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SECTION **B 1**

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Instrument Measurements of Changes in Meat Brought about by Cooking.

There are many machines for measuring the physical qualities of meat. Some can be adapted to measure a diversity of qualities more appropriate to other foods. In general, measurements on meat have tended to give a single index which can be correlated with a tenderness score or chew-count rating.

Cover, Ritchey and Hostetler (1) developed the thema that the tenderness or toughness of meat is not a simple quality, but includes several component sensations, which, although inter-correlated, do not necessarily all follow similar trends at the same time. They have suggested that the use of components of tenderness provides a new theoretical framework within which to approach the physical and chemical causes of variation in tenderness. It is, however, difficult to train a panel for such fine discrimination, and it remains to be seen whether these components can be related to particular physical or chemical factors affecting toughness, which is necessary if they are to be useful.

The Wolodkevitch Tenderometer can be used to produce a curve with several characteristics dependent on the nature of the sample of meat tested, and it is thought that some of these may be useful as objective counterparts to the sensory components recorded by Cover and her colleagues.

This paper gives a brief account of exploratory work on the changes indicated by a Wolodkevitch Tenderometer in samples of meat given different heat treatments.

Materials.

Samples were available from four muscles of each of 36 beef animals used in an investigation on animal nutrition conducted by the Royal (Dick) School of Veterinary Science. These samples had been held in deep freeze pending use.

Heat Treatments.

Samples of about 150 gm in weight were heated in plastic bags by immersion in water baths at 50°, 60 or 80°C for one hour, or at 100°C for 1 1/2 hours: of these periods about 30 minutes were taken in raising the temperature throughout the meat up to bath temperature.

At the end of the prescribed time the bags were removed and placed in cold water for half an hour.

Examination.

From each of the heat-treated muscle samples five rectangular blocks were cut each 2 cm x 1 cm x 1 cm with the long axis as nearly as possible parallel to the general direction of the muscle fibres.

The five sub-samples were then tested on the Tenderometer and a tracing of a force-time curve was obtained for each.

The Wolodkevitch Tenderometer.

This instrument can be arranged to record what happens when a sample is squeezed between two blunt wedges. A motor presses the lower jaw upwards at constant speed. The upper jaw is connected to the top of a calibrated spring firmly anchored at the other end. As the jaws move together the spring is extended. The extension is proportional to the force being exerted. A transducer attached to the spring and a recorder with a fast moving chart transforms the progress of extension of the spring into a force-time diagram similar to those shown in Fig 1. The system used gave on one axis a 25 cm deflection for a force of 10 kg and on the other axis a 5 cm displacement for a jaw closure of 1 cm in 6 seconds.

Results.

The various sub-sample replicates often differed among themselves, but four types of curve associated with the four heat treatments were recognisable, illustrated in the figures 1(a), 1(b), 1(c) and 1(d).

In these figures the line AB represents the trace obtained if no meat is placed between the jaws and the pressure between them is increased from zero to B. The angle OAB depends on the strength of the spring, the motor bringing the jaws together and the speed of chart movement.

If meat which has been heated to 50°C is placed between the jaws, a curve of the form 1(a) is usually obtained. In this the characteristics noted are, (i), the point T above which the curve is exactly parallel with the blank line AB (it may be displaced slightly if any tissue remains unsheared between the jaws) (ii), the distance AS which indicates the effective thickness of the sample less the jaw residue; (iii), the tangent of the initial angle OSI which is proportional to the compression of the sample when it is subjected to some convenient, arbitrarily decided, small, pressure increment, in this case from 0 - 300 grams; and (iv), the tangent of the main angle OCD where CD is tangential to the curve where its direction is changing most slowly, and (v), the area STAS.

Figure 1(b) represents the type of curve most frequently obtained when the meat has been heated to 60°C. It is similar to figure 1(a), except that there usually appears, in addition, (vi), a fairly definite point of inflection at a point H. The force exerted at this point is proportional to OH indicating the pressure at which the structure of the sample begins to give way by some internal displacement or rupture of the fibres. The so-called main angle OCD is much more easily defined at this temperature.

Figure 1(c) is typical of samples heated to 80°C. In this the point H marks a pressure at which the structure of the sample suddenly gives way, a shear point. The shear force proportional to OH can be measured with some certainty. By drawing EH parallel to AB, a characteristic area SHES, (vii), is defined which is proportional to the work done on the meat sample up to the time when it gives way. The main angle OCD is usually easy to define.

Figure 1(d), typical of samples heated to 100°C, and held at that temperature for about an hour, is similar to Figure 1(c) but the shear force OH is usually less.

Table 1 quotes mean values for these various parameters, (i) to (vii) derived from five replicates of 144 samples representing four muscles from each of 36 animals.

Table 1.

Mean Values for Tenderometer Curve Characteristics.

	Characteristic	Possible Interpretation	50°	60°	80°	100°
(i)	OT	Connective Tissùe Effect	18,9	16,3	16,6	13,5
(ii)	AS	Flabbiness-Sponginess	3,5	4,3	4,9	5,3
(iii)	Tan OS1	Softness to light touch	0,88	0,84	0,93	0,88
(iv)	Tan OCD	Firmness	2,75	2,10	2,46	2,20
(v)	Area STAS	Resistance to mastication	16,1	17,3	27,4	16,5
(vi)	OH	Shear value		5,9	9,2	7,4
(vii)	Area SHES	Work on compression prior to shear		7,8	12,3	11,8

Lengths are in centimetres and areas in square centimetres, but the units are not themselves of any absolute significance, since they depend on the particular equipment used. This was not changed during this trial, but is unlikely to be reproduced exactly in other laboratories.

The detailed results have been compared by an analysis of variance. Two sources of error have been separately estimated. That due to variation between animals was greater than that due to laboratory experimental error. ($P < .001$). Some of the interactions between the four factors, sex, plane of nutrition, muscle, and heat treatments were significant when tested against the variation between animals. When the results for each muscle are considered individually, the effects of heat treatment are found to be very highly significant in all the items quoted in Table 1, other than the tangent of the initial angle. The pattern of changes due to temperature was not always the same in different muscles, and the 60° results were not always significantly different from those at 50° or 80°.

Discussion.

The temperatures chosen for these trials were based on the experience quoted by Tuomy, Lechniar and Miller (2), Machlik and Draudt (3) and Cover, Ritchey and Hostetler. 50°C is about the lowest cooking temperature which taste panel members will accept. 60°C was expected to show effects due to the shrinkage of collagen, but this may have been rather too low to show a maximum effect. It was hoped that the difference between 60° and 80°C would show the effects of denaturation of the fibre proteins, while the difference between 80°C and 100°C should show differences due to the gelatinization of collagen.

The measurements made almost certainly reflect some of the changes in the various sensations contributing to the sensory appreciation of texture in meat.

It seems probable that the initial angle may be highly correlated with 'softness to tongue and cheek,' that the main angle may be correlated with 'softness to tooth pressure,' the shear height with 'friability,' and the areas under the curves with 'adhesion' and with the 'amount and tenderness of connective tissue.' These relationships have not however been proved. The height OT' is greatest when strong strands of connective tissue occur in the sample. It is often difficult to measure precisely but is thought to be a rough measure of one particular aspect of toughness. It also indicates a limit to the area STAS proportional to the total work done on the sample. It was originally expected that the lengths of the baseline AS would be constant since the samples were cut to a standard size, but in fact it was found that it showed a significant difference due to heat treatment. After cutting, the under-cooked samples at 50° and 60°C tend to collapse a little under their own weight, while those cooked to 80° or 100°C may increase in size as fibres separate by relaxation. This measurement may therefore reflect the flabbiness of under-cooked, or the sponginess of fully cooked samples.

Force-time curve characteristics developed from other instruments or by other modifications of the Wolodkevitch Tenderometer may be more accurate, more easily intelligible and easier to record automatically. Those quoted in this paper are capable of much improvement.

When the relationship between sensory assessments and objective measures such as those reported here has been more fully explored, it may be easier for research workers to study the conditions governing toughness, tenderness, and practical methods of control before or during cooking.

References.

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Effects of Heat Treatment