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Improved objective measures of eating quality

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Abstract

The current G1 Tenderometer is used by research laboratories and as a quality control instrument in many meat processing plants within New Zealand. While it is a reliable and relatively simple unit, its use is limited by several factors: The unit is bulky and relatively heavy (12kg); but perhaps more important are the limitations imposed by for pneumatics to operate the unit. While air compressors are widely available in meat processing plants, the pressure and mains power requirements limit the mobility of the unit and so they tend to be sited as permanent fixtures in laboratories. Furthermore, the peak pressure is displayed via an LED mounted on the front of the Tenderometer and the shear force value has to be manually recorded after each sample measurement.

Each machine, despite standardised manufacturing processes, generates different internal resistances due largely to the unavoidable friction forces that are inherent in pneumatic systems and, therefore, requires at least annual calibration. Furthermore, these effects result in instrument to instrument variability which can be particularly problematic for meat processors that have several instruments for tenderness auditing. The pressure required to shear a meat sample is displayed in Kilo Pascals which then has to be converted to kilograms shear force (kgf). The conversion formula is generated during the calibration procedure. While this conversion is easily achieved using a simple Excel based macro, the final shear force values are not given at the time of sample shearing.

To address these issues, a new Tenderometer, known as the G2, has been constructed as part of the current Meat Quality, Science and Technology programme, funded jointly by Meat & Wool New Zealand and Meat & Livestock Australia.

The key points of the design of this new unit (Diagram 1) are the miniaturisation and mobility of the unit, improved sample loading and automated sample shearing and data downloading. The device is based on an electric motor which pushes the meat against a fixed load cell. The unit does not therefore require compressed air, just a standard power socket to plug into or batteries.

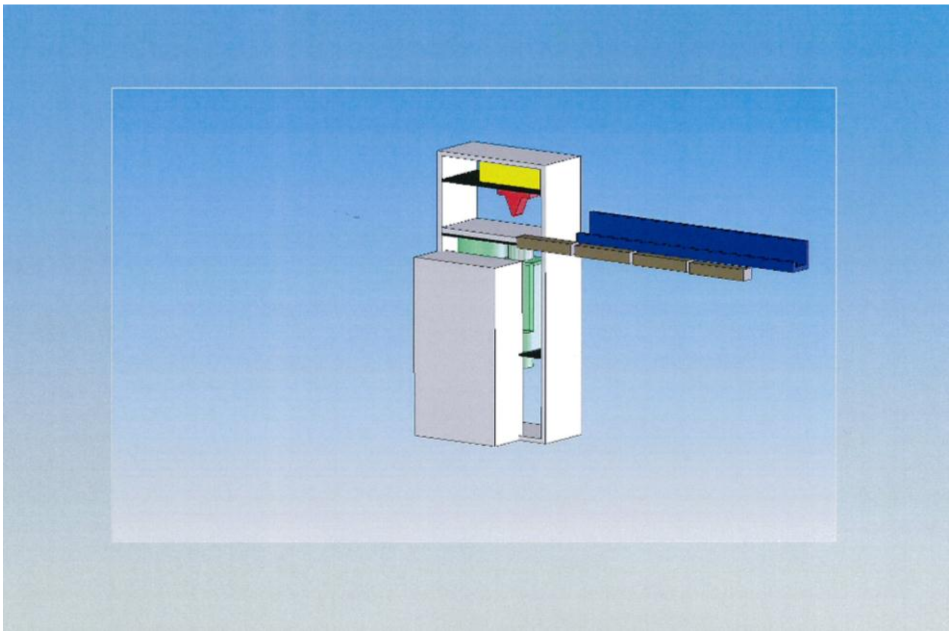


Diagram 1 – Drawing specifications of a new meat stretching commercial prototype machine.

The samples are placed in a line on a tray that presents the samples to the shearing head. The new sample loading and switch sequence allows automatic cycling of the unit; in essence, this means that the 10 sample bites can be loaded into the presentation tray and the unit will then

cycle automatically through the shearing procedures, testing and recording the values from each sample automatically without any further operator intervention. The unit is mains or battery powered and incorporates a digital read-out.

The data can also be downloaded direct to a laptop computer. The unit can be held easily in one hand and weighs just over 2 Kgs. The force required to shear the sample is displayed as Kgf's on an LED sited on the face-plate of the machine and because the load-cell is in a fixed position, this means that it can be removed and replaced without the need for recalibration.

Contents

1 Background

Although tenderness is recognised as the most important textural attribute to consumers, other attributes contribute significantly to the overall acceptability of meat eating quality. These include juiciness, cohesiveness and fibrousness.

It is generally recognised that shear force measurements provide a reasonable approximation of consumer acceptability of tenderness, but that there are many textural attributes that contribute to this ultimate acceptability. Under conditions when the tenderness has reached acceptable levels, these additional considerations begin to dominate, and it is probably under these conditions that the shear force measurement becomes inadequate. The more complete objective measurement of texture would therefore provide a better tool for understanding and describing this attribute.

Our previous work has developed methods of defining the force-deformation curve of meat during compression. Specific components of the force-deformation curve have been correlated with recognised textural attributes as described by a trained taste panel. During 2003-2004, the MIRINZ tenderometer was modified to provide texture analysis. This was principally achieved by replacing the shear blade with a compression head and incorporating a force transducer into the unit. The appropriate software was also modified to enable collection of the force-deformation curve onto a laptop computer.

Having developed suitable strategies for texture measurement, this program will now focus on identifying textural transformations across several muscles following different pre-rigor conditions and chilled storage. The involvement of both proteolytic and denaturation events in defining these textural changes will be quantified for 4 muscles (*m. longissimus dorsi*, *semimembranosus, gluteus medius*, *semi tendinosus*). The final cooked meat texture of these samples will also be measured using the existing texture analyser, the modified MIRINZ Tenderometer and the sensory texture panel. These data will be incorporated into the model that is being generated in PSHIP.150.07b, to enable texture to become part of the meat quality attributes that will ultimately be described and predicted by the CPMS system.

Better prediction of subjective assessment of toughness would have significant commercial and research benefits. This is being evaluated by modifying the MIRINZ Tenderometer to allow the use of a compressive, rather than cutting, head; to develop more detailed analysis of the force deformation curve; and to evaluate the implications of altering the rate of travel, to more closely mimic the speeds used during mastication.

Current research will investigate the modified Tenderometer with the conventional version and with subjective evaluation of meat processed under a range of processing conditions. The investigation will include a range of commercial muscles and cuts. Also, software will be developed to analyse the force deformation curve to provide improve predictions of eating quality. The outcome of this research will be a demonstrated prototype and methodology that can be used by researcher and processor QA staff alike to measure tenderness objectively. A communication strategy is proposed whereby the outcome of the project will be communicated to the wider industry to encourage faster adoption uptake by processors in Australia and New Zealand.

The final report will quantify the level of textural modifications that occur in key muscles of a beef carcass under different processing conditions. These data will be used to develop a texture model that will be incorporated into the meat quality model being developed in program.

2 Project Objectives

The objectives of the research were :

- To report on a design concept for a G2 Tenderometer based on a linear motor principle;
- To report on the construction and validation of a G2 Tenderometer; and
- To develop operating protocol and an industry bulletin for the G2 Tenderometer.

3 Materials & Methods

3.1 Report on a design concept for a Generation 2 (G2) Tenderometer based on a linear motor principle.

This unit is based on a linear motor that pushes a load cell against the sample. The samples are placed on a tray and then presented one by onto the shearing head. This procedure will speed up sample throughput. Data is displayed on a digital read-out but can also be downloaded direct to a computer or onto a USB memory stick.

3.2 Report on the construction and validation of the G2 tenderometer.

The prototype G2 tenderometer has been tested over the course of several trials that have been running at Carne Technologies recently. The unit has been tested against the G1 tenderometer using standard sample cooking and preparation procedures.

3.3 Develop operating protocol and an industry bulletin for the G2 Tenderometer

Standard Operating Procedures (SOP) were developed and evaluated in consultation with selected processors.

4 Results

4.1 Report on a design concept for a Generation 2 (G2) Tenderometer based on a linear motor principle.

A design concept for a generation 2 Tenderometer has been developed. The key points of this design are the miniaturisation of the unit and ease of use. The device is based on a linear motor which pushes the meat against a fixed load cell. The samples are placed in a line on a tray that presents the samples to the shearing head – this sample presentation format has the potential to be automated if required. The unit is battery powered and incorporates a digital readout ; data can also be downloaded either direct to a computer or onto a USB memory stick. The unit can be held easily in one hand and will weigh less than 1 kg.
This design will show the force directly applied to the sample. The unit measures kilogram force (Kgf) directly therefore does not require a conversion from kilogram Pascals (KPa). This design avoids friction artifacts. The unit is highly mobile being small, lightweight and battery powered.

Data can be automatically captured (see Figure 1).

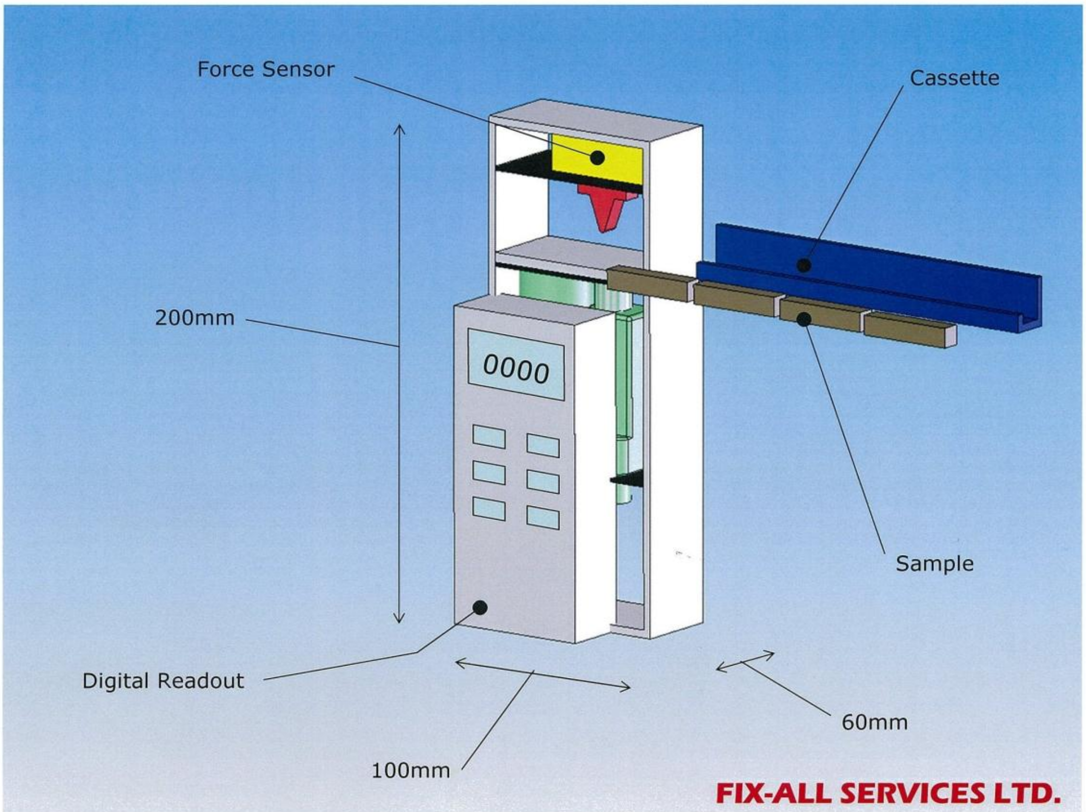


Figure 1 – Drawing specifications of a new meat stretching commercial prototype machine.

The G1 Tenderometer operates via a mechanical load that is applied to the meat sample from pressure employed from an air compressor that drives the shearing head. The pressure applied to the loading arm increases as it endures greater resistance from tougher meat samples. While this unit is widely used by research laboratories and commercial operations, it has several limitations: The unit is bulky and relatively heavy (10kg). However, more importantly are the limitations imposed by the use of pneumatics to apply the load: while air compressors are widely available in meat processing plants, the pressure and mains power requirements limit the mobility of the unit and they tend to be sited as permanent fixtures in laboratories. Furthermore, the peak pressure is displayed via an LED mounted on the front of the tenderometer and the value has to be manually recorded after each sample shear. Each machine, despite standardised manufacturing processes, encounters different internal resistances due largely to the unavoidable friction forces that are inherent in pneumatic systems.

In brief, the newly developed G2 Tenderometer is based upon a linear actuator that drives the specimen platform towards a static shearing blade that is in turn connected to a load cell that directly measures shear force. The force deformation information is displayed via an LED on the unit, but can also be acquired in real time using a software package (Rinstrum R300) and this in turn can store and transmit the data to any connected storage device such as a laptop or PDA. This system is highly portable, being battery operated and weighing 4.1kg. Furthermore, the G2 provides a direct method of measurement as the output values are in shear force Kgfs, while the force deformation curve output provides the opportunity for data analysis beyond simple peak force.

4.2 Report on the construction and validation of the G2 tenderometer

4.2.1 Construction details

i) Linear Actuator: The actuator chosen (Hiwin LAS-1-1-50-24) provides sufficient specifications for all the expected meat samples and potential testing objectives. A maximum force expected to be encountered in penetrating meat with a shearing attachment can be in excess of 40kgf (400N).

A force-deformation curve can be interpolated from the force-time data when the loading rate is constant throughout the loading cycle. Specifications provided by the manufacturers (see below) show that theoretically, the speed is relatively constant at 12 mm/s at 24 volts below 400 N. When attempting to validate these specifications it became apparent that the power provided by the two original 12 volt Ni-Cd batteries to the actuator dropped when an increased load was applied. However, the addition of a voltage regulator ensured that the batteries provided a constant (adjustable) voltage to the actuator. Following the addition of the regulator, the loading rate was shown to be constant when the motor was required to work harder. The stroke length is determined by an internal limit switch and was reduced from 50 millimetres to 40 millimetres. This provides a sufficient gap for loading and removing meat specimens stuck to the shearing attachment

ii) Voltage Regulator: A simple voltage regulator was produced to ensure voltage supplied to the actuator and the speed at which it operated was constant. The applied voltage was set at 15.6 Volts in order to operate at a similar speed to that of the G1 Tenderometer.

iii) Display: The Rinstrum R320 is a precision digital indicator using Sigma-Delta A/D technology to ensure fast and accurate weight readings. The setup and calibration are digital, with a non-volatile security store for all setup parameters. This instrument is fitted with rin-LINK communications as standard. This allows a temporary isolated communications link to be established with a PC and enables software upgrades and the use of computerised setup and calibration via the rin-VIEW software.

iv) Load Cell: The load cell is a miniature bending beam (Celtron MBB-100) type load cell that functions as a low profile platform scale for this low capacity scale application. It provides long term high performance and is sealed for protection of the cell from water and moisture damage.

v) Power Supply: Two Nickel Metal Hydride batteries, each supplying 1.3 ampere hours and 12 volts, are connecting in series to provide power to the display unit, load cell and actuator. The voltage regulator will maintain a constant voltage to ensure the actuator operates at a constant speed and have sufficient current available when forced to work harder and draw more current.

vi) Comparison between G1 and G2 tenderometers.

Over the period of two weeks, the G1 and G2 Tenderometers were used to measure the tenderness of a variety of cuts from beef carcasses that had been aged for different periods of time. This effectively generated a large number of samples that spanned the complete tenderness range. A correlation between the two Tenderometers is shown below using data derived from 3-days of evaluations. This shows that there is a significant relationship between the two units and this relationship has continued as larger sample numbers have been added to the database.

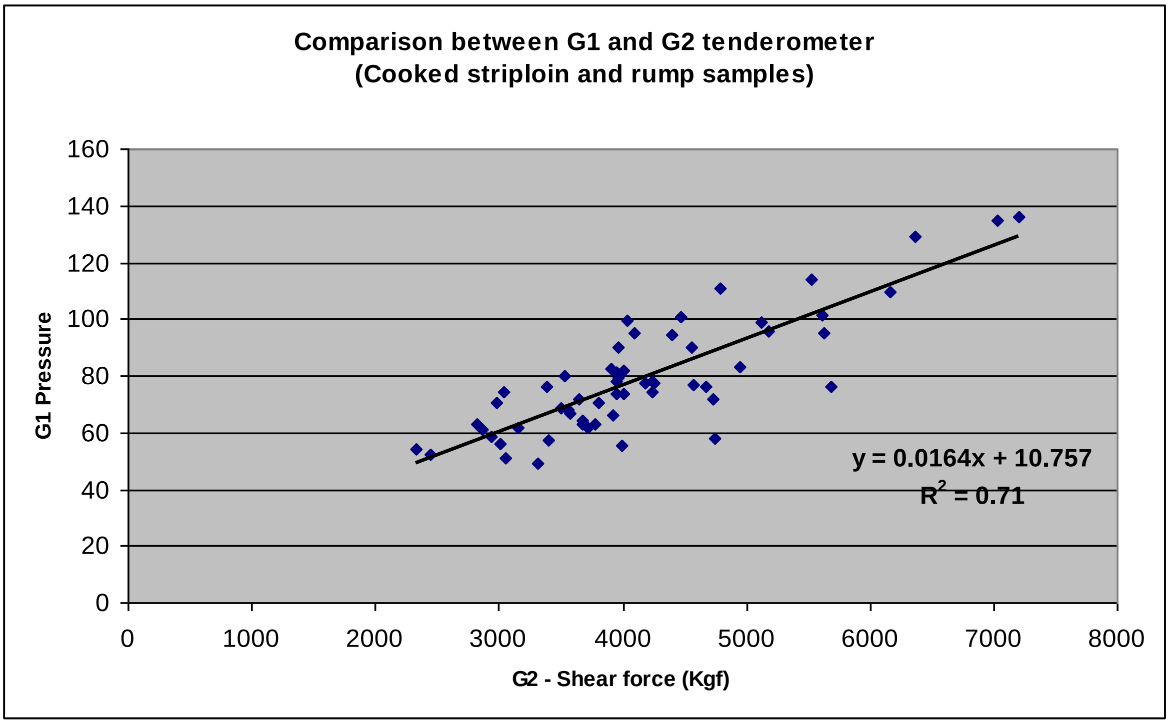
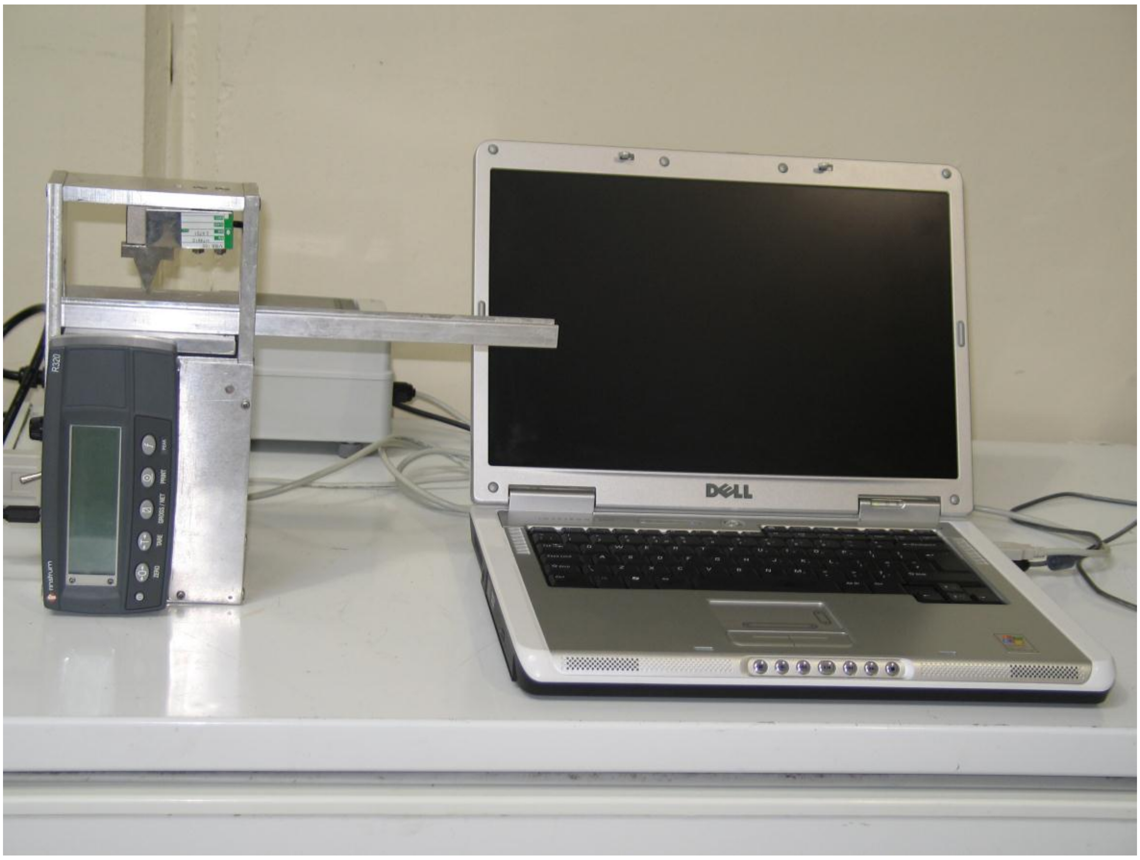


Figure 2 - Shear Focre (KgF) comparison between G1 and G2 Tenderometer

In summary, recent testing of the new G2 Tenderometer has enabled the recent modifications to the unit to be tested. These modifications include the incorporation of a fixed load cell position; this allows the load cell to be removed and replaced without the need for recalibration. The new sample loading and switch sequence will allow automatic cycling of the unit; in essence this means that the 10 sample bites can be loaded into the presentation tray and the unit will then cycle automatically through the shearing procedures testing and recording the values from each sample automatically without any further operator intervention.

Now the unit has been tested extensively and final modifications are complete, the next stage is to re-case the unit in a plastic moulded case which will allow it be easily cleaned and will ensure the unit is water-proof.

See a photograph below of the new G2 prototype G2 Tenderometer connected to a laptop PC (Photograph 1).



Photograph 1 - A photograph of the new G2 prototype tenderometer connected to a laptop PC.

4.3 Develop an operating protocol for the G2 Tenderometer.

The attached document has been written in the style of an industry bulletin (Appendix 1). This document outlines the advantages offered by the new G2 Tenderometer, and also provides detailed protocols to use for sample preparation and tenderness measurement.

5 Conclusion

To address issues with the current objective tenderness device known as the Tenderometer, a new G2 Tenderometer has been constructed as part of the current Meat Quality, Science and Technology program, funded jointly by Meat & Wool New Zealand and Meat & Livestock Australia.

The key points of the design of this new unit are the miniaturisation and mobility of the unit, improved sample loading and automated sample shearing and data downloading. The device is based on an electric motor which pushes the meat against a fixed load cell. The unit does not therefore require compressed air, just a standard power socket to plug into or batteries.

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6 Recommendations

Now the unit has been tested extensively and final modifications are complete, the next stage is to re-case the unit in a plastic moulded case which will allow it be easily cleaned and will ensure the unit is water-proof.

Consultation between MLA & MWNZ separately with a potential commercialiser is required in order to develop a suitable commercialisation pathway. As part of this process, a commercialisation agreement is required prior to first orders can be taken. Ongoing validation of G2 Tenderometer against G1 Tenderness is required.

Finally, to assist with acceptance by researchers and QA officers, it is proposed that a sample of units be produced and used as trialing units to create awareness in the industry. Supporting business development materials may also assist in creating awareness in the industry.

Appendix – Standard Operating Procedure – New G2 Tenderometer

Introducing the new G2 Tenderometer

Short-comings of the earlier G1 Tenderometer

The current Tenderometer is used by research laboratories and as a quality control instrument in many meat processing plants within New Zealand. While it is a reliable and relatively simple unit, its use is limited by several factors: The unit is bulky and relatively heavy (12kg); but perhaps more important are the limitations imposed by for pneumatics to operate the unit. While air compressors are widely available in meat processing plants, the pressure and mains power requirements limit the mobility of the unit and so they tend to be sited as permanent fixtures in laboratories. Furthermore, the peak pressure is displayed via an LED mounted on the front of the Tenderometer and the shear force value has to be manually recorded after each sample measurement. Each machine, despite standardised manufacturing processes, generates different internal resistances due largely to the unavoidable friction forces that are inherent in pneumatic systems and, therefore, requires at least annual calibration. Furthermore, these effects result in instrument to instrument variability which can be particularly problematic for meat processors that have several instruments for tenderness auditing. The pressure required to shear a meat sample is displayed in Kilo Pascals which then has to be converted to kilograms shear force (kgf). The conversion formula is generated during the calibration procedure. While this conversion is easily achieved using a simple Excel based macro, the final shear force values are not given at the time of sample shearing.

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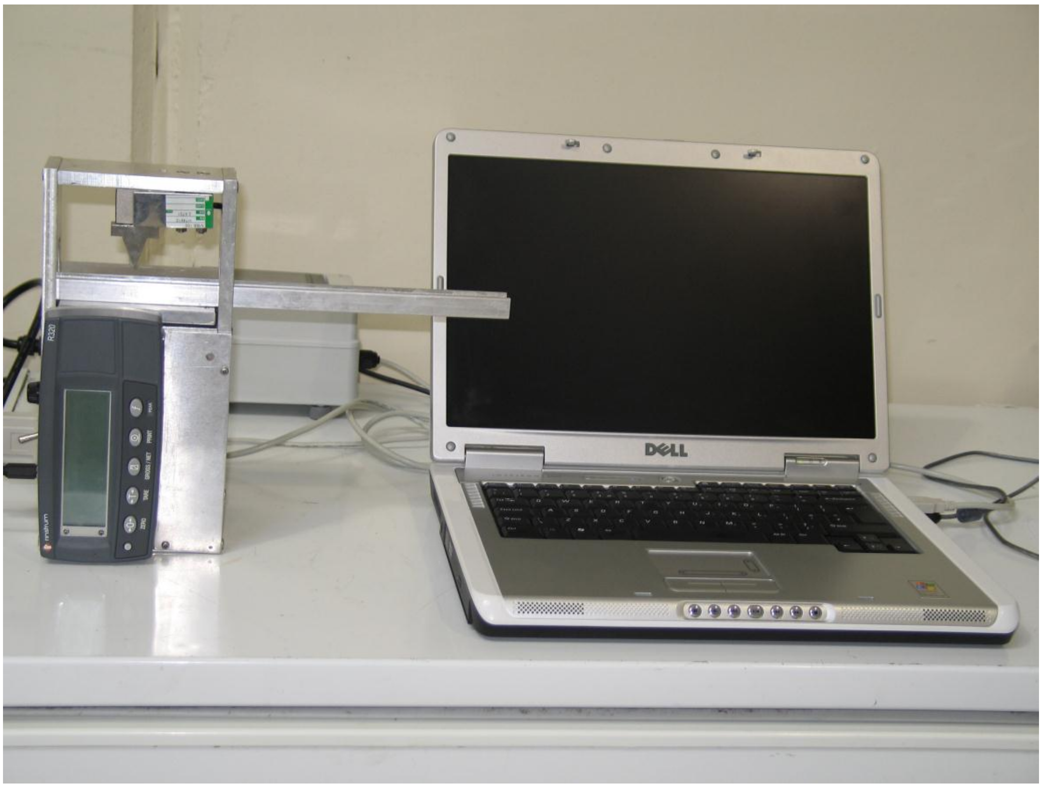
The unit has been tested extensively and final modifications are complete. The next stage is to re-case the unit in a plastic moulded case which will allow it be easily cleaned and will ensure the unit is water-proof.



Photograph A1 - A photograph of the new G2 prototype Tenderometer connected to a laptop PC.

Sample cooking and cutting protocols for the preparation of samples for the G2 Tenderometer are outlined below.

Tenderness Testing

i) Cooking procedure for shear force measurement

An end-point temperature of 75°C is used because tenderness is affected by the internal temperature of the meat and, therefore, should be standardized and consistent.

1. To reduce cooking time variability between samples, bone out the loin samples. Wherever possible, trim each muscle to an approximate sample size of 100g for lamb or 250g for beef.
2. Place the samples in unsealed plastic bags (200 x 250 mm, or larger), with a 100g weight to assist in submerging the meat sample in water.
3. Place the bags into the boiling waterbath so that the meat sample is completely submerged. Attach the bags to a rail across the waterbath by bulldog clips, to ensure that the open end of each bag is held above the surface of the water.
4. Monitor the temperature of the samples during cooking.
5. When the end-point temperature internal temperature of 75°C is reached at the centre of the meat sample, immediately transfer samples to an ice-waterbath or chiller with an air speed of at least 1m/s.
6. Once the samples have reached a temperature of 4°C, they can be prepared for Tenderometer testing.

7. Cooled samples can be stored at ≤ 2 °C for up to 48 hours before measuring shear force

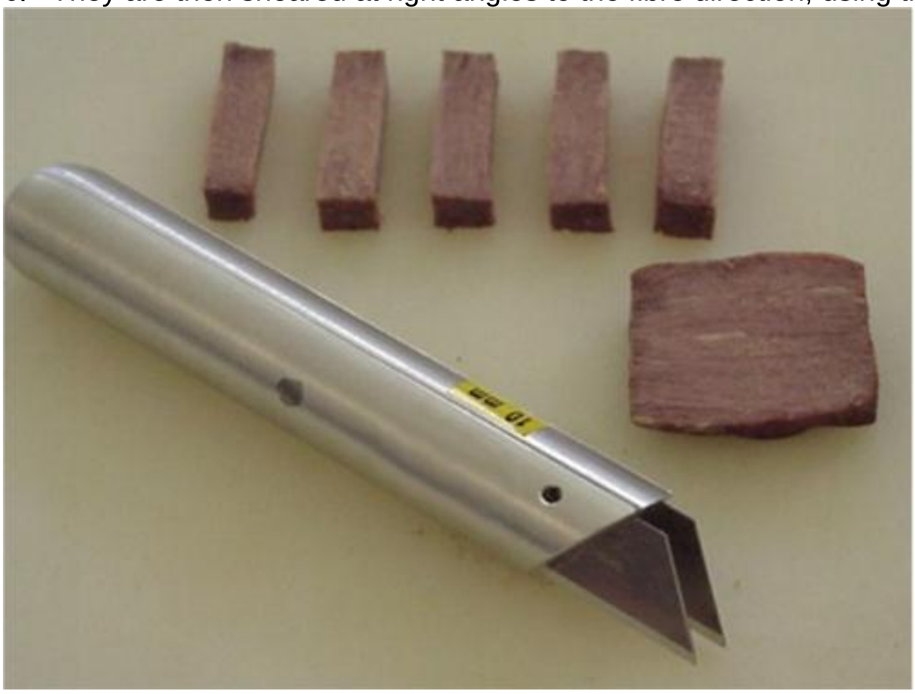
ii) Cook Loss

1. Weigh each sample before cooking and record the weight.
2. Place in suitable bag for cooking and cook using the procedure outlined above.
3. After cooking the samples should be cooled rapidly to <4ºC.
4. Before Tenderometer testing, dry the samples with a paper towel to remove the excess moisture.
5. Weigh the samples and record the weight.
6. The cook loss is presented as a percentage of the original uncooked weight

iii) Meat Tenderness Measurement Using the G2 Tenderometer

The basic principle in assessing meat tenderness is to determine the force required to shear through a 10 x 10 mm square cross-section sample at right angles to the fibre axis. Sample preparation must be accurate as it can affect the shear force results.

1. Cut a slice off the outside of the meat to enable identification of the grain (the direction the muscle fibres are lying) in the meat.
2. Score the meat with the Tenderometer knife (double-bladed scalpel with blades set 10mm).
3. Cut ten rectangular samples (bites) from each sample using the scored marks as guides. These sample bites must be cut exactly to specification; 10mm x 10mm cross section, and a length, parallel to the fibre axis, of at least 25mm.
4. Discard the edge pieces that have been cut away.
5. The 10 meat sample bites are placed end to end in the presentation tray.
6. They are then sheared at right angles to the fibre direction, using the G2 Tenderometer.



Photograph A2 - A photograph of sample preparation for G2 Tenderometer measurement.

Sample preparation

- For each bite, record the shear force (Kgf) reading that is displayed, or download the data direct to a laptop if one is connected to the G2 Tenderometer.
- Record up to 10 bites per sample, for smaller samples record as many bites as possible.
- The 10 Tenderometer readings for each sample are reported as a mean.