APPARATUS AND METHODS FOR MEASURING MEAT QUALITY

An apparatus (10) is provided for measuring meat tenderness. The apparatus has a transmitter means for transmitting a signal into meat to be measured, a receiver means (14) for receiving a signal returned from the meat, signal processor means (20) adapted for processing indicating the measured meat quality. In a typical application, the transmitter means is an ultrasound transducer (12) with a centre frequency of at least 2.0 Mhz and a 60 % bandwidth. The ultrasound signal is applied substantially perpendicular to the longitudinal direction of the muscle fibres in the meat sample (100). The returned back-scattered signal is sampled at between 50 and 200 Mhz and then gated and a window function applied at a predetermined time interval. The gated signal is then subject to a processing technique such as a fast Fourier Transform (FFT) for producing a desired spectrum with at least one distinct signature of the determination of the meat tenderness.
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APPARATUS AND METHODS FOR MEASURING MEAT QUALITY

TECHNICAL FIELD OF THE INVENTION

THIS INVENTION relates to apparatus and methods for measuring meat quality, and in particular but not limited thereto, to apparatus and methods which transmit signals into meat to be measured and process back-scattered signals from meat tissues for measuring meat tenderness.

BACKGROUND ART

Meat is graded and priced according to cuts from specific parts of carcass. For example, in beef meat ribeye fillet is perceived to be the most tender of the cuts and is therefore priced at a premium. Chuck beef is perceived to be relatively tough and can therefore only demand a relatively low price.

However, the quality of meat varies widely and is unpredictable from carcass to carcass even if they come from animals of the same breeding with similar age. While the amount of marbling was thought to be the quality indicator in beef, the industry has now accepted that tenderness is the true indicator of quality. Premium grade cuts of meat from one carcass may be less tender than lower grade cuts of another carcass. The quality of the same cuts of meat in shops are therefore inconsistent. Butchers and customers alike do not have any reliable and accurate means for determining the quality of the meat they are selling/buying.

The applicants are aware of several proposals for determining meat quality in terms of its tenderness. One such proposal attempts to predict meat tenderness by obtaining PH values in cold carcass. Other proposals employ X-ray imaging, electrical conductively analysis, near-infrared reflective and bioelectrical impedance measurement etc.

The prior art proposals are relatively slow and have been found to be inaccurate.

An object of the present invention is to alleviate or at least reduce to a certain degree one or more of the prior art disadvantages.

A further object is to measure meat quality in a non-invasive and non-destructive manner.
OUTLINE OF THE INVENTION

According to a broad aspect, the present invention resides in an apparatus for measuring meat quality. The apparatus comprises a transmitter means for transmitting a signal into meat, a receiver means for receiving a signal returned from the meat, signal processor means adapted for processing the returned signal for providing a measured meat quality and an indication means for indicating the measured meat quality.

Preferably the signal from the transmitting means is one within the radio frequency (RF) range. The transmitted signal may be audio, acoustic including ultrasound, optical, and the like, and can be in either analogue or digital form.

More preferably the transmitter means is an ultrasonic transducer and the transmitted signal is an ultrasound wave.

Conveniently the transmitted signal is applied substantially perpendicular to the longitudinal axis of muscle fibres in the meat. It should be noted however that the apparatus can be adapted for transmitting signals applied to the meat at angles other than perpendicular to the longitudinal axis or at a combination of predetermined angles.

The signal may be transmitted in pulse or tone burst form in pulse echo, pitch-catch mode or transmission mode.

The transmitted signal may be applied to a live animal, a carcass, a boxed (whole) meat or a slice of meat for measuring meat quality.

The meat may be that of any land or marine animals, and may include beef, pork, lamb, mutton, horse meat, poultry meat, tuna, flake etc.

The ultrasonic transducer is typically a ½ inch diameter compression wave transducer with a centre frequency of 2.0 MHz and a 60% bandwidth, or greater. Transducers with frequencies between 1 to 10 MHz can be adapted for the apparatus.

The transmitter means may comprise a combination of transducers of various characteristics or an array of transducers.

The receiver means is preferably adapted to receive the return signal following the signal transmission.

The returned signal may be in analogue or digital form from within a
predetermined range of depth into the meat. Typically the range is at least 2 inches into the meat. Conveniently, it is a back-scattered signal from meat tissue or an echo from a reflector, set on the remote side of the sample.

When the returned signal is in analogue form the apparatus may advantageously include an analogue to digital conversion means for converting the returned analogue signal received by the receiver means into a digital form. The sampling rate may be at any frequency between 50 to 1000 MHz, but typically between 50 and 200 MHz.

The signal processor means may be a computer unit or a programmed processor unit.

At the processor means, the received signal is preferably gated and/or a window function applied at a predetermined time interval prior to signal processing.

The signal processing is adapted to produce a desired spectrum or other analysis domain, with at least one distinct characteristic or signature for the determination of meat quality. Alternatively a pictorial representation of the meat structure may be produced for the determination.

The spectrum may be produced by any time domain signal processing techniques, including a Fast Fourier Transformation (FFT), cepstrum, correlations on times and frequency domain signatures, neural nets and pattern recognition including fractal statistics.

Accordingly the signal processor means may have a gating unit for gating the received signal at a predetermined time interval, and a signal processing unit for producing a desired signature for meat quality determination.

Any characteristics or signatures of the signal, signature or pictorial representation which correlate to meat quality may be used for the determination. The characteristics may include modulation frequencies, spectral peak separations, images of particular tissue or muscle etc.

The indication means may be a visual or audio indication unit. Preferably the indication means is a computer monitor unit or a display unit such as LCD display. Alternatively, the indication means may be a printer.

Typically the indication means indicates the meat quality in the form of
tenderness gradings in the range including:-
   Very tender
   Medium Tender
   Tender
5   Medium tough
   Tough
   Very tough
The gradings may be displayed graphically, numerically or in words, or a combination of 2 or more of the above. For example, 1 may indicate very tender,
10   2 medium tender etc.

   The apparatus may be a hand-held device with all components within a housing means so that it is convenient for a user to measure meat samples in different locations.

   If desired, a computer system may be adapted to function as one or more of the processor means, the indication means and the receiver means. While the transmitting means is a portable unit connectible to the computer system.

   In another aspect, the present invention resides in a method for measuring meat quality. The method includes the steps of:-
   (a) transmitting a signal into meat to be measured;
   (b) receiving a signal returned from the meat;
   (c) processing the returned signal for obtaining a measured meat quality; and
   (d) indicating the measured meat quality.

   The signal may be a RF signal including audio, optical and the like.

25   Preferably the transmitted signal is an ultrasound signal. More preferably the ultrasound signal is in the range of 1 to 10 MHz. Typically, the signal has a centre frequency of 3.5 MHz and a 60% bandwidth, or greater. The transmitting step may include positioning a signal transmitter at a predetermined position and at a predetermined angle in relation to the meat. Conveniently, the angle is determined in relation to the longitudinal axis of muscle fibres in the meat. The predetermined angle is typically substantially 90° to the longitudinal axis.

30   Where the received signal is in an analogue form, the returned signal may
be subject to a conversion step prior to the signal processing step. The conversion step converts the returned analogue signal into a digital signal. Sampling rates for the conversion may be selected from within a range of 10 to 1000 MHz and typically 200 MHz is used.

In the processing step the returned or digitised signal may be subject to:

* gating at a predetermined time interval for extracting a suitable portion of the signal with at least one distinct characteristic for processing;
* processing the gated signal for producing a signature which can be used for determining meat quality.

The gated signal is typically processed by a time domain processing technique for producing a useful spectrum. One example of the techniques is Fast Fourier Transformation (FFT).

A characteristic or signature of the spectrum which correlates to meat quality is then obtained. Such characteristics may include modulation frequency and modulation peak separations.

The processing step may include a calculation process for calculating the meat quality. The obtained or calculated meat quality is then indicated on the indication means.

**BRIEF DESCRIPTION OF THE DRAWINGS**

In order that the invention can be more readily understood and be put into practical effect, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the present invention and wherein:

- Figure 1 is a block diagram of the meat quality measurement apparatus according to the present invention.
- Figure 2 shows an application of one form of the meat quality measurement apparatus according to the present invention;
- Figures 3 and 4 show detailed muscle fibre structure of meat;
- Figure 5 is a pictorial image of a returned signal from a very tender beef grade sample using tone burst excitation;
- Figure 6 is a pictorial image of a returned signal from a tender grade sample using tone burst excitation;
Figure 7 is a pictorial image of a returned signal from a very tender grade sample using pulse echo excitation;

Figure 8 is the wave form of a digitised returned signal;

Figure 9 is the wave form of a digitised returned signal which has been gated;

Figure 10 is a spectrum obtained by processing the gated signal of Figure 9; and

Figure 11 is a graph showing the relationship between shear force, spectral modulation and meat tenderness grading.

Referring initially to Figure 1, there is shown an apparatus 10 according to the present invention. The apparatus 10 as shown is in the process of measuring the tenderness of a slice of meat 100. The apparatus 10 includes a trigger switch (not shown) for switching. The apparatus 10 has an ultrasonic transducer 12 which in use is placed substantially perpendicular to the longitudinal axis muscle fibres in the meat 100. The transducer 12 is excited in pulse-echo mode. A broad-band (0.5 to 35 MHZ) spike pulse-receiver 14 is employed to excite the transducer 12 and to receive back-scattered signals returned from the tissues in meat 100.

A trigger signal 16 controls the pulse receiver 14 for exciting the transducer 12 and receiving the back-scattered signals from the transducer 12.

An analogue to digital converter 18 is used to digitise the returned back-scattered signals at a sampling rate between 50 and 200 MHz (5 to 20 nanosecond sampling). An example of the digitised wave form is shown in Figure 8.

The digitised wave form is then subject to a gating process by a signal processing unit 20 at predetermined time intervals for obtaining characteristics which correlate with meat tenderness. Figure 9 shows a gated wave form.

The signal processing unit 20 subjects the gated wave-form to a Fast Fourier Transformation (FFT) for analysing the frequency domain of the resultant spectrum (see Figure 10) for determining meat tenderness.

As shown in Figure 10, the spectrum has distinct spectral modulation peak separations $\Delta f_i$. The separations $\Delta f_i$ are used to determine a weighted spectral
domain modulation increment $\Delta f_w$ by the formula.

$$\Delta f_w = \left[ \frac{\sum_{i=1}^{N} X_i \cdot \Delta f_i}{N} \right]$$

where $X_i$ = weighing function (related to significance of modulation frequency which may be determined from cepstral analysis or other spectral analysis)

$\Delta f_i$ = spectral peak separation (in spectrum)

$N$ = number of peaks in spectrum.

$\Delta f_w$ is then used to calculate shear force (measured by Warner-Bratzler shear value) by:

$$SF = A \cdot (\Delta f_w) + B$$

Where $SF$ = shear force (lbs)

$A$ and $B$ are constants determined by apparatus characteristics.

Figure 11 shows the correlation between shear force (SF) and spectral modulation and also tenderness grade.

The processor means 20 is programmed to indicate on the indications means 22 the meat tenderness grading which corresponds to the SF value calculated from $\Delta f_w$ of the returned back-scattered signal from the meat tissue.

The signal processor means 22 may be adapted to record the indications on a computer record medium such as floppy disks or on paper by way of a printer.

Referring to Figure 2, the A/D converter 18, signal processor means 20 and the indicating means 22 are replaced by a computer 24. In this case the meat 100 is a carcass hung on a rail 102 in a cold room. The transducer unit 12 is positioned to measure tenderness of the carcass.

Figures 3 and 4 shows detailed muscle fibre structure of a cut of beef meat.

As can be seen the muscle fibres extend substantially parallel to each other.

As can be seen in Figures 5 and 6 the pictorial representation of an ultrasonic C scan of the very tender meat (Figure 5) has a relatively larger area of dark coloured returned signal as compared to the tender meat representation
shown in Figure 6. This is used to grade tenderness.

Figure 6 shows that a pictorial representation of the meat of Figure 5 is substantially different when the apparatus 10 is excited in pulse echo mode.

Whilst the above has been given by way of illustrative example of the present invention, many variations and modifications thereto will be apparent to those skilled in the art without departing from the broad ambit and scope of the invention as herein set forth.
CLAIMS

1. An apparatus for measuring meat quality comprising a transmitter means for transmitting a signal into meat, a receiver means for receiving a signal returned from the meat, signal processor means for processing the returned signal for providing a measured meat quality, and an indication means for indicating the measured meat quality including tenderness and other quality traits.

2. The apparatus according to claim 1, wherein the signal is an ultrasonic pulse or oscillating signal.

3. The apparatus according to claim 2, wherein the signal is one of an audio, ultrasound, optical and the like signal.

4. The apparatus according to any one of claims 1 to 3 wherein the signal is in a analogue or a digital form.

5. The apparatus according to any one of claims 1 to 4 wherein the transmitter means is an ultrasonic transducer.

6. The apparatus according to claim 5 wherein the transducer transmits a signal with a frequency between 1 to 10 MHz.

7. The apparatus according to claim 5 or 6 wherein the ultrasonic transducer is a ½ inch diameter compression wave transducer with a centre frequency of at least 2.0 MHz and a 60% bandwidth, or greater or a combination of transducers of various characteristics or an array of transducers.

8. The apparatus according to any one of claims 1 to 7 wherein the signal is applied at a predetermined angle or a combination of predetermined angles to the longitudinal axis of muscle fibres in the meat.

9. The apparatus according to claim 8 wherein the angle is substantially 90°, or between 10° to 90°.

10. The apparatus according to claim 8 wherein the combination of angles are two or more angles selected from between 10° to 90°.

11. The apparatus according to any one of claims 1 to 10 wherein the signal is transmitted in one of the following modes: (a) pulse echo or (b) pitch-catch or (c) transmission or a combination of two or more of (a) and (b) and (c).

12. The apparatus according to claim 11 wherein mode (b) and (c) employ two or more transducers or paired transducers.
13. The apparatus according to any one of claims 1 to 12 wherein the receiver means is adapted to receive the return signal from within a predetermined range into the meat.

14. The apparatus according to claim 13 wherein the range is normally 2 inches into the meat.

15. The apparatus according to any one of claims 1 to 14 wherein the returned signal is a back-scattered signal from meat tissue.

16. The apparatus according to any one of claims 1 to 15 further comprising an analogue to digital conversion means for converting the returned signal into a digital form.

17. The apparatus according to claim 16 wherein the sampling rate at the conversion means is between 50 to 1000 MHz.

18. The apparatus according to claim 17 wherein the sampling rate is between 50 and 200 MHz.

19. The apparatus according to any one of claims 1 to 18 wherein the signal processor means is a programmed processor unit or a computer unit.

20. The apparatus according to any one of claims 1 to 19 wherein the returned signal is gated and/or window function applied at a predetermined time interval prior to signal processing.

21. The apparatus according to any one of claims 1 to 20 wherein the signal processor means is adapted to process the returned signal for producing a desired signature, spectrum or a pictorial representation of the meat structure with at least one distinct characteristic or signature for the determination of meat quality.

22. The apparatus according to claim 21 wherein the signature is produced by a time or frequency domain signal processing technique, pattern recognition including fractal statistics or neural net.

23. The apparatus according to claim 22 wherein the technique is Fast Fourier Transformation (FFT), cepstrum, correlations on time and/or frequency domain signatures, pattern recognition including fractal statistics or neural net.

24. The apparatus according to any one of claims 10 to 23 wherein the characteristic or signature correlates to the meat quality and includes modulation frequencies, spectral peak separations etc.

25. The apparatus according to any one of claims 1 to 24 wherein the meat
quality is graded in the range:

   Very tender
   Medium tender
   Tender
   Tough
   Medium tough
   Very tough

26. The apparatus according to any one of claims 1 to 25 wherein the apparatus is a hand-held portable device.

27. A method for measuring meat quality comprising the steps of:-

   (a) transmitting a signal into meat to be measured;
   (b) receiving a signal returned from the meat;
   (c) processing the returned meat signal for obtaining a measured meat quality;
   (d) indicating the measured meat quality.

28. The method according to claim 27 wherein the method further comprises a conversion step for converting the returned signal into a digital form prior to the processing step.

29. The method according to claim 28 wherein a sampling rate selected from a range of 50 to 1000 MHz is used in the conversion step.

30. The method according to any one of claims 27 to 29 wherein in the processing step the returned signal is gated at a predetermined time interval for extracting portion of the signal with at least one distinct characteristic or signature suitable for meat quality determination.

31. The method according to claim 30 wherein the gated signal is processed for producing a spectrum or a pictorial representation of the meat structure, from which the characteristic or signature correlating to meat quality is calculated.

32. The method according to claim 31 wherein the meat quality is indicated on an indicating means.
FIG. 3

Muscle

Group of muscle fibres

Myofibril

Myofilaments

Myosin

Actin

Fasciculus
FIG. 4
A. CLASSIFICATION OF SUBJECT MATTER

Int Cl: G01N 33/12, 29/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G01N 33/12, 29/10, 29/00, 21/00, 21/62, G01B 17/00

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