereas ossification and % bos indicus have a negative effect on the CMQ4 score. Sex and cooking method had no effects on the CMQ4 score (P>0.05). Except for temperature at pH 6, these effects on CMQ4 are similar to those previously found for the MSA model [15] and thus are not discussed further except where they interact with the effects of temperature at pH 6. Effects of temperature at pH 6 have not previously been reported for the MSA model. Figure 1 shows the effect of Temp at pH 6 and days aged on the predicted CMQ4 score for grilled striploin from a carcass which has been achilles hung and with mean values in the model for marbling score, ossification, % Bos indicus and rib fat. At a high temp at pH 6 of 40oC (ie. heat-toughened) in the striploin, the CMQ4 score was initially higher (predicted CMQ4 = 54) then the striploins with a lower temp at pH 6 (eg. temp at pH 6 =15oC, predicted CMQ4 = 47). After 14 days of ageing, the heat-toughened striploin failed to age much further whereas the non-heat-toughened striploins continued to age. After 35 days of ageing, the model predicted that the heat-toughened striploin was 9 CMQ4 points lower then striploins with a temp at pH 6 =15oC (temp at pH 6 = 40 oC v. 15oC, CMQ4 = 72 v. 63 respectively).

C. Effect of tenderstretch on the influence of temp at pH 6 on CMQ4 score There was an interaction between hanging method and days aged for the effect on CMQ4 (P<0.001). The effect of days aged and temperature at pH 6 on CMQ4 for Achilles hung carcasses is described in the section above. There was no significant effect of temp at pH 6 on CMQ4 scores for the tenderstretch (TS) hanging method (P>0.05; Figure 2). However, there was a reduced range of values for days aged for the tenderstretched carcasses and the range for temperature at pH 6 was reduced. Hence further examination with sufficient data covering a days aged and temperature at pH 6 range similar to the

AT hanging method may be needed to elicit the appropriate effect. Effect of temperature at pH 6 on the colour scores for the striploin Temperature at pH 6 influenced the AUSMEAT colour scores at grading for the striploin ($P<0.05$; Figure 3). As the temperature at pH 6 in the striploin increased from 10oC to 40oC, the proportion of colour scores 1C and 1B increased (pale red) and the proportion of colour scores 2, 3 and 4&5 decreased (red to dark red).

IV. CONCLUSION

Carcasses which are graded to be heat-toughened, as indicated by having a temperature at pH 6 >350C and thus a high rigor temperature, will have a paler meat colour at grading and also, more acceptable quality traits to the consumer at 1-7 days post-slaughter. After 14 days of ageing, the heat-toughened striploin fails to age and after 35 days of ageing will be 9 CMQ4 scores lower then the striploin entering rigor at an 'ideal' temperature.

ACKNOWLEDGEMENT

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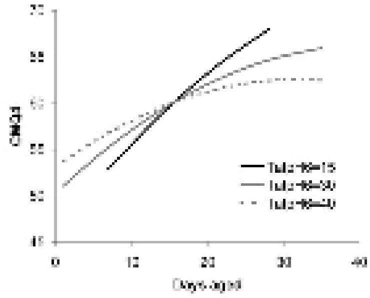
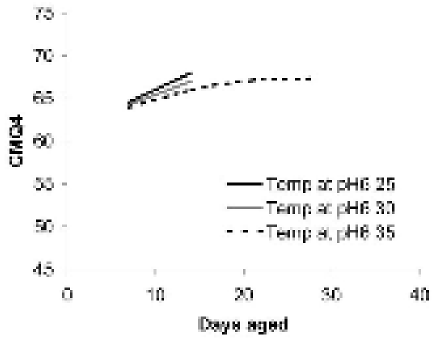
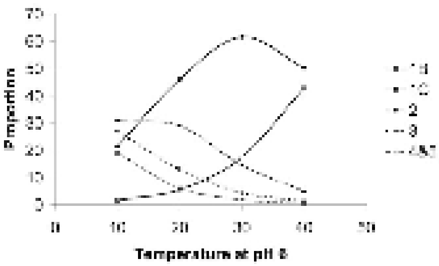


Table 1



Tabel 2



Tabel 3