DEVELOPMENT OF A TECHNIQUE FOR MEASURING TENDERNESS IN MEAT USING A "TENSIPRESSER"

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SUMMARY

In order to develop a methodology to accurately and objectively evaluate meat tenderness, the single most important factor in determining the grade level, we have investigated the use of a "Tensipresser"(an apparatus to measure physical resistance) using a modified probe. Meat samples were selected from the longissimus thorasis of twelve pigs raised by standard procedures to between 100 and 110 kg. These were cut along the meat grain in elongated cubes of 2 x 2 x 5 cm, and the samples were then divided into groups which were heated in hot water to 70 ℃ or 90 ℃ for 30, 60 and 90 minutes respectively. The outer portions of these samples were trimed off to leave the samples 1 x 1 x 4 cm. These were then tested with a Tensipresser using an up and down motion to imitate chewing action in order to measure tenderness (severing point threshold) and pliability. A round, hollow 5.5 mm diameter plunger (inner diameter 5 mm) was used. Using this method of placing the tip of the hollow plunger on the surface of the cooked meat and gently thrusting it into the meat using an up and down motion, we were able to accurately measure the breaking point threshold, which had been very difficult to measure with one-time, straight thrusting method. Likewise, we were able to measure the pliability of the meat as indicated by the value calculated from the graph of the resistant force on the plunger as a function of depth of penetration. When pork longissimus thorasis is compared as a function of cooking temperature, cooking time, and whether the meat had been in cold storage or frozen, it was found that there was no significant difference in the severing point threshold between meat that had been frozen and meat that had only been chilled, but that the values for 70 ℃ were higher than for 90 ℃ ($P<0.05$) and the values decreased as the heating time was increased ($P<0.01$). There was, however, a significant difference in pliability, with higher values for pliability of chilled meat over frozen (for all, $P<0.01$). Thus, from these results, we were able to determine that using this method, one can accurately measure both the tenderness and pliability of pork.

INTRODUCTION

The tenderness of meat is considered to be the most important characteristic to consider in evaluating meat quality. Accurately and objectively measuring this value, however, has presented a number of problems. The method that has been widely used as a standard method by the measuring of the Warner-Blatzler's shearing force value, but it has been shown to have a high level of variability in values. It also has the disadvantage of requiring a large number of trials, with the result that its use has been difficult unless the meat involved came in large amounts, such as beef roast, etc (Deatherage et al 1952, Paul and Bratzler 1955a,b). Likewise, recently, various measuring devices such as the Instron have been developed to gauge meat tenderness (Bouton et al. 1971, Bouton and Harris 1972a,b,c), but depending on how they are calibrated and what the measurement parameters are, as with the measuring of shearing force value, there is also a high level of variability, and thus, it has been difficult to truly standarlize quality control. Our experiments with an instrument called the "Tensipresser" has yielded a new method that requires only a small sample and gives quite accurate results in measuring the severing threshold point and the pliability, both of which are thought to be closely related to the tenderness of meat. The following is a summary of our methodology and findings.

METHODOLOGY AND MATERIALS

As is shown in Fig. 1, the meat sample is placed between the plunger of the Tensipresser and the tray that acts as a sample holder. This tray moves up and down to simulate chewing, and the amount of stress or pressure sensed by the stationary plunger is measure and displayed in the form of a wave pattern on the oscilloscope shown of the left. While not shown in the figure, the signal is analyzed by a computer connected up to the apparatus. The meat samples used were from 12 pigs raised by standard feeding to 100 - 110 kg weight. After slaughter, the carcasses were hung in cold storage for two days, and then the longissimus thorasis was removed from both the left and right half-carcasses, with one side being tested as the fresh meat sample while the other was vacuum sealed and quick frozen to -30℃. The frozen samples were later thawed and tested in the same manner as the chilled sample. As is indicated in Fig. 2, the meat samples were cut into cubes 2 x 2 x 5 cm with the long side parallel to the meat grain. These were then vacuum sealed in polyethylene bags and heated in hot water at either 70℃ or 90℃ for 30, 60 and 90 minutes respectively. As is shown in Fig. 3, the cooked sample on the left experienced some deformation due to shrinkage, and since there is a difference in the amount of shrinkage between the center of the sample and the outside, the outer portions were trimmed off to leave a sample 1 x 1 x 4 cm, as is shown on the right in Fig. 3.

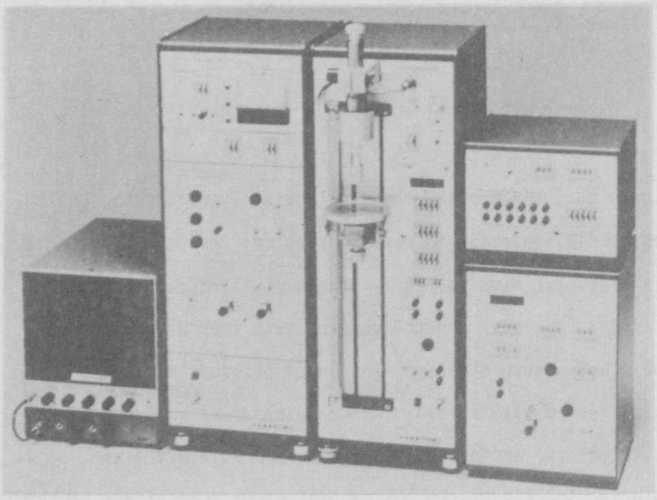


Fig. 1 Tensipresser

The meat sample is placed on the tray beneath the plunger in the center of the picture. As the tray holding the sample is moved up and down, the stress or pressure sensed by the plunger is displayed as a wave pattern on the oscilloscope on the left. While not shown in the figure, the signal is analyzed by a computer connected up to the apparatus.

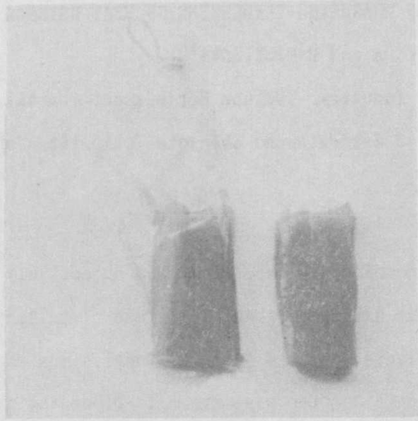


Fig. 2 Penetration of meat samples from pork longissimus thorasis

The meat samples were taken from the centtal portion of the longissimus thorasis and cut into 2 x 2 x 5 cm cubes with the elongated axis being parallel to the meat grain, as in the sample shown on the right. The sample on the left shows the meat having been vacuum packed in preparation for cooking in a hot water bath.

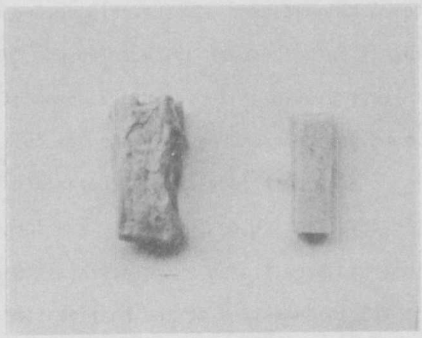


Fig. 3 Cooked meat and preparation of sample for measurement

The sample on the left has been cooked and removed from the polyethylene bag. This is then pared down to a meat sample of 1 x 1 x 4 cm by trimming off the outer portions. This prepares the sample for testing in the Tensipresser.

RESULTS AND DISCUSSION

A round, hollow plunger with an outer diameter of 5.5 mm and an inner diameter of 5 mm was used, and the sample was placed so that the grain of the meat was at right angles with the plunger. The tray on which the sample rests was then moved in 0.5 mm cycles up and down with each cycle progressing up an additional 0.04 mm. Thus in order to move upward a total of 10 mm, the apparatus goes through 250 cycles of up and down motion (see Fig. 4). The locus of stress as sensed by the plunger is shown in the graph in Fig. 5. The severing threshold value, which is thought to accurately indicate meat tenderness, was easily and accurately measured. Because the cylindrical plunger is hollow, the force it exerts on the meat fibers does not cause them to simply flatten out and separate (as would be the case with a solid plunger). Instead, since the meat fibers can be pushed up int the cylinder, they are cleanly severed when the threshold is reached. The threshold point at which severing of the fibers first begins appears to be most accurately represented by point D in Fig. 5, which is the peak value of the locus of stress on the plunger during the withdrawal phase when the plunger has been withdrawn 0.5 mm prior to being trust in again that 0.5 mm plus an additional 0.04 mm during the next cycle. When a vertical line is drawn through point D, point A is the point where it intersect with the line representing the peak stress values on the plunger at greatest penetration, and point C is the point of intersectio with the x-axis. The height of this line segment AC is thought to indicate the severing threshold value of the sample. A value that is thought to represent the pliability of a meat sample can also be calculated from the information plotted in Fig. 5. This value is calculated as the area of the ABC triangle (a) divided by the area of the AEBC region (b). The reason this is thought t represent pliability is because for meat that has little viscoelasticity, the curved line of points beginning at point B (when th plunger first touches the meat sample) to point A (BEA) approaches the straight BA line. Figures 6 and 7 show the results of us this method of determining the severing threshold value and pliability value for samples of longissimus thorasis of pork, with comparisons for different heating temperatures and times along with that of frozen versus fresh chilled meat. As for the severi threshold value, there was no significant difference between meat that had been frozen and meat that had only been chilled. Differences in cooking conditions, however, did alter the severing threshold value with the 70℃ being greater than the 90℃ sam (P<0.05), and with a decrease in value for longer cooking times. With respect to pliability, however, all of the variables had significant effect, with lower temperatures, shorter cooking times and fresh chilled over frozen having a higher pliability valu

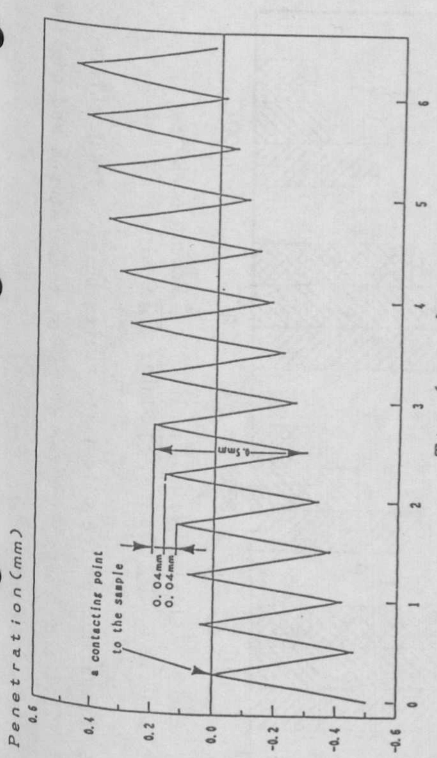


Fig. 4 Graph of motion of the Tensipresser sample tray
A hollow cylinder with an outer diameter of 5.5 mm and an inner diameter of 5 mm was used as the plunger. The meat sample was placed on the tray so that its long axis (and thus the meat grain) was perpendicular to the plunger. One up and down cycle involved a displacement of 0.5mm plus and additional 0.04 mm with each cycle as the sample was progressively penetrated. In order to move the entire 10 mm (the thickness of the sample), a total of 250 cycles was required. This is totally different from previous apparatus which could not cause penetration in this gradual, chewing-like method.

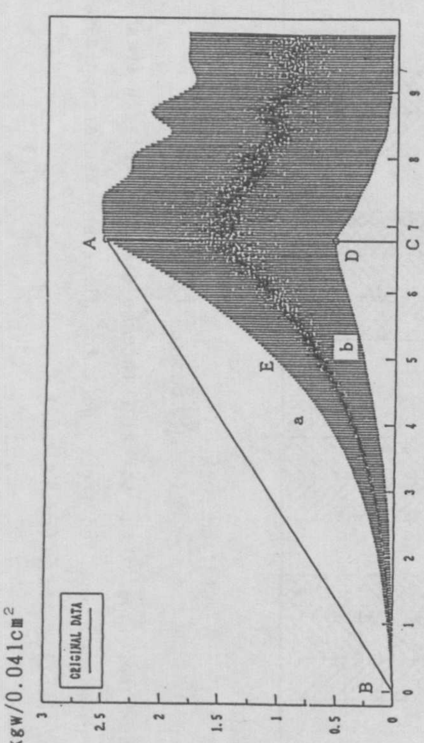
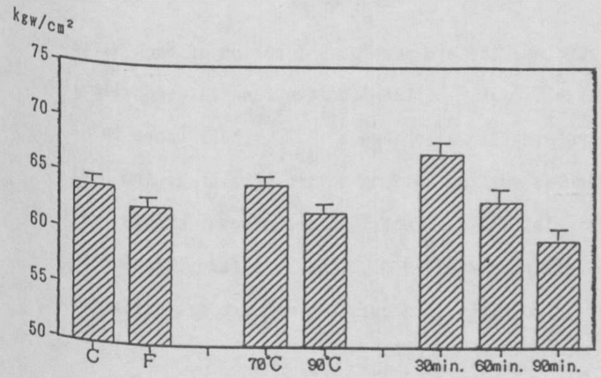


Fig. 5 Resistance (stress) encountered by the Tensipresser plunger as a function of its increasing penetration into a meat sample, mimicking chewing action
As the plunger gradually penetrated the meat sample in 0.5mm cycles of up and down motion, the stress felt by the plunger at the point of maximum withdrawal in each cycle (back pressure) reached a maximum values at point D, which was interpreted as the initial point of the actual severing of meat fibers. Point A is determined by drawing a vertical line through point D until it intersects with the curve representing the maximum values of stress encountered by the plunger at the maximum penetration during each cycle. The height of the line segment AC, then, has been interpreted to represent the severing threshold value of the sample. The value for pliability is calcurated by diving the area of the ABC triangle (a) by the area of the AEBC region (b).

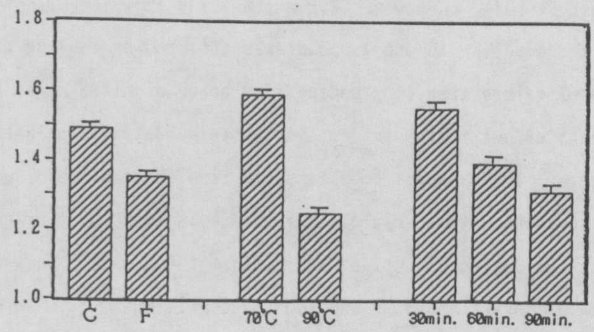


Source of variation	Results of F test
Method of storage of raw meat	
Heating temperature	*
Length of heating time	**
Method of stòrage vs. temperature	**
Method of storage vs. time	
Temperature vs. time	**

* P<0.05, ** P<0.01

Fig. 6 The analysis of variance of severing threshold values for pork samples handled with variations in storage conditions (frozen vs. fresh chilled), and heating temperatures and times (mean ± s.e.)

The bar graph above shows the effects on severing threshold values of various parameters as averaged with respect to the other variables as calculated by least squares method. The table below shows the results of the analysis of variance of each main effect and their interaction effect.



Source of variation	Results of F test
Method of storage of raw meat	**
Heating temperature	**
Length of heating time	**
Method of storage vs. temperature	**
Method of storage vs. time	**
Temperature vs. time	**

* P<0.05, ** P<0.01

Fig. 7 The analysis of variance of pliability values for pork samples handled with variations in storage conditons (frozen vs. fresh chilled), and heating temperatures and times (mean ± s.e.)

The bar graph above shows the effects on pliability values of various parameters as averaged with respect to the other variables as calculated by least squares method. The table below shows the results of the analysis of variance of each main effect and their interaction effect.

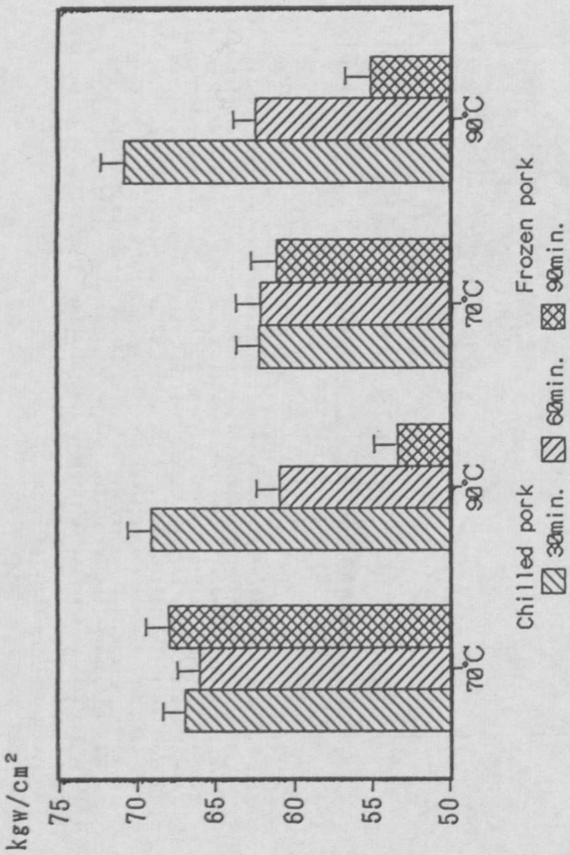


Fig. 8 Comparison of the severing threshold values between fresh chilled pork and frozen pork for different temperatures and heating times (mean±s.e.)

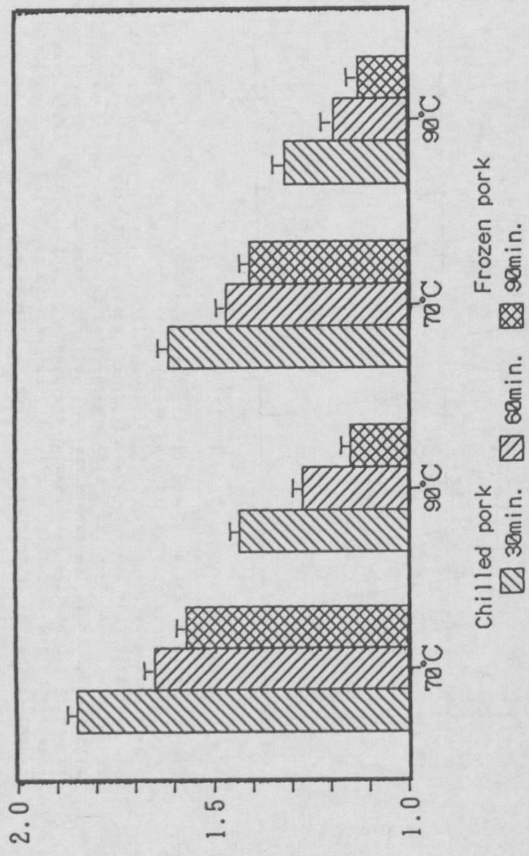


Fig. 9 Comparison of the pliability values between fresh chilled pork and frozen pork for different temperatures and heating times (mean±s.e.)

(each with $P<0.01$). Likewise, Figures 8 and 9 show the mean value of each subclass (single bar) as a function of each variable. The way the severing threshold point was affected by cooking time differed significantly between the two temperatures with the lowering of values with lengthening time being significant at 90℃ but with no significant change at 70℃. Thus, there was a significant effect of the interaction between heating time heating temperature as well as between method of starage and heating temperature. With respect to pliability, the interaction of each set of variables (main effects) in significant changes with respect to cooking time. In other words, both forms of storage and both temperatures yielded declines as a function of cooking time, but the degree of decline was different for each. This showed that it is possible to accurately measure the differences caused by different handling and cooking conditions.

CONCLUSION

With the use of the hollow plunger Tensipresser system, and by gradually penetrating the meat with an up and down motion, we have shown that the initial point of severing of meat fibers can easily be measured. Likewise, we have shown that the value we think accurately represents the pliability of meat can be easily calculated from the locus of stress on the plunger as a function of penetration. We were also able to accurately show through the use of this method how different variables of pork meat handling and preparation affected the final outcome of both meat tenderness and pliability.

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