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Eating quality of commercial meat cuts from Australian lambs and sheep

D.W. PETHICK[1], A.B. PLEASANTS[2], A.M. GEE[3], D.L. HOPKINS[4] AND I.R. ROSS[5]

[1]School of Veterinary and Biomedical Sciences, Murdoch University, South Street, Murdoch, WA 6150, Australia

ABSTRACT

Untrained consumer taste panels in Australia judged meat for tenderness, juiciness, flavour and overall liking and rated each sample for acceptability for a range of commercial cuts. Meat from lambs and yearlings had better ($P < 0.01$) eating quality (overall liking 65.5 ± 0.40) than mutton (overall liking 45.6 ± 0.40). There were significant ($P < 0.05$) differences in eating quality between cuts, with topside being least favoured (overall liking 49.7 ± 1.48) and rack being most favoured (overall liking 82.1 ± 1.48) for roasting. It was found that 3 classifications described the acceptability of sheep meat to consumers The best discriminator of this consumer score was the overall liking score, which in turn was most affected by the flavour. An overall liking score below 45.5 indicated meat of unsatisfactory eating quality, and a score above 71 indicated meat of excellent eating quality. Individual consumer perceptions of eating quality are variable. Using the frequency distributions of overall liking score and the relationship of this score to consumer perceptions the expected frequency of unsatisfactory eating quality could be defined. This measure can be used to grade sheep meat in terms of consumer experience of eating quality.

Keywords: sheep meat; eating quality; failure rate

INTRODUCTION

The Australian sheep industry has recently undertaken a large project to understand and improve the eating quality of sheep meat (including lamb, hogget and mutton). This work, coordinated by Meat and Livestock Australia (MLA), involved a cooperative effort between farmers, meat processors and scientists to use a large number of untrained consumers to measure the eating quality for a range of muscle types, processing methods, and nutritional effects. The information gathered in this study has been collated and published in a special issue of the Australian Journal of Experimental Agriculture (Pethick *et al.* 2005; Young *et al.,* 2005).

Untrained consumer judgement of eating quality is very variable and dependent upon a number of complex factors and interactions that currently defy description. Thus any quantitative model of sheep meat eating quality needs to be probabilistic. That is, an appropriate model needs to describe the frequencies with which meat of a certain classification will be accepted by consumers. Thus, the inherent variation in the product is made transparent and described in a way that assists quality assurance and product improvement.

A probabilistic description was provided by Thompson *et al*., (2005b) and Pleasants *et al*., (2005) using arguments based on conditional probabilities derived from a large consumer survey. Using this analysis a classification of sheep meat eating quality based on the frequency of failure was constructed, where failure is defined as a consumer being provided with meat that was described as unsatisfactory.

The initial study of sheep meat eating quality described by Pethick *et al.* 2005 had 2 disadvantages. It measured eating quality on individual muscles, and it was confined to a relatively narrow range of desirability. The results reported in this paper rectifies these disadvantages by measuring eating quality for commercial meat cuts and by using a wider range of desirability to the consumer.

MATERIALS AND METHODS

Animals and slaughter

Three animal groups were purchased for this experiment with 56 per group (total 168 animals). The lambs were second cross (Poll Dorset sire x Merino x Border Leicester dam) of mixed sex (female or male castrate) and all had no erupted permanent incisor teeth; the yearling animals were male castrate Merinos and had either 2 or 4 permanent incisor teeth; the mutton animals were non pregnant Merino ewes and had either 8 permanent incisor teeth or ‘broken mouths’. Each group of animals was purchased from a different commercial property and assembled onto a

[2] AgResearch Ruakura, Private Bag 3123, Hamilton, New Zealand
[3] Cosign Pty. Ltd., 20 Eleventh Avenue, Sawtell, NSW 2452, Australia.
[4] NSW Department of Primary Industries, Centre for Sheep Meat Development, PO Box 129, Cowra, NSW 2794, Australia
[5] Meat and Livestock Australia, PO Box 5622, Manama, Bahrain

common paddock (near Murray Bridge, South Australia) of dry cereal stubble with access to a barley/lupin grain mix (70:30) from a self feeder. After 3 weeks of common grazing the sheep were placed in yards with access to water but not feed. On the following day the animals were transported to a commercial abattoir. Slaughter involved electrical head stunning followed by exangusation. Each carcase received electrical stimulation post dressing for 25 seconds at 24 minutes post stunning (Shaw *et al.,* 2005). The electrical stimulation system consisted of rubbing electrodes (shoulder to rump) that delivered a constant current with a peak maximum of 300 volts at 15 hertz (RealCold Milmech, Brisbane, Australia). pH measurements were taken hourly beginning at 1 hour post stunning for 4 hours with ultimate muscle pH recoded at 72 hours (Pethick *et al.,* 2005).

Experimental design, Commercial cuts and consumer evaluation

Carcases were fabricated into 13 commercial roast cuts (topside, oyster cut, round, easy carve back leg, forequarter with and without fat, forequarter boned and rolled, back leg bone in, rump with and without cap, shortloin, rack with and without cap). Each cut had 12 replications. After preparation the cuts were vacuum packed, aged for 9 days at 2˚C and then frozen (Gee *et al*., 2006). Each cut was roasted in an oven using a temperature set at between 175ºC and 180ºC. After cooking the meat was served to consumers as single 4mm thick slices cut across the grain.

Cuts were tested using untrained consumers which were assembled in Sydney venues such as sporting clubs. The general consumer methodology is described by Thompson *et al.,* 2005b and Thompson *et al.,* 2005c with a more detailed description of this experiment by Gee *et al*, 2006. Each consumer tested (blind) 6 experimental samples (slices of a commercial cut) after first eating a starter sample such that each commercial cut replication was assessed 10 times by an untrained consumer. In total 1,920 consumers were used in this study. Each consumer rated the meat from 0-100 (0 bad, 100 excellent) for liking of smell, liking of flavour, the degree of tenderness, juiciness and overall liking and then gave the meat sample a single rating being one of awful, unsatisfactory, good every day, better than every day or premium.

Statistical methods

Overall Liking was analysed in terms of animal category (lambs, yearlings, Mutton) by cut within cooking method.

The residual frequency distribution for the variable Overall Liking was not Gaussian. An expression for this distribution was found by using the Gaussian distribution as a basis and expanding a series of Hermite polynomials to fit the distribution Buckland (1992).

RESULTS

The carcase weight and GR tissue depth (mean±sem) were 19.9±0.19kg and 13.2±0.47mm; 20.6±0.28kg and 9.8±0.45mm; 20.0±0.30kg and 3.8±0.38mm for lambs, yearling, and mutton sheep, respectively with each group of animals significantly differing in fatness ($P<0.0001$) from the other two groups.

The rate of pH decline was slow while the temperature fall was fast such that at 5 hours post slaughter the pH and temperature of the *m. longissimus lumborum* 6.45±0.01 and 7.5±0.13˚C respectively. The ultimate pH was 5.70±0.02, 5.81±0.03 and 5.85±0.03 for the lambs, yearling and mutton respectively with lambs significantly lower ($P<0.002$) than the other groups.

Consumers detected no significant difference between the eating quality measured by overall liking of meat from lambs or yearlings, but found lambs and yearlings to have meat of significantly ($P < 0.01$) better eating quality than Mutton. The least squares means for Overall Liking of meat for lambs and yearlings was 65.5 ± 0.40 compared to 45.6 ± 0.40 for Mutton.

The average Overall Liking score for cuts cooked by roasting is shown in Table 1. There appear cuts in distinct, significantly different ($P < 0.05$), categories of eating quality. Topside and oyster cut produce poor eating quality when roasted, while rump, shortloin and rack produce the highest eating quality when roasted

Consumer Overall Liking of all meat cuts was strongly related to the flavour of the meat, and to a lesser extent the tenderness and juiciness of the meat. The smell was confounded with flavour in the consumers' perception. For lambs and yearlings the regression across all cuts (n = 8139) is:

$$\text{Overall Liking} = -1.04\pm0.30 + 0.19\pm0.01\text{tender} + 0.09\pm0.01\text{juicy} + 0.74\pm0.01\text{flavour}$$

with residual standard deviation 8.3

For Mutton across all cuts (n = 4083) the regression is:

$$\text{Overall Liking} = -1.25\pm0.35 + 0.27\pm0.01\text{tender} + 0.05\pm0.01\text{juicy} + 0.68\pm0.01\text{flavour}$$

with residual standard deviation 9.9

The Overall Liking of mutton was more dependent on the level of tenderness and less dependent on the juiciness than lamb or hogget.

TABLE 1: The least squares means and standard errors for the sensory variables of the commercial cuts cooked by roasting for meat from lambs yearlings and Mutton.

Cuts	Smell	Tender	Juicy	Flavour	Overall Liking
			Lambs and Yearlings		
Topside	55.1^{1}	48.5^{1}	44.0^{1}	53.0^{1}	49.7^{1}
Oyster cut	57.7$^{1\,2}$	58.1^{2}	51.5^{2}	56.2^{12}	55.4^{2}
Round	61.1$^{2\,3}$	56.1^{2}	48.4^{2}	56.4^{12}	55.9$^{2\,3}$
Easy carve leg	57.9^{12}	60.8^{23}	52.4^{2}	59.6^{2}	59.1$^{2\,3}$
Forequarter without fat	63.8^{3}	60.9^{23}	55.2^{23}	59.2^{2}	59.3$^{2\,3}$
Forequarter boned rolled	58.7^{2}	60.1^{23}	59.9^{3}	58.7^{2}	59.6^{3}
Forequarter roast	63.3^{3}	64.4^{3}	59.2^{3}	60.1^{2}	60.3^{3}
Leg bone in	61.2^{23}	62.5^{3}	54.4^{23}	63.6^{3}	63.6^{3}
Rump without cap	60.8^{23}	69.2^{4}	61.7$^{3\,4}$	65.7^{3}	66.7^{4}
Rump with cap	65.8^{4}	72.8^{4}	65.4$^{4\,5}$	70.5^{4}	71.5^{5}
Shortloin roast	66.5^{4}	77.2^{4}	68.2^{5}	69.9^{4}	71.7^{5}
Rack roast with cap	66.0^{4}	82.5^{5}	73.8^{6}	75.2^{5}	77.3^{5}
Rack roast denuded	72.0^{5}	83.6^{5}	74.7^{6}	80.7^{5}	82.1^{6}
SEM	±1.34	±1.44	±1.55	±1.50	±1.48
			Mutton		
Topside	46.8^{1}	28.8^{1}	26.9^{1}	34.4^{1}	31.6^{1}
Oyster cut	44.8^{1}	31.8^{12}	35.5^{23}	28.1^{1}	28.3^{1}
Round	55.9^{12}	39.6^{34}	40.5^{3}	46.8^{2}	45.2^{2}
Easy carve leg	50.6^{1}	36.1^{34}	33.9^{2}	42.2^{23}	37.8^{2}
Forequarter without fat	53.6^{2}	34.1^{123}	34.2^{2}	41.1^{2}	39.1^{2}
Forequarter boned rolled	54.7^{23}	37.6^{234}	38.1^{2}	43.1^{23}	40.1^{2}
Forequarter roast	50.6^{1}	35.3^{234}	38.4^{2}	40.2^{2}	40.1^{2}
Leg bone in	56.3^{23}	40.7^{4}	35.3^{2}	47.4^{34}	45.6$^{2\,3}$
Rump without cap	60.4^{34}	46.7^{4}	40.1^{3}	53.8^{5}	49.1^{3}
Rump with cap	54.4^{2}	34.3^{12}	35.3^{23}	44.6^{23}	40.7^{2}
Shortloin roast	61.0^{4}	53.7^{5}	52.7^{4}	51.6^{45}	51.2^{3}
Rack roast with cap	62.4^{4}	58.1^{5}	55.9^{4}	57.7^{5}	55.8^{3}
Rack roast denuded	59.2^{2}	50.0^{45}	52.0^{4}	53.0^{45}	51.1^{3}
SEM	±2.06	±2.24	±2.21	±2.29	±2.27

Cuts with different superscript numbers within age category and sensory variable are significantly different ($P < 0.05$)

The variables tender, juicy and flavour may be manipulated through animal husbandry, processing or storage. Thus, the average eating quality for each cut, given as Overall Liking, and presented in Table 2 may be manipulated to some extent through practices in the supply chain e.g. tender stretch

TABLE 2: Logit regression coefficients for classification into 3 consumer eating quality categories (CEC) by Overall Liking score. These are used to calculate the probabilities given by equation (3) in the text.

Animal category	CEC	Intercept (a)	Slope (Overall Liking) (b)
Lamb	1	14.284 ± 0.645***	-0.252 ± 0.011***
	2	9.117 ± 0.502***	-0.123 ± 0.007***
Ewe	1	13.529 ± 0.683***	-0.222 ± 0.011***
	2	8.113 ± 0.616***	-0.104 ± 0.008***

*** $P < 0.001$

The residual (following fitting of the cut type) frequency distribution of Overall Liking was significantly ($P < 0.001$) different from Gaussian, with a frequency more concentrated about the mean and with fat tails (leptokurtic). Figure 1, while not the residual distribution because it includes variation between cuts, illustrates the general form of this distribution. Generally, any cut had a small proportion of samples having very low Overall Liking, and these tend to lower the average. Thus, the mode (the most likely value of Overall Liking for the cut) is slightly higher than the mean. An expression for this frequency distribution of the standardised value of Overall Liking (subtract mean and divide by the standard deviation) is given by:

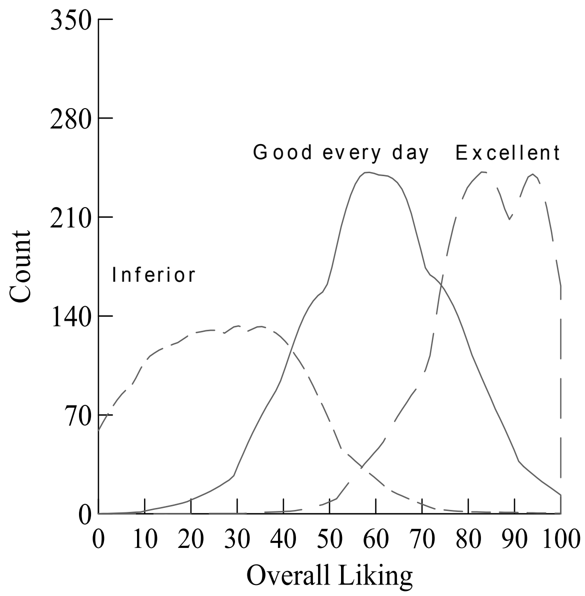
$$P\,[OL] = \frac{e^{-\frac{OL^2}{2}}}{2.1734}\left[1 - 0.04(OL)^4 - 0.15(OL)^3 + 0.23(OL)^2 + 0.44(OL) - 0.12\right] \quad (1)$$

where *OL* is Overall Liking.

This frequency distribution is important for calculating the expected failure rates for a particular meat cut.

Consumers measured the eating quality of sheep meat on a 5 point scale. However, a 3 point scale (the consumer evaluation categories: CEC) formed by combining scale 1 with scale 2 and combining scale 4 with scale 5 was found to be more useful. The frequency distributions for Overall Liking score on each of these 3 consumer evaluation scales is shown in Figure 1. There is a considerable amount of overlap in the Overall Liking of the meat allocated by consumers to the 3 different consumer evaluation scores. This overlap is a measure of the inherent variation of consumer perception of meat quality. It is this inherent variation that we seek to represent through the estimate of failure rate.

FIGURE 1: Smoothed Frequency distributions for Overall Liking in roasted products for each of the 3 consumer evaluation (CEC) scores (Inferior, Good every day, Excellent)



A logit analysis was used to relate Overall Liking to the 3 consumer evaluation categories (CEC). The logit regression coefficients are shown in Table 2. Using these estimates the probability of a meat cut with a nominated Overall Liking score (OL) can be calculated for each of the 3 consumer evaluation scores through the relationships:

$$P_{CEC}[CEC = 3 | OL] = \frac{1}{1 + \exp(a_1 + b_1\, OL) + \exp(a_2 + b_2\, OL)}$$
$$P_{CEC}[CEC = 2 | OL] = \exp(a_2 + b_2\, OL)\, P_{CEC}[CEC = 3 | OL] \qquad (2)$$
$$P_{CEC}[CEC = 1 | OL = \exp(a_1 + b_1\, OL)\, P_{CEC}[CEC = 3 | OL]$$

Where a_i is the intercept and b_i is the slope for the i^{th} consumer evaluation category in Table 2.

For example, a piece of sheep meat with an Overall Liking score of 50 would be rated as poor eating quality (CEC = 1) with probability 0.23, good every day eating quality (CEC = 2) with probability 0.73, and excellent eating quality (CEC = 1) with probability 0.04.

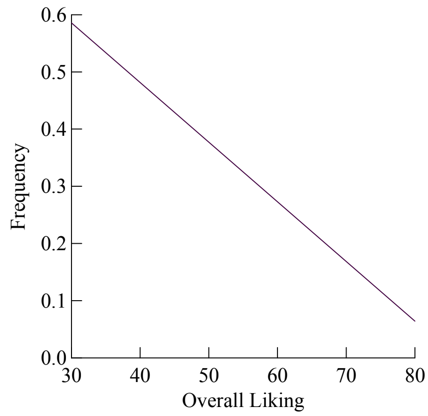
From this basis it is possible to calculate the probability that a given cut with an average Overall Liking given in Table 1 will fall within any of the consumer evaluation scores illustrated in Figure 1. The calculation of this probability must also take into account the relative frequency of Overall Liking for a given cut which would depend on the class of animal, the cooking method and pre- and post – slaughter treatment. This information defines the mean and the probability distribution of Overall Liking for the nominated meat cut, $P_{OL}[OL]$. Note that $P_{OL}[OL]$ has the form given in equation (1)

However, the perception of eating quality for the meat over the population of consumers also depends on the variable response of an individual consumer to a specific score of Overall Liking. Thus, the probability that a consumer will find a cut with a particular Overall Liking score unacceptable (CEC = 1) is the sum over Overall Liking of the probability that a cut with such characteristics will have a given Overall Liking ($P_{OL}[OL]$ above) multiplied by the probability that this Overall Liking score will result in consumer dissatisfaction $P_{CEC}[CEC|OL]$. From this the marginal distribution for the CEC is:

$$P[CEC = x] = \int P_{CEC}[CEC|OL]\, P_{OL}[OL]\, d[OL]$$

Figure 2 shows the results of this calculation for a range of Overall Liking scores for lamb cooked by grilling.

FIGURE 2: Graph of Overall Liking for a range of lamb cuts cooked by roasting *v* the frequency that a consumer will deem this cut poor eating quality.



From this graph, if this meat has an Overall Liking of more than 56 then the probability that this meat will have poor eating quality is 0.005 or 0.5%. That is, in the target population only 1 consumer in 200 would find the meal unsatisfactory. Similarly Figure 2 shows that if the meat has an Overall Liking of more than 42, then the probability that this meat will have poor eating quality is 10%

DISCUSSION

The value of the results reported here is in the exceptionally large number of consumer responses that were measured and in the care that was taken to standardise the methods of cooking and presentation of the meat for sampling. While the study provides information on the average consumer response to the eating quality for a range of commercial cuts, just as importantly the scope of the study gives good estimates of the variation (estimated by the standard errors) inherent in the consumer population for this measure.

A reliable system of classification of sheep meat eating quality is valuable to the industry in a number of ways. It indicates to the consumer (and those interacting directly with the consumer, e.g. retailers, restaurants) the eating quality of the meat. It also contributes to the development of quality assurance schemes along the sheep meat supply chain by having an objective measure of eating quality whose variation can be attributed to various elements of the supply chain.

Currently this variation, resulting as much from different consumer perceptions and preferences as from differences in rearing and processing, is included by calculating the expected failure rate of the meat cut based on estimates of the relevant frequency distributions. The failure rate is given by CEC = 3. A low frequency of failure can be achieved by choosing meat from cuts with an Overall Liking that is sufficiently high.

The frequency of failure adopted as the basic measurement of sheep meat eating quality has several advantages. It retains the concept of variation and uncertainty fundamental to consumer perceptions. While no meat cut can be guaranteed desirable (probability = 1.0) the probability of being undesirable can be reduced to known minimal levels by adopting strategies based on animal nutrition, meat processing and cut type.

While the estimated failure rate might be higher than many would like, this represents the fundamental fact that different consumers perceive eating quality differently and because of the large variability of this attribute there may be a significant cohort of consumers that will devalue the product. The way forward is not to ignore this phenomenon but to acknowledge and apply an understanding of this variability to improve sheep meat as a more desirable product.

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REFERENCES

Buckland, S.T. 1992. Fitting density functions with polynomials. *Applied Statistics 41:* (1) 63 -76.

Gee, A.L., Ross, I.R., Pethick, D.W., Hopkins, D.L., Knight, B. and Slack-Smith, T. 2006. Protocols for the preparation, fabrication, assembly, cooking, serving, sensory testing and scoring of commercial meat cuts from lamb, yearling and mutton. Final report, Meat & Livestock Australia, North Sydney, Australia.

Pethick, D.W., D'Souza, D.N., Anderson, C.A., Muir, L.L. 2005: Eating quality of Australian lamb and sheep meats. *Australian Journal of Experimental Agriculture 45*: 465-601

Pleasants, A.B., Thompson, J.M., Pethick, D.W. 2005: A model relating a function of tenderness, juiciness, flavour and overall liking to the eating quality of sheep meat. *Australian Journal of Experimental Agriculture 45*: 483 – 489.

Shaw, F.D., S. R. Baud, I. Richards, D. W. Pethick, P. J. Walker, J. M. Thompson 2005: New electrical stimulation technologies for sheep carcasses. *Australian Journal of Experimenhtal Agriculture 45:* 575 – 583.

Thompson, J.M., Hopkins, D.L., D'Souza, D.N., Walker, P.J., Baud, S. and Pethick, D.W. 2005a: Sheep meat eating quality: The impact of processing on sensory and objective measurements of sheep meat eating quality. *Australia Journal of Experimental Agriculture 45*: 561 - 573

Thompson, J.M., Pleasants, A.B., Pethick, D.W. 2005b: The effect of design and demographic factors on consumer sensory scores. *Australian Journal of Experimental Agriculture 45*: 477 – 482

Thompson, J.M., A. Gee, D. L. Hopkins, D. W. Pethick, S. R. Baud, W. J. O'Halloran 2005c: Sheep meat eating quality: development of sensory protocol for testing palatability of sheep meats. *Australian Journal of Agricultural Research 45:* 469-476.

Young, O.A., Hopkins, D.L. and Pethick, D.W. 2005: Critical control points for meat quality in the Australian sheep meat supply chain. . *Australian Journal of Agricultural Research 45:* 593 – 601.