S3P20.WP

INFLUENCE OF AGEING TIME, STORAGE TEMPERATURE AND PERCENTAGE LEAN ON THE EATING QUALITY OF PORK AND ITS RELATIONSHIP TO INSTRUMENTAL AND STRUCTURAL PARAMETERS

E. TORNBERG, G. VON SETH and A. GÖRANSSON

Swedish Meat Research Institute, POB 504, S-244 24 Kävlinge, Sweden

Please refer to Folio 20.

INTRODUCTION

The toughness/tenderness of pork has not been as focused on as that of beef and lamb. This is understandable in view of the more commonly tender pork, compared to that of other species. When the sensory properties of pork have been studied, mostly this has concerned the influence of breed (Fjelkner-Modig, S. 1985), aberrations in quality (Jeremiah, 1983; Tornberg *et al.*, 1992) intramuscular fat content (Fjelkner-Modig and Tornberg, 1986; Bejerholm and Barton-Gade, 1986; Göransson *et al.*, 1992) and ante-mortem factors (see the review by Ashgar and Pearson, 1980). The influence of the ageing of pork has been less studied (Bejerholm, 1991), in particular prolonged ageing at higher temperatures. Moreover, in a recent study by Göransson *et al.* (1992) it was shown that tenderness in the anterior piece of *m.longissimus dorsi* was negatively affected by percentage lean. Therefore in this study an experiment was set-up as a fractional factorial design, where ageing time (4, 6 and 8 days), storage temperature (2, 4 and 6°C) and percentage lean (57, 60 and 63%) comprised the factors.
When measuring meat tenderness, not only has sensory evaluation been used, but also, mostly, some instrumental methods of texture analysis. Often different results are obtained, depending on the method used, since test conditions vary between laboratories. Moreover, poor correlations between instrumental and sensory methods are often found. Szczesniak and Torgeson (1965) found in their review paper correlation coefficients varying from r=-0.001 to r=-0.942.

The tensile test is a good texture analysis, as there is a well-defined stress and strain set-up, using uniaxial tensile forces, which will give the basic mechanical properties of the meat. Tensile tests are also better than any shear or compression tests as it is easier to observe where the meat breaks and how the fracture propagates as the meat is pulled apart. Therefore, we have in this investigation performed tensile strength measurements along and across the fibres. For comparison, shear-force tests were also carried out using a modified version of the Warner-Bratzler (WB) shear device. The tensile testing of beef has been used (Bouton and Harris, 1972a; 1972b; Munro, 1983; Purslow, 1985) but to our knowledge nothing has been published so far using this type of analysis on pork.

The structure of the meat samples has also been carried out in order to give a fuller description of the textural characteristics of the meat samples.

MATERIAL AND METHODS

Experimental design and sampling procedure

Longissimus dorsi (LD) muscles were selected from 36 (18 gilts and 18 boars) commercially crossbred pigs (Hampshire (Swedish Yorkshire x Swedish Landrace)). Factors which might affect the eating quality, such as pH_1 (45 minutes post-mortem), carcass weight, pH_{24} and FOP_{24}, were kept as constant and normal as possible. It turned out to be very difficult to follow all the restrictions that were set-up, therefore some pigs with a percentage lean of 56% and

62% were included in the 57% and 63% groups, respectively. The LD muscles were cut out the day after slaughter, vacuum-packed and stored at the chosen temperatures and days.

Chemical analysis

The content of IMF (SBR-method, NMKL; 1974) was analyzed in a 4cm section of the LD muscle removed at the last rib.

Sensory analysis

The pork loins were assessed by a trained 9-member taste panel. Two-cm slices were fried for about 2x3 minutes (165oC) to an internal temperature of 68oC. Tenderness, chewing time, chewing residual, flavour and juiciness were judged on a 9-point scale, where 1 = very tough, very short, very small, weak flavour and very dry and 9 = very tender, very long, very large, strong flavour and very juicy.

Tensile strength and shear-force measurements

Tensile strength measurements were performed on the right side loin and measured in a uniaxial mode using an Instron Universal Testing Machine (4301). The measurements were performed on dumb-bell shaped slices (2x5x0.5cm) which were punched out from a bigger slice (5x15x2cm) in such a way that the fibres ran both parallel and perpendicular to the direction of the applied stress. Before the small slices were cut out, the bigger slice was fried to an internal temperature of 68oC. Pneumatic action grips (Instron) were used to hold the test strips, with a gauge length of 35mm set between them. The extension rate was 48mm min^{-1}. Eight replic for each direction were made. The registered parameters were fracture stress perpendicular (kPa) and fracture stress parallel (kPa).
Shear-force measurements were performed on the left side loin using a modified Warner-Bratzler (WB) device described by Bouton and Harris (1978). Prior to analysis, the 3cm thick slices were fried on a single-side griddle at 165oC to an internal temperature of 68oC (2x6 min). Twelve pieces with a cross-sectional area of 0.7x1.5cm were cut out. The peak shear-forces (N) were determined.

Structure analysis

Meat samples were fixed and embedded mainly according to Kotter (1955) described by Tornberg and Larsson (1986). Thin transversal sections (15μm) were cut in a cryostat microtome and the microstructures were studied under a light microscope. Photographs from two meat samples/LD were taken and an image analysis system was used for determination of the number of fibres per area unit, surface area per fibre and total fibre area per area unit. About 275 fibres/LD were studied.

Statistical analysis

Data was analysed using the SYSTAT program (WILKINSON, 1990) using Turkey's test, Pearson correlation matrix and Regression analysis. The regression model used to predict the influence of the different factors on the recorded sensory, instrumental and structure traits was:

$$Y = CONSTANT + k_1 (TEMPERATURE) + k_2 (DAYS\ POST\text{-}MORTEM, DPM) + k_3 (PERCENTAGE\ LEAN)$$

Before the analysis was performed, all three factors were normalised to vary between -1 and +1. One pig was excluded because it was considered to be an outlier.

RESULTS AND DISCUSSION

Sensory traits

Chewing time and chewing residual were significantly influenced by changes in percentage lean (Table 1), while for the other evaluated sensory parameters such as tenderness, juiciness and meat flavour no significant differences could be observed. When studying the sensory profile, chewing time and chewing residual are often used together with tenderness because these traits are easier to quantify. Although no significant difference in tenderness was seen, the tendency was the same as for the chewing time and a good correlation coefficient between them was also seen r=-0.885***. The fact that meat seems to get tougher with higher percentage lean is a remarkable result as one of the most important goals in the breeding of pigs in to increase the percentage lean. This was also shown by Göransson *et al.* (1992), where they showed that the intra-muscular fat content had no bearing on tenderness. This observation was further substantiated in this investigation, where the correlation coefficients between tenderness and percentage lean and IMF were r=-0.37* and r=0.07$^{n.s.}$ respectively.

The different storage temperatures had no significant effect on the sensory traits, whereas an increase in the storage time from four to eight days increased the meat flavour (P=0.056) from a value of 5.5 to 5.9.

Using regression analysis with normalised values, varying between
-1 and +1, the degree and type of influence of the different parameters on the sensory properties is feasible, comparing the regression coefficients. Figure 1 shows the influence of storage time, temperature and percentage lean on the sensory trait tenderness. The model explained 25% of the variation with a significance level of P=0.03. Both storage time and percentage lean influenced tenderness significantly and to the same extent (≈0.2 units), although in the opposite direction. This means that storage time increases tenderness whereas percentage lean decreases it.

Instrumental traits

From Table 2 it can be seen that the fracture stress obtained from meat samples in parallel mode is about three times higher than that in perpendicular mode. Another interesting observation that can be extracted from Table 2 is the tendency for fracture stress perpendicular to fibre direction to increase at higher percentage lean, unlike fracture stress parallel. It was also observed the tendency that the fracture stress parallel muscle fibre direction, unlike the fracture stress perpendicular to muscle fibre, declined with ageing temperature (2 to 6°C) from 193 to 157kPa. An increase in ageing time from 4 to 8dpm gave rise to the same tendency, i.e., a decrease in fracture stress parallel to fibre direction from 183 to 148kPa. This has also been observed for beef by Bouton and Harris (1972c) and Purslow (1991). None of the investigated factors affected the shear-force values.

Using the same type of regression analysis as with tenderness, the influence of ageing time, temperature and percentage lean on fracture stress perpendicular is visualised in Figure 2.

The only significant influence is exerted by percentage lean, giving a greater fracture stress perpendicular the higher the percentage lean. This behaviour is contrary to that observed for the fracture stress parallel to the muscle fibre direction (Figure 3), because for the fracture stress parallel to the fibre direction, the largest influence is obtained for storage temperature and time and not for the percentage lean. As we know that the two latter parameters govern the myofibrillar tenderness and that the fracture has to go across the fibres in the parallel mode the achieved relationship seems plausible.

These results suggest that fracture stress perpendicular and parallel, respectively, measure different aspects of the sensory evaluated tenderness, since the latter is governed by both percentage lean and storage time. By choosing tensile strength measurements, it is possible to study separately the different and relevant factors affecting meat tenderness.

Structural traits

Storage time and temperature did not influence the type of meat structure measured in this investigation, i.e., the transverse fibre dimensions. However, there was an almost significant (P=0.078) increase in the transverse fibre surface area, comparing the lowest and the highest percentage lean (Table 3). Consequently, the number of fibres per area unit decreased with percentage lean, whereas the total fibre area was constant.

A regression analysis between number of fibres and storage temperature, time and percentage lean, using normalised values, gave the result (Figure 4) that only percentage lean significantly influenced the number in fibres of the studied factors. The same relationship was obtained for the fracture stress perpendicular (Figure 2), which suggests that the maximum force needed to separate fibres and fibre bundles is governed by their size. Evidently, the fracture stress perpendicular is lower if the number of fibres is higher or if the transverse fibre area is smaller at a constant total fibre area.

CONCLUSIONS

There is a risk that meat becomes tougher when the pigs get too lean. This phenomenon is not explained by the differences in IMF but rather by the meat structure itself. Choosing tensile strength instead of shear-force measurements makes it possible to study separately the different and relevant factors affecting meat tenderness.

REFERENCES

ASGHAR, A., and PEARSON, A.M. 1980. Influence of ante-and post-mortem treatments upon muscle composition and meat quality. *Adv. Food Res.* 26:53pp.

BEIJERHOLM, C., and BARTON-GADE, P.A. 1986. *Svin-spisekvalitet.* Manuscript No. 720E.

BEIJERHOLM, C. 1991. The effect of ageing on the eating quality of normal pork loins. *Proc. 37th ICMST.* 1:48pp.

BOUTON, P.E., and HARRIS, P.V. 1972a. The effects of cooking temperature and time on some mechanical properties of meat. *J. Fd. Sci.* 37:140-144.

BOUTON, P.E., and HARRIS, P.V. 1972b. A comparison of some objective methods used to assess meat tenderness. *J. Fd. Sci.* 37:218-221.

BOUTON, P.E., and HARRIS, P.V. 1972c. The effects of some post-slaughter treatments on the mechanical properties of bovine and ovine muscle. *J. Fd. Sci.* 37:539-543.

BOUTON, P.E., and HARRIS, P.V. 1978. Factors affecting tensile and Warner-Bratzler shear values of raw and cooked meat. *J. Text. Studies.* 9:395-413.

FJELKNER-MODIG, S. 1985. *Sensory and Biophysical properties of pork.* Thesis, Lund.

FJELKNER-MODIG, S., and TORNBERG, E. 1986. Intramuscular lipids in M. longissimus dorsi from pork, as related to breed and sensory properties. *J. Food Quality.* 9:143-160.

GÖRANSSON, Å., von SETH, G., and TORNBERG, E. 1992. The influence of intramuscular fat content on the eating quality of pork. *Proc. 38th ICMST.* Clermont-Ferrand, France. 2:4.07.

JEREMIAH, L.E. 1983. The influence of inherent muscle quality upon the cooking losses from the palability attributes of pork loin chops. *J. Anim. Sci.* 1:223pp.

KOTTER, L. 1955. Neue Wege bei der histologischen Wurstuntersuchung. Beri. Münch. *Tierärtzl. Wschr.* 68:360pp.

MUNRO, P.A. 1983. The tensile properties of frozen and thawed lean beef. *Meat Sci.* 8:43-61.

NMKL, Nordisk Metodik-Komité för levnedsmidler. 1974. Fedtbestemmelse i köd og ködvarer efter SBR. Forskrift nr. 88. Teknisk forlag, Köbenhavn.

PURSLOW, P.P. 1985. The Physical Basis of Meat Texture: Observations on Fracture Behaviour of Cooked Bovine M. semitendinosus. *Meat Sci.* 12:39-60.

PURSLOW, P.P. 1991. Measuring meat texture and understanding its structural basis. In: VINCENT, J.F.V., and LILLIFORD, P.J. (eds). *Feeding and the exture of food.* (Proceedings Soc. Exp. Biol. Symp. Edinburgh, 1989). Cambridge University Press, Cambridge, 35.

SZCESNIAK. A.S., and TORGESON, K.W. 1965. Methods of meat texture measurements viewed from the background of factors affecting tenderness. *Adv. in Food Research.* 14:33-165.

TORNBERG, E., and LARSSON, G. 1986. Changes in water distribution of beef muscle during cooking - as measured by pulse-NMR. 32nd European Meeting of Meat Research workers, Ghent, 9:4, 437-440.

TORNBERG, E., ANDERSSON, A., GÖRANSSON, Å., and von SETH, G. 1992. Water and fat distribution in pork in relation to sensory properties. OECD Seminar "Pork Quality, Genetics and Metabolic Factors", Helsinki.

Table 1. Means values and standard deviations of the sensory properties of porcine LD with different percentage lean.

Sensory properties:	Percentage lean (%) 57 Mean	sd	60 Mean	sd	63 Mean	sd
Tenderness	6.1	0.6	5.9	0.6	5.7	0.8
Chewing time	4.0[b]	0.4	4.3	0.5	4.6[b]	0.6
Chewing residual	3.2[c]	0.3	3.3	0.4	3.6[c]	0.6
Juiciness	6.3	0.7	5.9	0.5	6.1	0.6
Meat flavour	5.8	0.5	5.7	0.4	5.7	0.2

Levels of significance: b=0.01; c=0.05.

Table 2. Mean values and standard deviations of the instrumental texture measurements of porcine LD with different percentage lean.

Instrumental texture properties	Percentage lean (%) 57 Mean	sd	60 Mean	sd	63 Mean	sd
Fracture stress, perpendicular (kPa)	47.6	8.4	46.4[c]	9.3	57.6[c]	15.0
Fracture stress, parallel (kPa)	171.7	58.6	172.2	58.0	176.5	48.3
Warner-Bratzler shear force (N)	68.8	14.2	69.0	17.3	77.7	15.7

Level of significance: c=0.069.

Table 3. Mean values and standard deviations of the meat structural traits of porcine LD with different percentage lean.

Structural properties	Percentage lean (%) 57 Mean	sd	60 Mean	sd	63 Mean	sd
Surface area per fibre (x 10^{-3} mm²)	3.1[c]	0.5	3.4	0.5	3.6[c]	0.5
Number of fibres per area (mm²)	299[c]	44	274	44	259[c]	40
Total fibre area per unit area (%)	91.3	3.2	91.2	4.2	91.3	4.1

Level of significance: c=0.078.