Chapter 3.

COMPARISON OF THE USE OF A TRAINED TASTE PANEL WITH CONSUMER EVALUATION OF EATING QUALITY

3.1 Introduction

The ultimate arbiter of eating quality is the consumer. However, Gillmore and Prescott (1993) stated that humans are notoriously unreliable measuring devices, subject to an endless array of distractions, emotions, illnesses and sensitivities. Consequently, the evaluations made by untrained consumers are generally considered to be surrounded by a large amount of variation both within and between individuals. The training of a taste panel theoretically removes the influence of irrelevant factors and individual preferences, and panel results would therefore be thought to suffer less variation than untrained consumer evaluations. A taste panel is trained to provide a method of sensory evaluation which is relatively quick, cheap and repeatable. The panel will generally have greater sensory acuity than consumers and be able to detect smaller differences between samples.

Gilmore and Prescott (1993) put the view that any form of training removes panellists from the realm of the consumer. This may be applicable in terms of preference evaluations, but it is not known whether a trained taste panel will evaluate samples in a similar way to consumers or what effect training has on the panellists' sample evaluation in comparison with untrained consumer evaluations of the same samples, and with the panellists' evaluations prior to their training.

It is generally believed that if the trained panel can not detect a difference between samples, then neither will consumers (Gilmore and Prescott, 1993). However, it is important to know what differences the trained panel is detecting in terms of those detected by the untrained consumer. Bresson and Behling (1977) stated that trained panels have been used to minimise

unnecessary (and costly) extensive hedonic testing of samples which in fact were not really perceived as different by the average consumer.

This study was designed to investigate the differences between trained panellist and consumer evaluations of meat samples and the variation surrounding these evaluations, both prior to and at the completion of training.

3.2 Materials and Methods

Sample Preparation

Meat samples were sourced from three muscles which differed in tenderness. Four striploins (*m. longissimus thoracis et lumborum*) were obtained, two from electrically stimulated carcases (LT-ES), and two from non stimulated carcases (LT-NS). Six *m. semitendinosus* (ST) and seven *m. supraspinatus* (SU) were also obtained from a local wholesaler. Consequently, each muscle group comprised samples from different animals.

All samples were cut in half and frozen at -20°C until required for use. The samples were then thawed by holding them for 48 hours at 1°C. Samples for the first tasting had been frozen for 4 days and those for the second tasting for 4 weeks at the time of thawing.

The epimysial connective tissue and external fat was removed from all samples. They were cut into 250±5g blocks and weight and pH were recorded. The blocks were cooked in plastic bags in an 80°C waterbath for 60 minutes and then cooled for 30 minutes under cold running water to prevent any further cooking. Sample blocks were patted dry and the post-cooking weight recorded. Blocks were then refrigerated in plastic bags at 5°C for four hours. The external surfaces were removed and the remaining meat was cut into 1.5cm cubes which were placed in plastic bags and refrigerated overnight.

The following morning, the cubes were placed on pre-numbered plates (random three digit codes) and were served at room temperature.

Sensory Evaluation and Design

Tasters (panellists and untrained consumers) were presented with four cubes, one each taken from LT-ES, LT-NS, ST and SU (order was randomised), and an instruction and score sheet (see instruction and score sheet one in appendix A). They were asked to evaluate the cubes

for tenderness and juiciness. Sensory evaluations were made on a continuous, unstructured 10 cm line anchored at each end by the terms extremely tough or dry (0) and extremely tender or juicy (6). Tastings were conducted under green light.

Two tastings were conducted, the first tasting was prior to the training of the taste panel, but post panel selection, and the second tasting was after the taste panel had completed their training (appendix B details the selection and training procedure). Both of these tasting sessions included panellists and untrained consumers. A random selection of 40 untrained consumers (students) from a residential college at the University were asked to do evaluations at each of the two tastings. At both tastings, consumers who had not performed a beef evaluation previously were selected.

The trained panel comprised 20 panellists, each of whom evaluated four cubes at two tastings. At the second tasting, the panellists received cubes from the same meat samples evaluated in the first tasting. This was achieved by halving each sample prior to the first tasting.

Statistical Analysis

To examine the main effects on tenderness and juiciness, the data from the taste panel and consumers was analysed separately because essentially they were two different populations. The tasters in the taste panel were considered as fixed effects, while those in the consumer groups treated as random effects. The panellists were classed as a fixed effect because they were a group of tasters who could be used repeatedly as a fixed group. The untrained consumers were a random selection of individuals who were different for the two tastings, and were therefore classified as a random effect. Consequently, the tenderness and juiciness data from the taste panel was analysed using a univariate generalised linear model and the consumer data was analysed using an univariate mixed model in SAS (1992).

The model used to examine tenderness and juiciness evaluations from the taste panel was:

$$Y_{hik} = \mu + T_h + M_i + TA_k + TM_{hi} + e_{hik} \qquad (3.1)$$

where;

Y_{hik} = tenderness or juiciness evaluation for the *h*th tasting, *i*th muscle, and *k*th taster

μ = mean intercept

T_h = the effect of the *h*th tasting

M_i = the effect of the *i*th muscle

TA_k = the effect of the *k*th taster

TM_{hi} = the effect of the interaction between the *h*th tasting and the *i*th muscle

e_{hik} = the random error

The model used to examine tenderness and juiciness evaluations from consumers was the same as equation 3.1, with taster being treated as a random effect:

$$Y_{hik} = \mu + T_h + M_i + TA_k + TM_{hi} + e_{hik} \qquad (3.2)$$

To examine the amount of variance between tasters, the data was split into four sub-groups: taste panel, tasting 1 (tp 1); taste panel, tasting 2 (tp 2); consumers, tasting 1 (cons 1), and; consumers, tasting 2 (cons 2). Univariate models containing terms for muscle, taster and the muscle by taster interaction were run and the least square means for tenderness and juiciness scores were obtained. The variance of the least square means was obtained for the four muscles within each sub-group.

To examine within panellist variation and repeatability, a multivariate analysis was performed using REG (Gilmore, 1989) with the taste panel tenderness and juiciness scores at tastings one and two as the dependent variables (separate models for tenderness and juiciness). The model contained terms for both muscle and taster (as fixed effects) and the error correlation matrix was obtained. The error correlation matrix provided an indication of the within panellist variance and panellist's ability to repeat their score on the same sample of meat.

3.3 Results

Table 3.1 shows that muscle, taster and muscle x tasting had significant effects ($P<0.05$) on taste panel tenderness evaluations. Taste panel juiciness evaluations were significantly affected ($P<0.05$) by muscle, tasting and taster. The muscle x tasting interaction was not quite significant ($P=0.06$) for taste panel juiciness evaluations.

Table 3.1. The effect of tasting, muscle and taster on tenderness and juiciness evaluations made by the taste panel.

	Tenderness			Juiciness		
	DF	F Value	Sign	DF	F Value	Sign
Tasting	1	0.28	ns	1	13.45	***
Muscle	3	22.64	***	3	13.01	***
Taster	21	3.56	*	21	2.47	***
M x T	3	2.01	**	3	3.18	P=0.06

*** P<0.001, ** P< 0.01, * P<0.05 ns = not significant (P>0.05)
T = tasting, M = muscle DF = degrees of freedom

Untrained consumer tenderness evaluations (Table 3.2) were significantly (P<0.05) affected by both the main effects (tasting and muscle) and also the muscle x tasting interaction. Muscle and the muscle x tasting interaction also had significant effects (P<0.05) on consumer evaluations of juiciness.

Table 3.2 The effect of muscle and tasting on tenderness and juiciness evaluations made by untrained consumers.

	Tenderness				Juiciness			
	NDF	DDF	F Ratio	Sign	NDF	DDF	F Ratio	Sign
Tasting	1	209	6.01	*	1	209	0.01	ns
Muscle	3	209	10.08	***	3	209	9.36	***
M x T	3	209	4.63	**	3	209	4.09	**

*** P<0.001, ** P< 0.01, * P<0.05 ns = not significant (P>0.05)
T = tasting, M = muscle DF = degrees of freedom

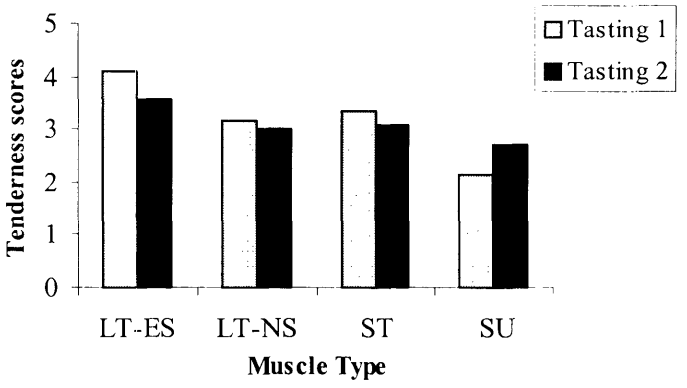

Figure 3.1 Least square taste panel tenderness scores for the four muscles at tasting one (pre-training) and tasting two (post-training). 0 = very tough, 6 = very tender

The tasting x muscle interaction for taste panel scores is shown in Figure 3.1. There was a general trend for the LT-ES samples to be evaluated most tender, followed by ST and LT-NS, with the SU samples being evaluated as toughest. The taste panel evaluations show similar scores between muscles over the two tastings, although the differences were not consistent. At

the first tasting, panellists did not detect a difference between LT-NS and ST samples. However, at the second tasting the LT-ES and ST samples were evaluated similarly. The LT-ES and LT-NS samples were evaluated slightly tougher at the second tasting, whereas the ST and SU samples were evaluated more tender at the second tasting compared to the first tasting.

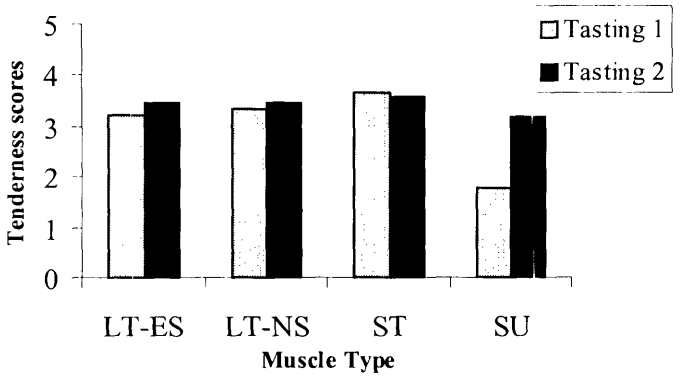

Figure 3.2 Least square untrained consumer tenderness scores for the four muscles at tastings one and two. 0 = very tough, 6 = very tender

Figure 3.2 shows untrained consumer scored muscles similarly at the two tastings, except for SU samples. There was also less range in the mean muscle scores given by consumers compared to those given by the taste panel. The consumer scores from the second tasting displayed comparatively little variation in tenderness scores between the four muscles.

The mean tenderness scores for LT-ES, LT-NS and ST samples given by both the taste panel and consumers showed less than one unit variation within each muscle. By contrast, there was about one and a half units variation in the mean consumer tenderness scores for SU samples.

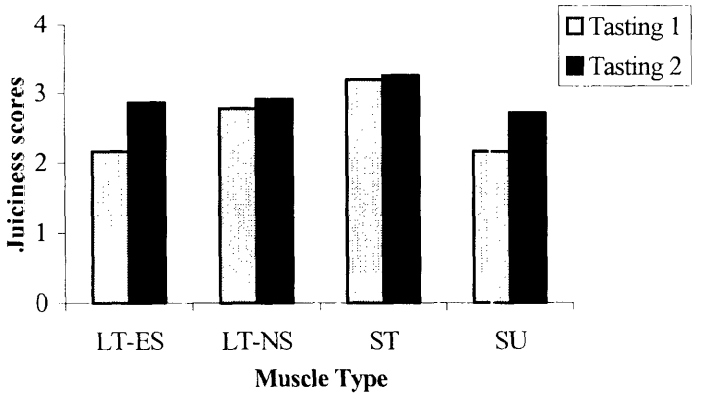

Figure 3.3 Least square mean taste panel juiciness scores for the four muscles at tasting one (pre-training) and tasting two (post-training). 0 = very dry, 6 = very juicy

Figure 3.3 shows that all muscles were evaluated by the taste panel as drier at the first tasting than at the second, although the magnitude of the difference between tastings varied. There was essentially no difference in the taste panel juiciness scores for LT-NS and ST samples evaluated at tasting one and two. There was a larger difference (0.7 unit) between taste panel juiciness scores from the first and second tastings in the LT-ES and SU samples.

Figure 3.4 shows that untrained consumers at the first tasting evaluated LT-NS and ST samples as more juicy, and LT-ES and SU samples as drier than the consumers at the second tasting. There was only minor variation in the juiciness scores from consumers at the second tasting.

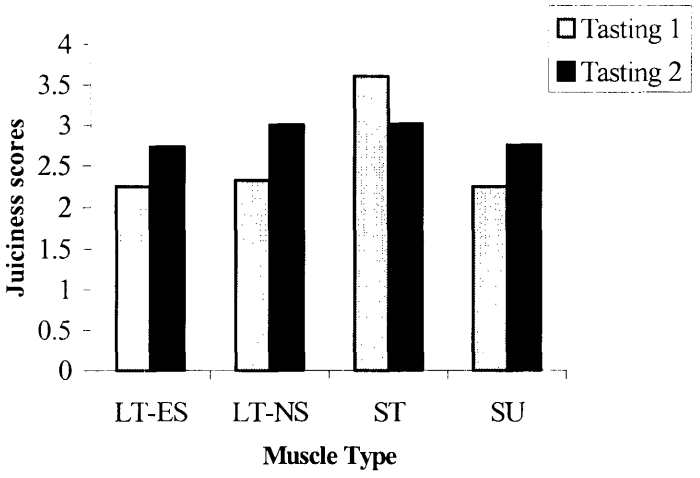

Figure 3.4 Least square mean untrained consumer juiciness scores for the four muscles at tasting one and two. 0 = very dry, 6 = very juicy

Similar scores were found in juiciness scores for the taste panel and consumers, however, much wider variation was observed in the consumer scores.

The variance of least square means tenderness and juiciness evaluations (Table 3.3) were lower for the panel than consumers at both tastings. The variance of taste panel tenderness and juiciness scores did not decrease after training (tasting 2).

Table 3.3 Variance of least square tenderness and juiciness means for panel and consumer evaluations at tastings one and two.

	Tenderness				**Juiciness**			
Muscle	tp 1	tp 2	cons 1	cons 2	tp 1	tp 2	cons 1	cons 2
LT-ES	0.88	0.91	1.85	1.72	0.70	0.67	1.04	1.58
LT-NS	0.61	0.57	1.56	1.47	0.55	0.32	1.32	2.16
ST	0.55	0.73	2.54	1.90	0.65	0.76	1.66	1.65
SU	0.91	0.74	1.42	1.70	0.53	0.77	1.36	1.70

tp 1= taste panel, tasting 1, tp 2 = taste panel, tasting 2. cons 1= consumers, tasting 1, cons 2 = consumers, tasting 2.

A simple correlation matrix was obtained and the correlation between tenderness scores in tasting one and tasting two was 0.42. The correlation between juiciness scores at the two tastings was 0.27.

The error correlation from the multivariate analyses of taste panel tenderness and juiciness scores showed a correlation of 0.17 for tenderness scores and 0.26 for juiciness scores for individual panellists to repeat their score on the same sample at the two tastings.

3.4 Discussion

The tenderness scores from the panellists for the four different muscles showed reasonably similar scores both before and after training. This would suggest a reasonably high relationship between panellists' evaluations of the same samples. These scores were also similar to the evaluations made by the untrained consumers in the first tasting, except untrained consumers did not detect such a difference between LT-ES and LT-NS.

The difference in muscle scores from the untrained consumers at the second tasting did not display the same scores as the other groups and showed less difference in tenderness scores between the four muscles. The lack of discrimination could possibly indicate that more consumers were required for the tasting.

The results indicate that the taste panel were evaluating samples in a similar manner to consumers, particularly for the first consumer tasting. The panel tended to show more differences between muscles than untrained consumers. This would agree with other reports that trained panels are more critical than untrained consumer (eg. AMSA, 1995). Similarly, Chambers *et al.* (1981) reported that trained panellists were more consistent in their scoring and generally discriminated among sensory sensations and scored samples with greater precision than a semi-trained panel.

The panellists ranked the tenderness of different muscles in a similar manner before and after training. Slight differences in mean tenderness scores were observed for the muscles at the two tastings. Such differences may be expected given the observations of Hovenier *et al.* (1993). They found a repeatability of 0.50 for repeated tenderness scores from one panellist within the same animal. However, repeatability decreased to 0.08 for two repeated tenderness scores of different panellists within one animal (after a two week training period). Similarly, the correlation between tenderness evaluations at the two tastings in the present study was 0.42. It should be highlighted that the correlation coefficient reported includes the between and within taster co-variance and is not a true indication of the within taster repeatability. When the error correlation matrix was obtained after adjustment for both muscle and taster, the correlation between a panellist's tenderness scores at tasting one and two for one sample decreased to 0.17. This value provides a true indication of the ability of one taster to repeat their score on the same sample of meat, and is not inflated due to the inclusion of between taster co-variance. This repeatability would appear rather low, but further work would be required to investigate whether this was attributable to human and/or meat sample variation.

The low repeatability within taste panellists reinforced the fact that a sample of meat should not be evaluated by only one taster. Rather, a number of panellists (or consumers) should evaluate the same sample of meat for a realistic evaluation of tenderness and juiciness of that sample.

Taste panel juiciness scores at the first tasting displayed similar scores to tenderness evaluations, except LT-ES and SU samples were evaluated as the driest of the four muscles. Similarly, Wheeler *et al.* (1990b) found panel juiciness scores were lower in samples from stimulated carcases than non stimulated carcases. Electrical stimulation has also been reported to cause a decline in water holding capacity (Martin *et al.*, 1983) which may have lowered juiciness scores. However, in contrast, juiciness has been reported to increase with electrical stimulation (Kostov *et al.*, 1987; Aalhus *et al.*, 1992; Olsson *et al.*, 1994).

This dryness in LT-ES samples was not detected at the second tasting when there was minimal variation in juiciness scores. These scores were similar to consumer juiciness evaluations at their respective tastings. The lack of variation in juiciness scores at the second tasting may possibly have been caused by a longer freezing. Although if this were the case, then it would appear to affect muscles differently.

It was interesting to note that the error correlation matrix for taste panel juiciness scores between the two tastings was the same as the simple correlation between these scores. This is suggesting that the relationship between panellist's juiciness scores across the two tastings was not inflated by the co-variance between panellists which occurred with tenderness evaluations.

The variance for panel mean muscle tenderness and juiciness scores did decrease slightly for half the muscles at the second tasting. However, the mean variance for the other muscles increased slightly at the second tasting. It could be concluded from this result that training did not have a large effect on reducing the between panellist variation which might have been expected. To achieve such a reduction, a longer and more intense training period may have been required. It may also be a reflection of the normal heterogeneity which exists in meat or natural variation between panellists, which is also apparent in the consumer population and maybe therefore more difficult, and perhaps unnecessary, to eliminate.

Despite training not affecting the between panellist variance significantly, the between individual variation, as estimated by the least square mean variance was shown to be greater for consumers than for the panel for both tenderness and juiciness evaluations. This indicated that the panel selection procedure was effective in reducing between individual variance. This finding was similar to Bennett *et al.* (1956) and Chambers *et al.* (1981) who reported trained panellists were more consistent in their scoring than untrained consumers. Variation around consumer scores may also have been deflated if consumers did not use the extremes of the scale.

3.5 Conclusion

Based on the results from this study, it was concluded that the taste panel evaluated meat in the same manner as untrained consumers, but detected more differences between samples. The panel selection procedure was effective in selecting efficient panellists and reducing between individual variation, but training did not result in a reduction in the variation between panellists' evaluations. The repeatability of panellists' to score the same sample highlighted the fact that to obtain a realistic evaluation of meat tenderness and juiciness, each sample needs to be evaluated by a number of panellists, or consumers. It was concluded that the trained panel could be used and would evaluated tenderness and juiciness in a manner similar to untrained consumers.

Chapter 4.

THE EFFECT OF COOKING METHOD AND TEMPERATURE ON THE SENSORY EVALUATION OF BEEF EATING QUALITY

4.1 Introduction

It is important that the method used in the laboratory to cook beef for sensory evaluation is standardised as much as possible to minimise experimental variation. This raises the dilemma of deciding on which cooking technique to use and whether to cook to a set end point internal temperature, or for a set time.

Using a standardised technique such as cooking in a waterbath is generally believed to provide consistent and even heat transfer rates across all samples. However, such a technique is not used by consumers when they cook high quality (low connective tissue content) meat, such as steaks. Grilling or frying are typically used by consumers in this case. However these cooking methods are subject to a decrease in control and standardisation during cooking compared to waterbathing.

Traditionally, high quality cuts of beef have been cooked at high temperatures for a short period of time in the belief that this type of cooking was most beneficial in terms of enhancing sensory attributes. However, it is well established that the increased tenderisation which results from cooking meat for long periods at low temperatures may be attributed to the solubilisation of collagen that occurs without extensive hardening of muscle fibres (Paul, 1963). As early as 1937, Cover found that well done roasts were more tender when cooked at 124°C than 225°C. Bramblett *et al.* (1959), Bramblett and Vail (1964) and Laakkonen *et al.* (1970a) have also reported that increased tenderness can be achieved using low temperature cooking.

When McDowell *et al.* (1982) cooked beef to 60°C, the waterbath cooking resulted in increased tenderness (measured both objectively and by sensory evaluation) compared with oven

roasted samples. Berry and Bigner (1995) reported broiler grilling (similar to hot plate) increased all shear values compared to grilling.

Although tenderness has been shown to be enhanced using low temperature cooking combined with long cook times, it is not known whether similar benefits can be obtained when steaks are cooked at low temperatures, but for relatively short periods of time (eg. 10 minutes).

This study was designed to investigate, i) the effect on tenderness and juiciness of cooking in a waterbath compared to cooking methods typically used by consumers (grilling and frying) and, ii) to determine whether the sensory evaluation of steaks was influenced by using high or low cooking temperatures when cooked to the same internal temperature.

4.2 Materials and Methods

Animals and slaughter

Forty two steers from the Cattle and Beef Industry CRC (Armidale) straight breeding program, intended for the domestic market, were finished on grain for 70 days. The cattle were trucked to the local abattoir, held overnight in pens with water available and killed the following day (captive bolt stunning). After stunning, carcases were electrically stimulated using effective low voltage stimulation (200 milli-amps, peak voltage 45 volts, 40 seconds duration) and the dressed carcases were chilled overnight.

Carcases were boned out the following day and one striploin (*m. longissimus thoracis et lumborum*) (LT) was removed from twelve carcases. Striploins were vacuumed packed and aged at 1°C for seven days then frozen and held at -20°C until required for use.

Preparation and cooking of steaks

Frozen striploins were cut into 22mm steaks using a band saw. The steaks were thawed by holding for 24 hours at 5°C. Steaks had all epimysial connective tissue and subcutaneous fat removed, trimmed to 125±2 grams, weight and pH recorded.

Two steaks from each striploin were allocated to each of the five cooking treatments:

1) waterbath;
2) hot plate - high temperature;

3) hot plate - low temperature;
4) double grill - high temperature, and;
5) double grill - low temperature.

Preliminary experiments were conducted to establish the cooking temperature and time required to cook steaks to an internal temperature of 70°C (a medium degree of doneness) measured by thermocouples inserted into the geometric center of the steaks. The following cooking procedures were employed.

Waterbath (W); the 20 steaks were placed in individual plastic bags and cooked in an 80°C waterbath for 10 minutes.

Hot plate - high temperature (HH); a commercial hot plate was preheated to 250±5°C. Two steaks, from the same striploin, were cooked for seven minutes. Steaks were turned and position swapped after three and a half minutes. There was a one minute interval between the cooking of steaks. All steaks were cooked in the same area on the hot plate to avoid temperature variations across the hot plate.

Hot plate - low temperature (HL); the commercial hot plate was preheated to 170±5°C. The cooking procedure was the same as for HH, except steaks were cooked for 10 minutes and were turned after five minutes.

Double grill - high temperature (DH); a commercial double grill (Sunbeam) was preheated to 235±5°C. Two steaks from the same striploin were placed in the wire rack such that they were positioned in the center of the griller. Steaks were cooked for eight minutes.

Double grill - low temperature (DL); the same procedure was used as for DH, except the griller was preheated to 170±5°C and steaks were cooked for 12 minutes.

After cooking, steaks were placed in plastic bags and cooled under cold running water for 30 minutes to consistently and rapidly stop the cooking process. Steaks were patted dry with paper towel before being weighed and stored overnight at 1°C.

The following day, six 1.5cm cubes were cut from each steak. The colour (L*, a*, b* values) of the cooked cubes on the (internal) cut surface was recorded using the Minolta Chroma meter (CR 300 series, DP 301).

Sensory evaluation

The tasters included a random selection of untrained consumers at a beef field day and staff of the Department of Animal Science at UNE. Due to lower number of people at the beef field day than expected, the UNE trained taste panel was also used to finalise the evaluations. Therefore tasters were either untrained consumers, or the trained panel. Sensory evaluations were made on a continuous, unstructured line anchored at each end by the terms extremely tough or dry (0) and extremely tender or juicy (100) (see score sheet 2 in appendix A). Each taster was asked to evaluate five cubes of meat (one from each of the cooking treatments) from the same striploin for both tenderness and juiciness. This allowed a comparison of cooking treatment on a within animal basis and removed any confounding effect of between animal variation.

Statistical analysis

Tenderness and juiciness scores were analysed using univariate mixed models in SAS (SAS, 1992). The effect of using untrained consumers and the trained panel was included as a fixed effect called taster group. Cooking treatment was also classed as a fixed effect. The Minolta colour L*, a*, b* values were included as covariates and taster within striploin, and striploin were classified as random effects.

The initial model used to examine tenderness and juiciness evaluations was:

$$Y_{hikl} = \mu + C_h + TG_i + L + A + B + T(S)_{kl} + S_l + e_{hikl} \qquad (4.1)$$

where;

Y_{hikl} = tenderness or juiciness for the hth cooking technique, ith taster group, Minolta L* value, Minolta a* value, Minolta b* value, kth taster within lth striploin and lth striploin

μ = mean intercept

C_h = the effect of the hth cooking technique

TG_i = the effect of the ith taster group

L = the effect of Minolta L* value

A = the effect of Minolta a* value

B = the effect of Minolta b* value

$T(S)_{kl}$ = the effect of the kth taster within lth striploin

S_l = the effect of the *l*th striploin

e_{hikl} = the random error

To ensure that the sensory scores were adjusted to the same degree of doneness, the colour L*, a* and b* values were included in the model as covariates.

In the above analysis, cooking technique had a significant effect on tenderness and juiciness. Therefore, a second analysis was then performed specifically to investigate the effect of the interaction between cooking method (double grill and hot plate) and temperature (high and low), fitted as fixed effects, and contained the following terms:

$$Y_{hiklm} = \mu + C_h + T_i + CT_{hi} + TG_k + L + A + B + T(S)_{lm} + S_m + e_{hiklm} \quad (4.2)$$

where;

Y_{hiklm} = tenderness or juiciness for the *h*th cooking method, *i*th cooking temperature, *k*th panel, Minolta L* value, Minolta a* value, Minolta b* value, *l*th taster within *m*th striploin and *m*th striploin

μ = the mean intercept

C_h = the effect of the *h*th cooking method

T_i = the effect of the *i*th cooking temperature

CT_{hi} = the effect of the interaction between the *h*th cooking method and the *i*th cooking temperature

P_k = the effect of the *k*th panel

L = the effect of Minolta L* value

A = the effect of Minolta a* value

B = the effect of Minolta b* value

$T(S)_{lm}$ = the effect of the *l*th taster within *m*th striploin

S_m = the effect of the *m*th striploin

e_{hiklm} = the random error

Cooking loss was initially included in equations 4.1 and 4.2, but was not significant ($P>0.05$) and did not influence the other results. It was therefore removed from the equations. The Minolta colour values were not significant ($P>0.05$) for tenderness or juiciness evaluations. However, they were left in the model because the interdependence between these three

covariates was likely to have been very high and their interdependence may have influenced results, without the three covariates themselves being significant.

4.3 Results

Results from the analyses using equations 4.1 and 4.2 were the same, except equation 4.2 showed the nature of the interaction between cooking method and temperature. Consequently, results from the analysis using equation 4.1 have not been shown. However, the effect of the waterbath method can be compared to the other cooking techniques in Table 4.2. Table 4.1 shows whether cooking method and temperature, panel and degree of doneness (as measured by L, a*, b*) had significant effects on tenderness and juiciness scores.

Table 4.1 Effects of cooking method and temperature and panel when adjusted for degree of doneness on tenderness and juiciness evaluations.

	Tenderness				**Juiciness**			
	NDF	DDF	F Ratio	Sign	NDF	DDF	F Ratio	Sign
C	1	339	32.25	***	1	339	28.51	***
T	1	339	0.01	ns	1	339	7.94	**
C x T	1	339	7.71	**	1	339	2.85	P = 0.09
Panel	1	339	0.82	ns	1	339	5.72	*
Minolta L*	1	339	0.27	ns	1	339	0.16	ns
Minolta a*	1	339	1.03	ns	1	339	1.90	ns
Minolta b*	1	339	3.11	ns	1	339	0.63	ns

*** P<0.001, ** P<0.01, * P<0.05 ns = not significant (P>0.05)
NDF = numerator degrees of freedom, DDF = denominator degrees of freedom
C = cooking method (double grill, hot plate) T = cooking temperature (high, low)

Tenderness and juiciness evaluations were significantly (P<0.01) affected by cooking method (Table 4.1). The interaction between cooking method and temperature (Table 4.1) had a significant effect (P<0.01) on tenderness evaluations, but not on juiciness evaluations (P=0.09). Cooking temperature and type of panel also had significant effects on juiciness evaluations. The colour covariates did not (P>0.05) have a significant effect on either tenderness or juiciness evaluations.

Table 4.2 Least square tenderness and juiciness means (± standard error) and percent cooking loss for the five cooking techniques.

Cooking technique		Tenderness	Juiciness	Cooking Loss
Waterbath	(W)	62±3	49±3	29.34%
Double grill - low	(DL)	85±3	71±3	19.67%
Double grill - high	(DH)	79±3	73±3	16.15%
Hot plate - low	(HL)	60±3	57±3	25.15%
Hot plate - high	(HH)	72±3	65±3	21.86%

The least square tenderness and juiciness means (Table 4.2) show that the W technique produced toughest and driest steaks (tenderness score = 62 and juiciness = 49). The HL, HH and DH cooking techniques produced intermediate tenderness scores (67 - 79). Tenderness scores were highest (85) for samples cooked by the DL technique. The results were similar for juiciness scores with the double grill technique producing the juiciest steaks (72) regardless of the cooking temperature. Overall, cooking with the double grill produced more tender and juicy steaks than cooking on the hot plate.

For the hot plate and double grill, the effect of cooking at high and low temperatures on tenderness scores differed. The lower temperature cook using the double grill produced more tender steaks (85) than cooking at the higher temperature (79). However, this trend was reversed when samples were cooked on the hot plate (low temperature = 67, high temperature = 72).

Juiciness scores followed a similar trend to tenderness scores, except for the high and low temperatures used with the double grill producing steaks of similar juiciness (73 and 71, respectively). Juiciness scores also tended to correspond with percent cooking loss, although greater differences in juiciness scores were apparent compared with cooking loss values. The correlation between juiciness scores and percent cooking loss was -0.41. A -0.35 correlation existed between tenderness scores and percent cooking loss. The correlation between tenderness and juiciness scores was 0.56.

4.4 Discussion

In the current study differences between the cooking techniques in tenderness and juiciness were apparent. Toumy and Lechnir (1964) summarised that during cooking, meat first becomes tougher due to changes in the muscle proteins, then after long periods of heating, it becomes more tender because of the transformation of collagen to gelatin. Shorthose (1991) stated, however, that when steaks were cooked (by dry heat) methods, there was insufficient time for any connective tissue softening and so only myofibrillar toughening would occur.

The W cooking technique resulted in the lowest tenderness and juiciness scores and greatest cooking loss. It was likely that the cooking time for the waterbath samples meant steaks were not in a collagen softening temperature range long enough to allow any conversion of collagen to gelatin. Instead, the cook time increased the amount of myofibrillar toughening which resulted in greater toughness and dryness. This result also indicated that sensory evaluations made on meat cooked by the waterbath technique would be underestimated compared with when meat is cooked by other more conventional techniques to the same degree of doneness.

Using the observation of Shorthose (1991), the longer the cooking time, the tougher the steaks would be expected to get (if it can be applied across different temperatures). However, this theory did not apply consistently in this study because the longest cook time was DL and these steaks received the highest tenderness, and equal highest juiciness scores. The scores for the HL steaks were lower than scores for both DH and HH, and HL steaks had the longest cook time of these three treatments, which agrees with the observation of Shorthose.

The double grill resulted in higher tenderness and juiciness scores than the hot plate or waterbath. Berry and Leddy (1990) reported charbroiled steaks were more tender, juicy and had lower shear values and cooking loss than steaks cooked using an electric broiler. However, the charbroiled steaks were also reported to be less well done than the broiled steaks and this was likely to have contributed to the differences in tenderness and juiciness between cooking methods reported. Berry and Bidner (1995) reported that slower, low temperature broiling and rapid high temperature broiler grilling did not enhance palatability of steaks as much as a more intermediate time and temperature grilling system.

Samples cooked using the hot plate showed the opposite trend to those cooked in the double grill. The HL steaks were scored tougher and drier than HH steaks. Laakkonen *et al.*

(1970a) suggested that a more severe surface browning may impede subsequent heat penetration, probably due to a severely coagulated surface layer. Such an effect may have given rise to the interaction observed between the cooking methods and temperatures.

Reports of low temperature cooking resulting in more tender meat have generally been from samples which were roasted or cooked in moisture for long periods such as one to six or more hours. Such extended cooking times allows sufficient time for collagen transformation to gelatin and tenderness to increase. However, it is unlikely that the cook times (seven to 12 minutes) used in this experiment were long enough for sufficient collagen transformation resulting in increased tenderness.

Although it was attempted to cook steaks to the same finish using the different treatments, there was likely to have been small differences in the internal temperatures of steaks. To correct for differences in degree of doneness which may have existed between cooking treatments, colour values were recorded and included in analyses. However, tenderness and juiciness were not influenced by degree of doneness as measured by Minolta colour values, because these three (L*, a*, b*) covariates were not significant in either analyses.

The interaction between cooking method and temperature on tenderness scores may simply be a reflection of different stages of myofibrillar and collagen shrinkage and protein denaturation occurring in the steak. The interaction observed in this study also indicates that both cooking method and temperature (hence, cook time also) affect the changes which occur within meat during the heating process. These effects are not yet understood and require further investigation.

Juiciness scores showed a similar trend to tenderness scores and were inversely related to percent cooking loss. Steaks cooked using the double grill received the highest juiciness scores and had the lowest cooking loss. It is not known why this occurred, but cooking using the double grill somehow allowed the steaks to retain moisture compared to the other cooking techniques.

The strong correlation between tenderness and juiciness scores (r=0.56) would suggest tenderness and juiciness were affected similarly by cooking treatment, tasters were not scoring tenderness and juiciness separately, or were influenced by the 'halo' effect suggested by Shorthose and Harris (1990). Romans *et al.* (1994) stated that the expression of juice from the myofibrillar proteins of meat has been attributed to the shrinkage of both myofibrillar and

connective tissue structures. It is not possible to determine whether the correlation was attributable to tasters and/or similarity in meat attributes *per se*.

4.5 Conclusion

Results from this study show that when meat was cooked to an internal temperature of 70°C using a waterbath, it received lower tenderness and juiciness scores. When samples were cooked using the waterbath, tenderness and juiciness were underestimated compared with meat cooked using either grilling or on a hot plate. Tenderness and juiciness did not increase when longer time, lower temperature cooking treatments were used for the cooking of steaks. The study highlighted that both cooking method and temperature (and consequently, cooking time) affect the eating quality of steaks in a manner which is complex and not yet understood.