A New Technique for Measuring Meat Texture and Tenderness

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Summary

This paper describes a new technique for measuring meat texture and tenderness. A prototype instrument using the new technique has been developed. The instrument incorporates a rotating pin shear head assembly that is applied directly to the meat, thus significantly reducing sample preparation. Other interesting features include high sensitivity, 'non-destructive' testing, possible application to foods other than meat and use as an on-line quality control tool.

Prototype instruments have been evaluated on rest-length and cold-shortened muscle, in both the raw and cooked states, as well as on dairy products. The initial results are very encouraging, showing a clear discrimination between cooked rest-length and cold-shortened muscle. Early indications are that measurements on raw muscle may allow prediction of cooked meat tenderness, but few data have so far been collected.

Introduction

Quality control of the textural properties of food requires that the relevant textural attribute be rapidly measured, so that remedial action can be taken during processing.

Meat has peculiar textural properties that result from many factors including; grain structure, animal age, stress before slaughter, degree of carcase stimulation, the rate of carcase cooling after slaughter, and time and temperature of meat aging. Stress-related factors can produce a condition known as PSE (Pale-Soft-Exudative), particularly in pigs or DFD (Dark-Firm-Dry), found mainly in beef, with both these conditions the meat has an altered texture which may enable early detection and, for quality control purposes, redirection of the affected product to more appropriate processing.

Traditionally, meat is eaten cooked. Thus texture or toughness assessment of a particular meat sample is usually performed on cooked samples. For quality control purposes, it is important to be able to assess meat texture in the raw state, regardless of whether the meat is to be consumed raw or cooked. Several studies have attempted to correlate taste panel assessment of cooked meat texture against measurements on the raw product. The most successful of these (Shorthose *et al*, 1988) found a significant correlation with measurements using the RV1 apparatus fitted to an Instron Universal Testing Machine. A portable version, the RV4, was less successful. The effects of cold-shortening can be measured by testing the yield point (Locker and Wilde, 1982) or the compression characteristics (Sale *et al.*,1984; Lepetit *et al.*,1986) of raw muscle after rigor.

Design Concept

MIRINZ set out to devise a method of measuring raw muscle texture that could distinguish cold-shortened from rest-length post-rigor muscle. The resulting instrument would ideally; automatically establish sample size, avoid the problems of clamping a sample, be used for monitoring other foods and be incorporated into a portable instrument for on-line measurement of product.

During eating, the sensation of food texture is derived from biting (using incisors - Fig. 1(a)) or chewing (using molars - Fig.1(b)). The main purpose of biting and chewing is to break food into manageable chunks for ease of swallowing and subsequent digestion. Most of the biting-type devices for measuring meat tenderness, including the MIRINZ tenderometer, have jaws that meet tip to tip. They apply a pinching action to the sample resulting in a shearing of the muscle fibres. In contrast, the human jaw allows the incisor teeth to overlap (Fig.1(a)), providing a shearing action that grips the food and stretches it beyond its yield point, thus pulling it apart into smaller pieces. The perception of texture is most likely due to a food's tensile strength before yield. Therefore elasticity and plasticity are important considerations in assessing the texture of foods.

An instrument designed to measure texture or tenderness should attempt to duplicate the action of the human jaw and teeth, by placing the food sample under tensile stress until it yields. The instrument described here utilises two sets of concentric pins (Fig. 2) that can be rotated relative to each other. Both pin sets are plunged into the sample so that the sample covers their whole length. The outer set acts as an anchor ring, holding the sample in place while the inner set is rotated. The force required to rotate the inner set is measured against the angle of rotation and the resulting data are captured for presentation and analysis. The ring of pins allows measurements to be made independent of fibre grain direction in two dimensions. Inserting of the pins parallel to the grain of a cut muscle allows the characteristics of the inter-fibre connective tissue to be assessed.

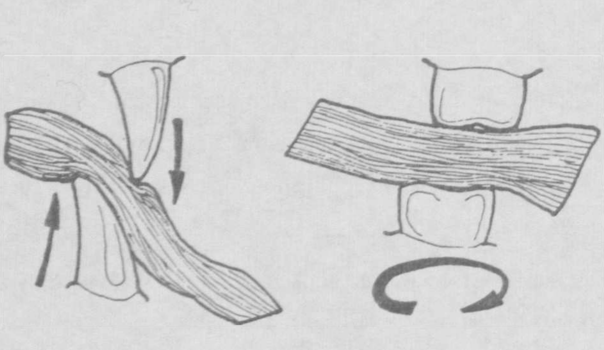

Figure 1. The action of teeth on meat

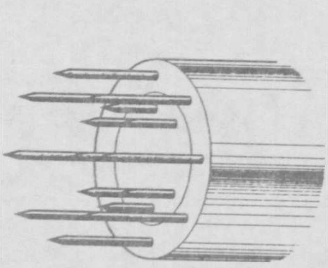

Figure 2. The pin assembly of the sampling head of the new instrument

Materials and Methods

Semimembranosus (SM) muscle pairs were excised from bull caracasses immediately after hide removal after which the outer membrane sheath was removed. The muscles were then subjected to different cooling regimes for 24 hours to induce various degrees of toughness. The muscles were then stored at 0°C for approximately 24 hours before being tested raw or tested after cooking. For cooking, each meat sample contained in a stout plastic bag, was suspended in a water bath at 100°C and cooked until its centre reached 85°C, as determined by a thermocouple inserted into the thermal centre of the sample. Cooking was terminated by immediately placing the cooked samples into an ice and water slurry and holding them there for at least two hours.

Two each Longismus Dorsi (LD), Gluteus Medius (GM) and Psoas Major (PM) muscles were obtained from the boning room of a local slaughter plant. The beef sides from which the muscles were removed had been cooled overnight in a standard chiller facility. The muscles were held for a further 24 hours at 0°C before being tested. The tests were conducted immediately after the samples were removed from the ice-water slurry.

Each cooked SM, LD, GM and PM muscle was cleaved longitudinally (parallel to the grain) to expose a flat surface. Half of the muscle was tested on the new instrument and half on the MIRINZ tenderometer. For the new instrument, a portion of the sample flat surface was forced onto the pins until the sample covered their entire length. The rotating pin set drive (synchronous motor) was then turned on and the torque response of the instrument's action on the meat was recorded over time (synonymous with rotation). As many tests as possible were carried out over the available length of a muscle sample. Usually there were three tests per sample, but occasionally there were as many as five or as few as two. The other half of the muscle was sliced by a pair of scalpels mounted 10 mm apart and the slices were assessed on the MIRINZ tenderometer. At least five tenderometer readings per sample were taken.

The cooked LD, GM and PM muscles were treated in a similar manner, each muscle being cut approximately in half along the fibre grain before testing.

A number of muscles were also tested in the post rigor raw state by cutting a 30 mm thick slice from the end of the muscle under test and placing this sample on the instrument pins with the fibre grain parallel to the direction of the pins (end-grain). The test was conducted as described above. The remainder of the muscle was cooked as above for comparative tenderometer tests.

The texture profile resulting from each test was recorded on a YT recorder (Bryans, 29000) for immediate visual confirmation of the progression of the data, and also on a computer system using a MetraByte DAS-20 analogue-to-digital interface card. The data from each test trace were analysed to provide a record of features established from the initial tests. These features were considered representative of the characteristics of the instrument response on meat. A number of dairy products were tested to gauge thire relative responses.

Results and Discussion

The initial results showed different responses to cold-shortened and rest-length muscle. A typical example of the differences is shown in the typical torque/rotation response in figure 3 where (a) is the response from a cold-shortened muscle of a pair and (b) is the response from the rest-length muscle of the same pair. The example shows responses for raw end-grain tests. The response of cooked muscle is similar to that of (a) with differing slope depending on tenderness. Each trace in figure 3 is the average of three test responses.

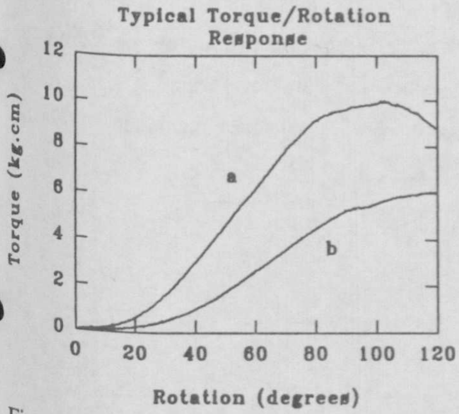

Figure 3. A typical response on meat

The features most apparent with cooked and raw samples were as follows:

- Cooked muscle measured normal to the fibre grain:

  For cold-shortened muscle the response had a much higher peak yield and a greater initial slope compared to the rest-length muscle.

- Raw muscle measured parallel to the fibre grain:

  For rest-length muscle the response showed significantly more rotation of the inner pin set before the muscle structure began to resist movement and produce a torque response, compared to the cold-shortened muscle. The position of the peak yield, rather than the peak yield itself, appeared to be of possible significance

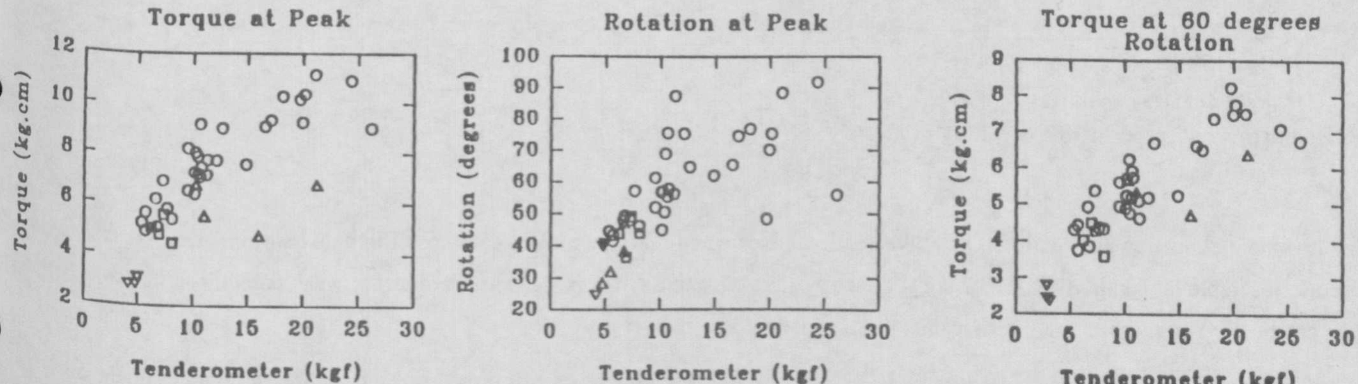

Figure 4(a,b,c) Comparison of readings by the new instrument and the MIRINZ tenderometer on cooked meat.

key: ○ SM, △ LD, □ GM, ▽ PM

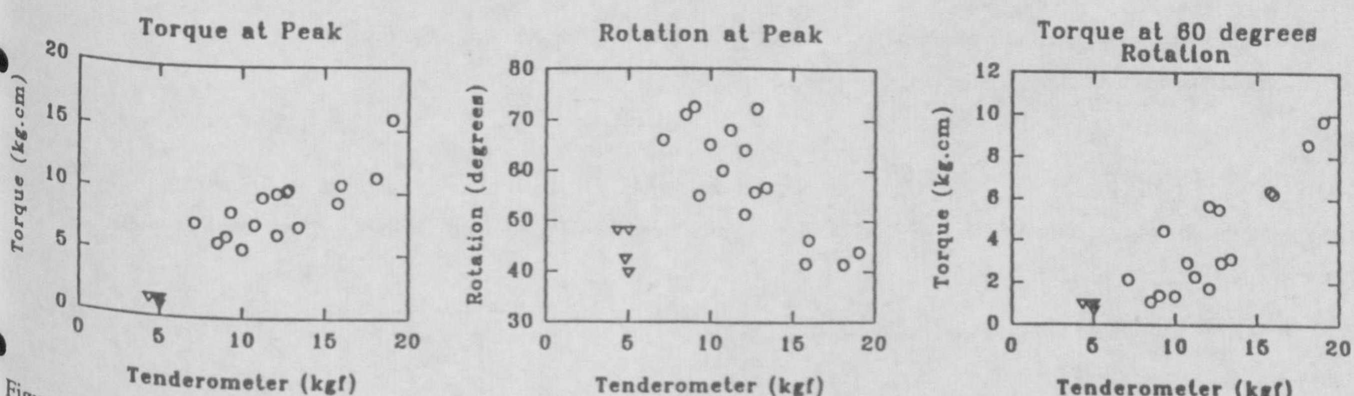

Figure 5(a,b,c) Comparison of the new instrument (raw sample - see text) and the MIRINZ tenderometer (cooked sample - see text).

key: ○ SM, ▽ PM

We found no significant differences in the responses for raw meat tested normal to the fibre grain or on the end-grain measurements of cooked samples.

Three response features: the torque at peak yield, the angular rotation at the peak yield and the torque at a rotation angle of 60°, were chosen as representative of any particular response and were subsequently used as the basis for analysing the data.

The results of the comparison tests between new instrument and the MIRINZ tenderometer on cooked meat are shown in figure 4. The results of the comparison tests between raw muscle tested on the new instrument and a section of the same muscle tested on the tenderometer after cooking are shown in figure 5.

The data shown in figures 4 and 5 were subjected to a linear regression analysis, resulting in the correlation coefficients that follow. In figure 4(a) the data show good correlation ($r = 0.79$), as do those of Figure 4(c), ($r = 0.87$), which are similar to findings of Graafhuis et al. (1991) who compared the MIRINZ tenderometer with the Warner-Brazler shear test apparatus. The data of Figure 4(b) are less well correlated ($r = 0.54$). Figure 5 shows the correlation of all data collected to date from tests on raw muscles compared with MIRINZ tenderometer values from a cooked section of the same muscle. There is a good correlation on Figures 5(a) and 5(c) (r = 0.90 and 0.88 respectively), however because there are only 19 data points, it would be unwise to conclude that a definitive method has been found for predicting meat tenderness from measurements on raw meat samples. The data of 5(b) show no correlation (r = 0.12). Since the data for torque at peak yield, destructive test, provide a similar result the data for torque at 60°, a 'non-destructive' test, it seems best to consider the latter as the more appropriate test to consider for future development.

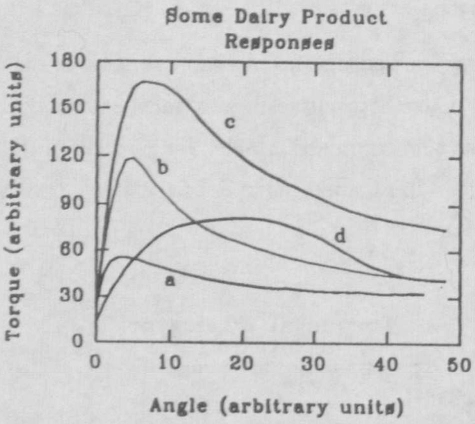

Figure 6. The instrument response to some dairy products

Figure 6 shows responses from the various dairy products as tested to date. The responses are:

(a) Semi-soft butter

(b) Standard butter

(c) Cheddar cheese

(d) Edam cheese

Each trace is the average of three tests although the homgeneity of the products mean that there was little variation between the responses on each product.

Conclusions

The new instrument compares well with the MIRINZ tenderometer when used on cooked samples. The new instrument's relative ease of use through reduced sample preparation, should make it a viable alternative to devices in current use. Further work is required to confirm that the instrument can be used on muscle groups other than those tested to date.

Early indications are that the new instrument may be able to predict the tenderness of cooked meat from measurements made on the raw product in rigor. Further work is required to confirm that the techniques here, largely applied to SM muscle, are valid for the different level of connective tissue in other commercial meat cuts.

Further development of the technique into a portable hand-held instrument is planned to test its effectivenessin commercial meat processing plants.

Further work is required to assess the value of the new instrument in determining the textural properties of dairy products and other foods The initial indications are however encouraging.

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