INFLUENCE OF PH ON MYOGLOBIN DENATURATION (DEGREE OF DONENESS) IN SET COOKED BEEF FILLET STEAKS.

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W-3.15

SUMMARY

As part of a program to validate product specifications for purchasing beef by Qantas Flight Catering Ltd, an experiment was undertaken to examine the effect of pH on the cooked degree of doneness, when steaks were prepared using a time constant cooking process. A total of 66, 120 g centre cut fillet steaks (*M. poas major*), evenly distributed over the pH range of 5.4 to 6.4, were sourced from carcasses which had 2 permanent incisors erupted. pH, marbling and steak dimensions (weight, diameter and thickness) were measured. The steaks were frozen and later thawed prior to undergoing the first cook in an automatic griller, chilled overnight and the final cook in a convection oven at 180°C for 13 minutes. Degree of doneness was subjectively assessed and internal steak colour and temperature measured. There were significant effects for pH, steak thickness, cooked temperature ($P<0.01$) and steak weight ($P<0.05$) on the subjective assessment of cooked degree of doneness. An increase in 1.0 unit of pH resulted in a decrease of 1.8 doneness scores (assessed on a scale 1=rare to 5=well done).

The results demonstrate the importance of limiting pH ranges and steak dimensions as a means of controlling the acceptability of doneness of beef fillets prepared using automatic cooking processes.

Introduction

The food services industry is placing increasing emphasis on the consistency and quality of its cooked products, which is reflected in tighter purchasing specifications being implemented across a range of food products. Often the variation in beef quality traits such as tenderness, flavour, size, shape and doneness of the cooked product are unacceptably high and a source of customer complaint. There is a need to develop product specification systems which will minimise variation in these meat traits.

Doneness of a cooked steak is one of the first quality attributes a consumer will assess on a cooked meat dish. Apart from temperature and cooking time, Trout (1989) showed that pH was an important factor controlling denaturation of the myoglobin and therefore, degree of doneness. These results were obtained using ground meat samples and it is important to establish the effect of pH using portion control cut steak, which comprise a large portion of the steaks used by the catering industry. As part of a program to validate product specifications for purchasing beef by Qantas Flight Catering Ltd, this experiment was undertaken to examine the effect of pH on the cooked degree of doneness in portion cut steaks cooked using a time constant, part cook/chill/reheat cooking process.

Materials and methods

Sixty six, 120 - 130 g beef tenderloin steaks *(M. psoas major*) were sourced from carcasses which had been electrically stimulated and had 2 permanent incisors erupted. Tenderloins were removed from the carcass, vacuum packed and stored at 2-5oC for 10 days prior to sampling for this experiment. Steaks were selected to give an even distribution of pH over the range 5.4 to 6.4 which was measured using a Jenco microcomputer pH meter model 6007, with an Ionode meat probe IJ42.

One centre cut fillet steak was cut from a full tenderloin, and its fresh weight, pH and steak dimensions (thickness and diameter) recorded. A digital image was analysed for marbling percentage (the number of white pixels as a percentage of surface area). The steaks were then placed on a polystyrene tray, vacuum packaged and frozen at -15°C for 28 days. The steaks were thawed in a chiller at 2°C for 36 hours, prior to weighing and undergoing the first cook.

The first cook was done using an automatic gas conveyor griller with a cooking time of 2.43 minutes. After the first cook all steaks were placed in a commercial chiller (0-2°C) for 18 hours. The following day each steak was placed in an alfoil cooking dish with vegetables and then covered with alfoil to replicate a typical economy class airline meal. The final cook was completed using two airline convection ovens set at 180°C for 13 minutes. The position of the trays during cooking was recorded.

After cooking, steaks were removed from the trays, weighed and cut along the longest axis. One half of the steak was cut into four cubes and subjectively assessed by a trained panel of four chefs for degree of doneness (1 = rare to 5 = well done) and eating quality (juiciness, flavour and tenderness on a 6 point scale where 1 = very poor and 6 = excellent). The chefs regularly assessed the eating quality traits of tenderloin steaks over the full range of the scale. The other half of the steak was cooled at room temperature for a minimum of 20 minutes and colour of the cut surface assessed using the CIE-L*,a*,b* space (Warner, 1989) measured by the Minolta Chroma meter (CR-310). The Minolta readings were a mean of at least three measurements along the length of the cut surface.

Thaw loss percentage was calculated as fresh weight minus the thawed weight prior to the first cooking, expressed as a percentage of fresh weight, whilst cooking loss was calculated as thawed weight minus final cooked weight, expressed as a percentage of thawed weight.

Using univariate analyses, the effects of pH, steak weight, thickness and diameter, marbling percentage and cooked internal temperature (as both linear and curvilinear terms) on doneness and percentage thaw and cooking losses were examined. Non-significant ($P>0.05$) terms were sequentially deleted from the model until the simplest significant model was obtained.

Due to high correlations within the taste panel assessments of eating quality (juiciness, flavour, and tenderness) and within the three dimensions of the colour space (L*,a*,b*), these characteristics were analysed as multivariate traits using the same initial model and model reduction procedure to the univariate analyses. When the final multivariate models were obtained, a canonical variate analysis was used to assess the significance of the independent variables on the components of the multivariate traits (ie. eating quality and colour space).

Results

Means, standard deviations and ranges for variables from both the fresh and cooked steaks are shown in Table 1. The steaks were cut to comply with rigorous catering specifications, and there was little variation in fresh steak weight (coefficient of variation of 2.5%). However, there was considerably more variation in steak thickness and diameter. Although the average doneness of the steaks was just over a score 3 (ie medium), the scores ranged from 1 (ie rare) to 5 (ie well done). Cooked internal temperature of the steak also varied widely with a range of almost 30°C.

When adjusted to the same cooked temperature, doneness scores were significantly affected by pH ($P<0.001$), thickness ($P<0.01$) and fresh weight ($P<0.05$) (Table 2). A 1.0 unit increase in pH resulted in a 1.8 unit decrease in doneness score. A 10 mm increase in thickness resulted in a 0.5 unit decrease in doneness, whilst a 10 g increase in weight resulted in a 0.6 unit increase in doneness. Higher cooked temperature (due to differences in position of the ovens) also resulted in an increase in doneness score.

For the multivariate analysis of eating quality, both pH and cooked temperature were significant ($P<0.05$). The canonical vector for pH indicated that the major effect was on the flavour and tenderness dimensions, with relatively little effect on juiciness (the standardised elements of the canonical vectors were 1.18, 0.92, and 0.53, respectively). The canonical vector for cooked temperature indicated that the major effect was on the tenderness and juiciness dimensions and to a lesser extent flavour (the standardised elements of the canonical vector were 0.75, 0.61, and -0.43, respectively).

pH had a significant effect ($P<0.01$) on both percentage thaw and cooking loss, with an increase of 1.0 unit in pH resulting in 8 and 6 percentage units decrease in thaw and cooking loss, respectively (Table 3). A 10°C increase in cooking temperature resulted in 4 percentage units increase in cooking loss. The multivariate model showed that pH had a significant effect ($P<0.05$) on cooked meat colour. The standardised elements of the canonical vector for pH were 1.04, 0.03 and -0.20 for the L*, a* and b* dimensions respectively, indicating the major effect of pH was through the lightness (L*) colour dimension. The standardised elements of the canonical vector for cooked temperature were -0.03, 1.27 and -0.83 for the L*, a* and b* dimensions respectively, which indicated that the effect of cooked temperature on colour was largely through the a*, and to a lesser extent the b* colour dimensions, with relatively little influence on the L* colour dimension. The regression coefficients for the effects of both pH and cooked temperature on the colour dimensions are shown in Table 3.

Discussion

When steaks were cooked under a set-timed two-stage cooking regime those steaks with high pH resulted in a lower doneness score and a darker colour (ie a lower L* value). Trout (1989) showed that when cooked to 65°C, beef mince with a pH of 5.5 had almost a three-fold increase in the percentage of myoglobin denaturation compared with mince with a pH of 7.0. As cooking temperature increased the extent of myoglobin denaturation increased at all pH levels, so that at temperatures of 75°C or above, pH had little effect on myoglobin denaturation of beef muscle. Similarly Oreshkin and Borisova (1988) reported that denaturation loosening of the myofibril proteins occurred at a lower temperature in low pH beef.

Steaks at the front of the oven had a lower cooked temperature, which was reflected in the a lower doneness score. Surprisingly steak thickness had a significant effect on doneness, after adjustment for cooked temperature. The effect of cooked temperature on the dimensions of the L*a*b* colour system agreed with Lyon, Greene and Davis (1986) who found that differences in cooked temperature were most strongly reflected in an a decrease in the redness (a*) and yellowness (b*) dimensions.

The effects of pH on percentage thaw and cooking loss have been well documented (Lawrie, 1985). At low pH levels these losses can be of the order of 30 to 40% of the initial weight of the fresh product and represent a substantial loss to the catering industry.

The relationship between pH and eating quality of beef is complex. Most studies show an improvement in tenderness of very high pH meat (eg. Bouton et al., 1957), although the effect of low pH is more variable. A number of studies have found a curvilinear relationship with a maximum toughness at a pH of 6 (Bouton et al., 1973), but these reports are confined to muscles that are able to shorten pre-rigor in the carcass (Eikelenboom, 1993). Other studies have shown a linear relationship between pH and tenderness (Dransfield, 1981). A number of mechanisms have been proposed to explain more tender meat at higher pH, including increased water holding capacity, enhanced protease activity and reduced cooking loss. However, Marsh (1993) considered that the effect may simply occur via the effect of pH on doneness. Based on the results from Trout (1989) he proposed that the lower degree of myoglobin denaturation in high pH meat would result in more tender meat. After adjustment for cooked temperature, the multivariate analysis of eating quality in this study showed a significant effect of pH, largely via the flavour and tenderness dimensions. Flavour decreased as pH increased which is consistent with results from Bouton et al. (1957). However over the range of pH sampled in this study there was a linear trend for tenderness to increase with increasing pH given the same cooked temperature. High pH steaks will be less done at the same cooked temperature and will require further cooking to attain the desired degree of doneness. This further cooking will increase protein hardening and loss of juiciness.

Conclusion

Ultimate pH accounted for a significant proportion of the variation in doneness of steaks prepared under automated cooking procedures. This relationship was independent of cooked temperature. Food industries that require restricted variation in doneness should source product within a narrow pH range. Even when steaks are sourced within a 10 g weight range, both the weight and steak thickness caused variation in doneness. Low pH steaks were scored as having a better flavour but were less tender at the same cooked temperature. The contrasting relationships between cooked temperature and pH on degree of doneness may explain some of the variation in the scientific literature between ultimate pH and tenderness. Low pH steaks also had higher losses both during the thawing and cooking processes.

Acknowledgments

The authors wish to acknowledge the contributions of the Meat Research Corporation to this project.

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