Accelerated processing sheep meat

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Comparison of the G2 Tenderometer and the Lloyd Texture Analyser

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1. Background

A number of different machines have been used to test aspects of meat tenderness, but the best known is that based on the Warner-Bratzler shear (Bourne, 2002). The stainless-steel blade of the device comes in various configurations and the application of the blade to the sample can be in either a tension mode (cutting up through the sample) or in a compression mode (cutting down through the sample). The configuration of the latter blade is shown below.

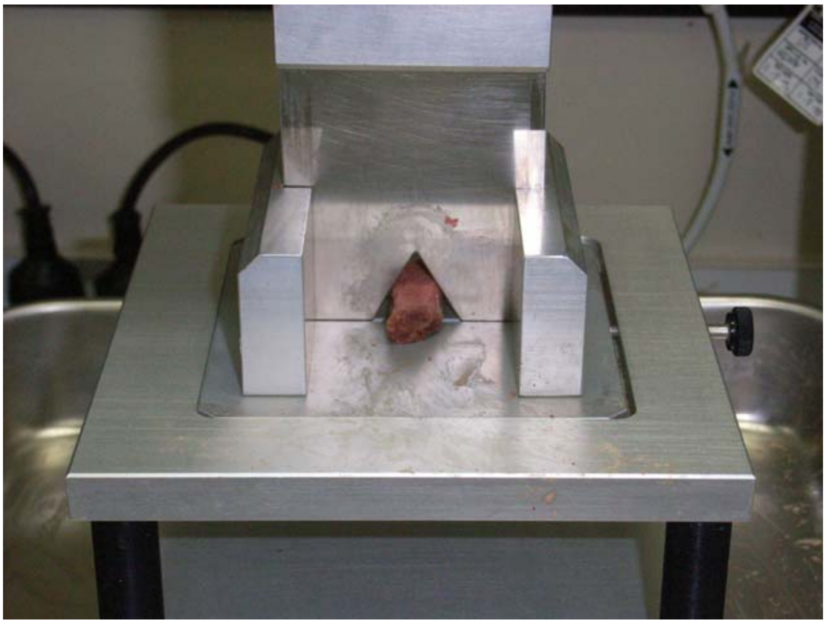

Figure 1. Warner Bratzler blade fitted to a Lloyd Texture analyser.

An alternative machine (tenderometer) was developed by MIRINZ in New Zealand (MacFarlane & Marer, 1966) which uses a blunt ‘tooth’ to shear through the sample. The relationship between the data obtained from the tenderometer and a machine using a Warner-Bratzler (WB) was first established by Graafhuis et al. (1991). This showed that the data were linearly related by the following model;

WB Shear force (kgf) = 0.63 x Tenderometer (kgf) + 0.61

This makes WB values 64% of tenderometer values and a number of studies in New Zealand have based their assessment of shear force on the tenderometer (eg Rosenvold et al. 2009). Recently a new version of the tenderometer has been developed called the G2 with the intent of providing industry with a cheaper machine for testing shear force than machines that use a WB device such as the Lloyd Texture analyser. These former machines enable other tests such as compression to be conducted, whereas the G2 is a single use machine. To facilitate the commercial application of the G2 two comparison studies were undertaken against a Lloyd Texture analyser using a WB shear. The cutting blade of the G2 is shown (Fig. 2).

Figure 2. Cutting blade of the G2 tenderometer.

2. Materials and Methods

2.1 Samples and measurements – experiment 1

The lumbar section of the m. *longissimus lumborum* (LL) was taken from 26 sheep carcases and portioned into cranial and caudal samples with an average weight of 73 grams. Details of the processing of the carcases were outlined elsewhere (Hopkins et al. 2007), but they were aged for 5 days post-slaughter.

Samples were cooked from frozen in plastic bags at 70°C for 35 min in a water bath, removed and cooled under running water and stored chilled until testing. The samples were allocated in a balanced design to cooking batches (1 or 2) and treatment (WB or Tenderometer). Samples with a cross-sectional area of 1 cm^2 were prepared for testing by either machine, by cutting strips along the grain of the muscle, with 6 replicates tested per sample.

2.2 Samples and measurements – experiment 2

The lumbar section of the m. *longissimus lumborum* (LL) was taken from 48 sheep carcases which had been hot boned and portioned into cranial and caudal samples with an average weight of 64 grams. Half the samples (n = 48) were frozen at day 0 and the other half aged for 5 days. The samples were allocated to cooking batch (1 to 6) and treatment (Lloyd or Tenderometer) across ageing days. Cooking and measurement procedures were the same as for experiment 1.

3. Results

3.1 Statistical analysis and results – experiment 1

Linear mixed models using restricted maximum likelihood (REML) with the statistical package ASReml (Gilmour et al. 2006) were used to analyse the data. The model fitted was;

Shear force (Newtons) = Mean + Cooking Batch + Portion + Treatment + ***Individual + Error***

Individual and *error* were fitted as uncorrelated random effects.

The results of the ANOVA are shown in Table 1 along with the coefficients.

Table 1. Results of the analysis for experiment 1.

Fixed effect	Probability	Coefficients	Standard error	Z ratio
Batch 1	0.68			
Batch 2		-1.16	2.77	-0.42
Portion – Caudal	0.70			
Portion - Cranial		0.43	0.81	0.53
Treatment – Lloyd	0.79			
Treatment - Tenderometer		0.22	0.81	0.27

The variance components (not shown) indicate that the variation across individual carcases is much larger than the variation within carcases. There were no significant effects ($P > 0.05$) due to batch, portion or treatment and the tenderometer gave values 0.22 Newtons (± 0.81) larger than the Lloyd.

3.2 Statistical analysis and results – experiment 2

Data for experiments 1 and 2 was combined for analysis and the following model was fitted;

Shear force (log: Newtons) = Mean + Experiment + at(Expt,1):Treatment + at(Expt,2):(Age + Treatment + Age x Treatment) ***+ Expt:Cooking Batch + Individual + Individual:Portion + error***

Here terms in bold/italic were fitted as independent random effects and the ***error*** term corresponds to residuals within each sample (i.e subsamples with samples). The error variances were originally allowed to differ for samples within each Age × Treatment combination. The fixed effects part of the model allows for differences across experiments, differences across treatments (machines) within experiment 1 and for differences across age × treatment combinations within experiment 2.

The error variances within the same treatment in experiment 2 were not significantly different ($P > 0.05$), but did differ significantly ($P < 0.05$) between treatments (machines). There was no significant ($P > 0.05$) interaction between treatment and age within experiment 2. There was a significant difference ($P < 0.001$) between experiments for shear force as shown in Figure 3. The trellis plot presents box-plots of the mean log (shear force: SF) for each age × treatment, where the mean is the average over the six sub-samples within each sample.

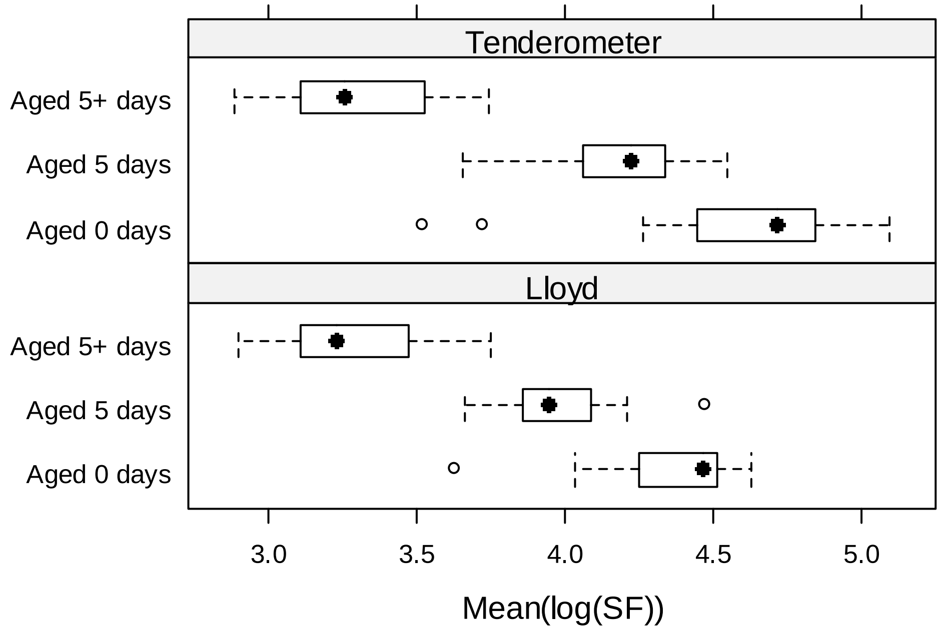

Figure 3. Trellis plot showing the mean and range of shear force results on the log scale for each treatment according to days aged. Aged 5+ refers to experiment 1 and aged 0 and 5 to experiment 2.

From the above summary we observe, for each experiment, more variation within subsamples in same sample for testing using the Tenderometer than when using the Lloyd. There is also more variation for tests performed in experiment 1 than in experiment 2. A test of repeatability within samples for each machine in experiment 2 revealed a coefficient of variation of 11.8 and 12.3 % respectively for the Lloyd and Tenderometer machines.

There was a significant effect ($P < 0.001$) of ageing within experiment 2 and a significant effect of treatment ($P < 0.001$). The coefficient for treatment was 0.225 ± 0.040 on the log scale such that an average Tenderometer shear force result, on the log scale, is estimated to be 0.22 units higher (in absolute terms) than the corresponding result than using the Lloyd machine. On the original scale, average Tenderometer shear force results are therefore estimated to be exp (0.22) = 1.25 times those for Lloyd.

A summary of the predicted means for shear force on the original scale is given in Table 2. This shows clearly that the Tenderometer measures higher values than the Lloyd.

Table 2. Results of the analysis for experiments 1 and 2.

Fixed effects	Machine	Mean	Std. Error	LSD Rank
Experiment 1	Lloyd	28.2	1.43	a
	Tenderometer	28.4	1.43	a
Experiment 2 (0 days aged)	Lloyd	80.8	3.69	d
	Tenderometer	101.3	4.64	e
Experiment 2 (5 days aged)	Lloyd	56.2	2.56	b
	Tenderometer	70.4	3.22	c

A comparison of data obtained on the same animal was also undertaken. In Figure 4 is a plot of average results for the Lloyd vs. Tenderometer, were the points correspond to pairs of results from the same animal. Points plotted as black are from experiment1, those in red from experiment 2. Data in Figure 4 is on the original scale whilst in Figure 5 the data is on the log transformed scale (i.e. log of the averages, not averages of the logs).

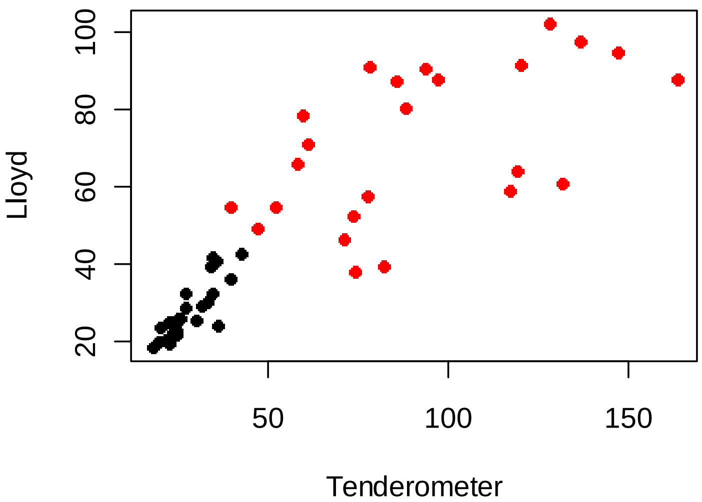

Figure 4. Plot of data points for Lloyd results vs. Tenderometer original scale

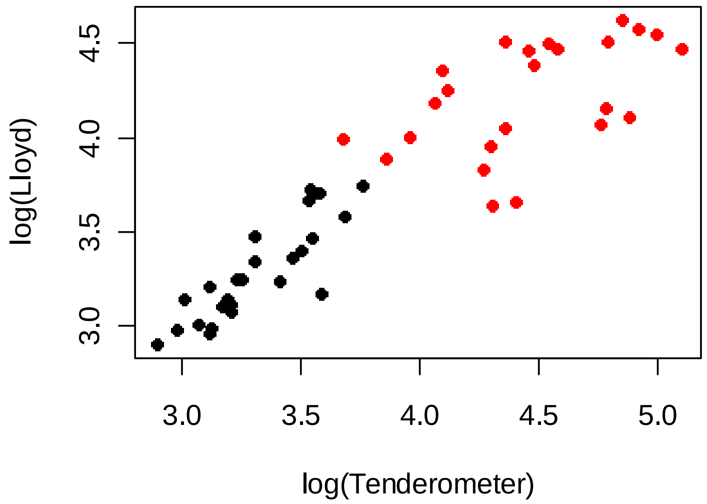

Figure 5. Plot of data points for Lloyd results vs. Tenderometer log scale

Based on the **assumption** that animals selected across the two experiments are a random sample of animals and that animal effects and the random effects within animals are normally distributed (on the log scale), then the above log-transformed results can be fitted using a bi-variate normal model. The mean shear force from this analysis for the Lloyd is 3.74 ± 0.76 and 3.86 ± 0.92 for the Tenderometer.

From this we can obtain the distribution of log (average Lloyd) **given** log (average Tenderometer). A (bias adjusted) back transformation can then be used to estimate the mean and standard deviation of average Lloyd shear force **given** average Tenderometer shear force on the same animal. This allows a plot of the expected value for the Lloyd given a value for the Tenderometer (solid line) and the range ± one standard deviation around that line (dashed lines) (Figure 6).

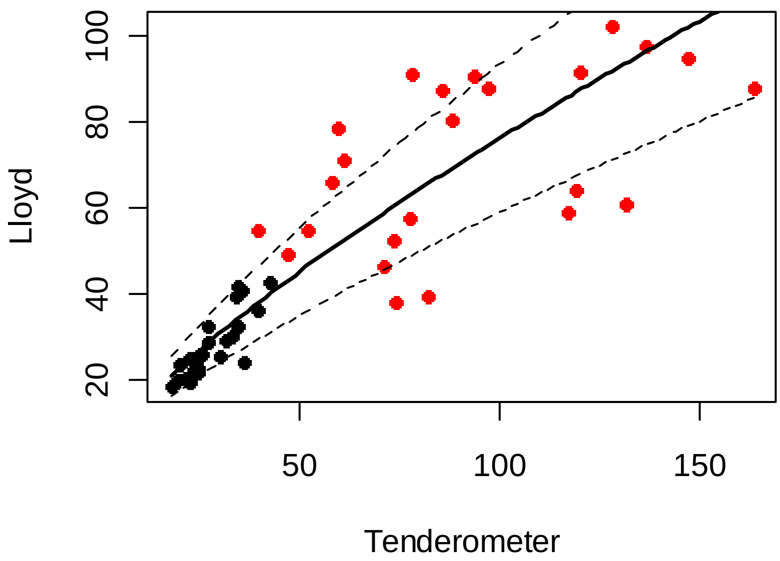

Figure 6. Plot of data points for Lloyd results vs. Tenderometer original scale and the expected value for the Lloyd given a value for the Tenderometer (solid line) with the standard deviation shown as the dashed line.

As can be seen from the above plot that there is a large variation associated with Lloyd results given a Tenderometer result. Part of this variation arises because the results are being predicted on the same animal, not the same cut. Tighter bounds may be realised if results were for the same cut.

4. Discussion

Several important observations emerge from the two experiments. Firstly it is apparent that for tender meat (experiment 1) there is no difference between machines for the measurement of shear force. However when tougher samples are compared the difference between machines appears and it seems that the difference increases as the meat becomes tougher with a 21 Newton difference for 0 day aged samples in experiment 2. This increase in difference between machines is also shown in Figure 6. In experiment 2 the testing of tougher samples lifted the range to what would be expected in beef. There is also more variation between samples measured with the Tenderometer.

Based on the data here the Lloyd produces results 75% of the Tenderometer which is a lower under estimate than found by Graafhuis et al. (1991) using an earlier version. The difference between machines may well be due to the shearing device, with the Lloyd having a sharper blade than the Tenderometer which can be seen by comparing Figures 1 and 2. The Tenderometer has a much blunter shearing blade and it is feasible that when confronted with tough samples this results in the register of higher values. In essence the Tenderometer can be used as a QA tool within a process, but the results will not be comparable with those of a Lloyd which is used extensively in research laboratories.

It should be stressed however that Graafhuis et al. (1991) applied regression to the data in their study and this should strictly be used when the same samples are tested by both machines. The analysis to derive Figure 6 was designed to apply the regression approach, but as stated this is based on specific assumptions. A comparison between machines within a cut would provide another approach to determining the relationship between machines.

5. Conclusions

The G2 tenderometer is a compact device that is suited to use as a QA tool within a processing works. Data on shear force generated by the G2 will not however be comparable to that generated by a Lloyd. A conversion of 0.75 could be applied in those cases where a comparison with Lloyd results was desired.

6. Acknowledgements

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