4:6 Myofibril fragmentation index and sensory properties of pork and beef during post mortem storage.

S. FJELKNER-MODIG

Swedish Meat Research Institute, POB 504, S-244 00 Kävlinge, SWEDEN.

Introduction

The sensory properties of meat, especially tenderness, are improved by post mortem storage. At a storage temperature of 2-4°C a tenderising time of 7 days is satisfactory for electrically stimulated beef but 14 days is necessary for non-stimulated beef (Dransfield et al., 1980-81, Fjelkner-Modig & Rudérus, 1983). 4-5 days are sufficient for pork (Dransfield et al., 1980-81).

When evaluating the different factors that affect tenderness it would be of great value to be able to follow the tenderising process with an instrumental method that agrees well with sensory evaluation.

Histological studies have shown that the myofibrils, due to weakening in the region of the Z-lines, break into shorter and shorter fragments during ageing (Davey & Gilbert, 1969, Olson et al., 1976). The degree of fragmentation has been quantified as a) myofibril fragmentation index (MFI) - by measuring the absorbance of a defined myofibril suspension (Olson et al., 1976), b) the average number of sarcomers per fibril - by examining myofibril sediment in a phase contrast microscope (Møller et al., 1973, Jeremiah & Martin, 1978) and c) fragmentation index (FI) - by weighing residue fraction after homogenisation, stepwise filtration and centrifugation (Reagan et al., 1975, Davis et al., 1980).

The myofibril fragmentation accounts for about 50% of the variation in tenderness of beef steak (MacBride & Parrish, 1977, Olson & Parrish, 1977, Calkins et al., 1980, Davis et al., 1980). Olson & Parrish (1977) have reported significant correlation coefficients between MFI and sensory evaluated tenderness for M. longissimus dorsi of both beef and veal, aged for 1 and 7 days. The correlation coefficients ranged from 0.65 (bovine, C-maturity, aged 7 days) to 0.95 (veal, aged 7 days). An increase with ageing time was noticed in both tenderness and MFI. However, no information was given concerning the relationship between the increase of MFI and the tenderness increase. Most often correlation coefficients between 0.4 and 0.7 are reported for bovine meat of a defined ageing time (MacBride & Parrish, 1977, Møller et al., 1978, Calkins et al., 1980 and Davis et al., 1980). The main reasons given for the variation in correlation coefficients were the age of the cattle, the maturity and grading quality of the carcasses and differences in the MFI analysis.

Olson et al. (1976) are the only ones who have followed the tenderising process by recording both MFI and tenderness. However, they have not reported any statistical evaluation. Moreover, they recorded tenderness as shear force values and, as shown by Olson & Parrish (1977), Fjelkner-Modig & Rudérus (1983) and others, a shear force value is not always a good predictor of sensory tenderness (r = -0.5 to -0.95).

The purpose of this study was to follow the tenderising process by MFI and sensory evaluation in both beef and pork and to evaluate MFI as a predictor of tenderness.

Materials and Methods

M. longissimus dorsi (LD, 11th vertebra thoracica - 5th vertebra lumbalis) was cut from three bovine carcasses and six porcine carcasses one day post mortem. The beef samples are denominated B1-3 and the pork samples P1-3 and H1-3. B1 and B2 were young bulls and B3 a heifer, all of Swedish lowland breed. They were about 2 years old when slaughtered, electrically stimulated, graded and chilled according to routine methods. The carcasses were all of normal grade and the final pH (recorded by a Knick Portamess 651 pH-meter with an Ingold 404 glass electrode) were 5.4 (B1), 5.6 (B2) and 5.5 (B3).

The samples denominated P1, P2 and P3 were taken from crossbred gilts of Swedish Landrace and Swedish Yorkshire and the rest (H1, H2 and H3) were crossbred gilts of Hampshire, Swedish Landrace and Swedish Yorkshire. The gilts were slaughtered at 6 months and graded and chilled according to routine methods. The carcasses were all of normal grade and the final pH were 5.6 (P1), 5.4 (P2), 5.8 (P3), 5.5 (H1), 5.4 (H2) and 5.6 (H3).

MFI was determined at the same time as the sensory evaluations were made at 24, 48, 96 and 168 hours post mortem. The bovine samples were also analysed at 240 hours post mortem. The samples were stored in plastic bags at +4°C.

MFI was determined as absorbance value at 540 nm in a myofibril suspension. The MFI method of Olson et al. (1976) was used.

The sensory evaluation of the beef samples was performed by 10 trained persons. The pork samples were evaluated by 8 judges.

Slices of 1.5 cm thickness were fried at 180°C on a double sided griddle immediately before the sensory evaluation. The frying was interrupted at a centre temperature of 65°C. The end point temperature was recorded by thermocouples. The slices were cut into pieces, 2.5 x 2.5 cm, which were served hot. The judges were asked to evaluate tenderness (1 = very tough, 9 = very tender), chewing time (1 = very short, 9 = very long), chewing residual (1 = very little, 9 = very much) and for the pork samples also juiciness (1 = very dry, 9 = very juicy). At each session the judges were served 3 samples, one at a time. Between the samples the panelists were asked to rinse their mouths with distilled water and an unsweetened biscuit.

The points given by the judges were first studied by comparing the scores from each individual judge with a weighed average value at each time post mortem. In time some of the judges showed a scoring pattern, diverging from the average values, although they previously had shown good agreement with the group. Using a linear regression analysis, the scores of those judges correlating poorly with the average values, were excluded from further statistical analysis.

For further statistical analysis the results from the six remaining panelists were transformed by using the linear regression coefficients. By this transformation, the bias caused by different usage of the scales among the judges, was reduced to a minimum. The relationship between the transformed sensory results and MFI were analysed by linear regression analysis. The relationships between the sensory attributes were studied by calculating the partial coefficients.

Results

The results of the MFI determinations and the sensory evaluation are shown (at different points of time) in Table 1 (beef) and Table 2 (pork). The sensory attributes, i.e. tenderness, chewing time, chewing residual and juiciness are given as average values.

Analysis	Time post mortem (hours)	Sample B1	B2	B3
MFI	24	53	58	76
	48	64	62	86
	96	67	*	86
	168	78	67	88
	240	84	83	100
Tenderness	24	2.4	1.9	5.6
	48	1.5	2.8	5.5
	96	2.0	2.3	7.2
	168	2.3	2.7	7.0
	240	2.9	3.3	7.6
Chewing time	24	7.6	6.9	5.2
	48	8.1	8.1	4.0
	96	8.2	7.8	3.5
	168	6.4	7.5	3.4
	240	6.7	5.9	3.1
Chewing residual	24	7.3	6.7	4.7
	48	8.1	7.6	3.8
	96	7.4	7.2	3.6
	168	6.2	8.2	2.7
	240	6.1	5.3	2.9

* = missing value

Table 1. The MFI-values (absorbance at 540 nm x 100) and the results from the sensory evaluation of M. longissimus dorsi from 3 beefs.

The meat from the two young bulls (B1 and B2) was surprisingly tough even after 10 days of ageing at +4°C. The increase in tenderness and the decreases in chewing time and chewing residual, were less for B1 and B2 than for B3. However, the increase in MFI values from 1 to 10 days post mortem, were almost the same for all three samples.

The meat samples from the three-breed crosses (H1-H3) were more tender and gave shorter chewing time and less chewing residual than those from the two-breed crosses (P1-P3) (Table 2).

Analysis	Time post mortem (hours)	Sample P1	P2	P3	H1	H2	H3
MFI	24	82	60	68	81	71	65
	48	85	73	80	82	82	73
	96	86	*	91	90	90	85
	168	100	98	95	101	106	99
Tenderness	24	2.5	3.9	4.0	3.6	4.8	4.0
	48	3.6	4.7	3.9	3.8	5.6	5.8
	96	3.3	3.3	4.0	4.4	6.5	5.2
	168	6.4	5.1	4.9	6.5	6.7	6.6
Chewing time	24	7.7	8.0	6.5	5.6	6.2	7.1
	48	7.3	7.0	6.4	6.1	5.0	6.7
	96	6.9	6.2	6.0	5.9	4.5	4.5
	168	5.2	5.4	5.3	4.3	3.2	3.0
Chewing residual	24	7.3	7.2	5.5	7.1	6.3	5.7
	48	6.9	7.7	6.1	5.7	5.6	6.1
	96	6.8	6.1	5.6	5.8	4.0	4.6
	168	4.6	5.2	6.5	3.5	3.2	3.5
Juiciness	24	6.6	7.0	7.2	6.7	7.4	6.9
	48	7.3	7.4	7.8	7.1	7.4	6.7
	96	6.7	5.8	7.1	7.6	7.3	7.2
	168	7.5	7.4	7.0	7.9	7.8	7.5

* = missing value

Table 2. The MFI values (absorbance at 540 nm x 100) and the results from the sensory evaluation of M. longissimus dorsi from 6 porks.

The samples from the two-breed crosses showed a wider variation in eating quality than those of the three-breed crosses. This may be due to differences in meat quality. P2 showed PSE properties to some extent, i.e. a rapid pH fall (pH_{30} min post mortem = 5.6) and a rather high drip during storage (5% compared to 1-3% for the others). In P3 the pH fell very slowly (pH = 6.4 3 hours post mortem) and the final pH was about 0.3 units higher than normal for this crossbreed.

The linear relationships between MFI and the four sensory attributes are shown in Table 3 as linear correlation coefficients. Significant non-zero correlation coefficients are indicated by stars (* = $p \leq 0.05$, ** = $p \leq 0.01$ and *** = $p \leq 0.001$).

Sample	Linear correlation coefficients MFI versus			
	Tenderness	Chewing time	Chewing residual	Juiciness
B1				
B2	0.35	-0.64***	-0.54**	
B3	0.22	-0.51*	-0.48*	
All bovine	0.63***	-0.72***	-0.75***	
	0.70***	-0.81***	-0.80***	
P1				
P2	0.96***	-0.73***	-0.75***	0.47*
P3	0.21	-0.49*	-0.27	0.30
P1-P3	0.14	0.00	-0.27	0.20
H1	0.24	-0.40**	-0.26*	0.15
H2	0.86***	-0.67***	-0.70***	0.78***
H3	0.80***	-0.69***	-0.75***	0.30
H1-H3	0.59**	-0.64***	-0.72***	0.44
All pork	0.57***	-0.58***	-0.67***	0.49***
	0.38**	-0.50***	-0.49***	0.31*

* = P <0.05
** = P <0.01
*** = P <0.001

Table 3. The results of linear regression analysis of MFI and sensory attributes of M. longissimus dorsi from 3 beefs (B1-B3) and 6 porks (P1-P3 and H1-H3).

Chewing time showed the best linear relationship to MFI for both beef ($r = -0.81$) and pork ($r = -0.50$). However, the variation between the samples was wide. The MFI method gave no good explanation of the various sensory attributes for the samples of the two porks (P2 and P3), which to some extent showed divergent meat quality.

The sensory attributes chewing residual and chewing time had a very close relationship for the beef samples but not for pork (Table 4). Chewing time and chewing residual for the individual samples showed about the same relationship to tenderness for both pork and beef. However, the variation between individual samples was wide. Particularly low correlation coefficients were again noted for the two pork samples P2 and P3.

Sample	Partial correlation coefficients					
	Juiciness versus			Tenderness versus		Chewiny time verus
	Tenderness	Chewing time	Chewing residual	Chewing time	Chewing residual	Chewing residual
B1						
B2						
B3				-0.6F	-0.68	0.72
All bovine				0.28	-0.39	0.90
				-0.87	-0.85	0.89
P1				-0.81	-0.87	0.93
P2						
P3	0.48	-0.49	-0.38	-0.76	-0.75	0.39
P1-P3	-0.12	0.02	-0.34	-0.11	-0.18	0.57
H1	-0.06	0.05	0.34	-0.01	0.19	-0.22
H2	0.19	-0.25	-0.24	-0.36	-0.27	0.30
H3	0.65	-0.46	-0.43	-0.71	-0.75	0.52
H1-H3	-0.08	-0.35	-0.35	-0.69	-0.68	0.77
All pork	0.26	-0.23	-0.40	-0.5[illegible]	-0.48	0.34
	0.36	-0.31	-0.40	-0.5[illegible]	-0.65	0.49
	0.24	-0.28	-0.32	-0.49	-0.51	0.49

Table 4. The partial coefficients of the sensory attributes of M. longissimus dorsi from 3 beefs (B1-B3) and 6 porks (P1-P3 and H1 and H3).

Juiciness showed a rather low relationship to the three tenderness attributes for all samples (Table 4). The correlation coefficient between juiciness and chewing residual was almost the same for all samples ($-0.49 \leq r \leq -0.34$). The other two relationships i.e. juiciness versus tenderness and chewing time varied rather much.

Discussion

The MFI method explained 66% of the improvement in sensory tenderness of beef during ageing. This agrees well with results published earlier on relationships found when measurements have been made on meat samples aged for a specific time ($R^2 = 18\%$, Reagan et al., 1975, $R^2 = 56\%$, MacBride & Parrish, 1977, $42\% < R^2 < 90\%$, Olson & Parrish, 1977, $R^2 = 46\%$, Calkins et al., 1980, $R^2 = 50\%$, Davis et al., 1980). The MFI method explained about 40% of the improvement in sensory tenderness of M. longissimus dorsi from porks with normal meat quality (P1, H1-3). Including the samples P2 and P3 in the statistical analysis, MFI accounts for only about 25% of the variation in sensory tenderness. This suggests that for sensory tenderness of pork, the degree of myofibril fragmentation is not as important as for beef (for correlation coefficients see Table 3).

Chewing time showed the best linear relationship to MFI, closely followed by chewing residual. Tenderness is an attribute which is very hard to define properly and exactly. Despite intensive training, bias can occur in the judgement of tenderness. Therefore, not surprisingly, the widest variation in correlation coefficients was found between MFI and the attribute "tenderness".

Juiciness is an important sensory property of pork (Skelley et al., 1973). Often juiciness shows a covariation with tenderness (Skelley et al., 1973), but the correlation coefficients between juiciness and the three sensory attributes were low (Table 4). Also the relationship between juiciness and MFI was low.

There are variations in correlation coefficients between the individual samples. However, for beef these are not as wide as those reported by Olson & Parrish (1877) and Davis et al. (1980). It could be that the variation in the tenderising process in a carcass is smaller than the variation between carcasses of different age, maturity, quality grade and slaughter conditions.

The low correlation coefficients noted for P2 and P3 could be due to their divergent meat quality. During ageing their MFI-values increased to the same level as the other samples, but their sensory attributes did not improve to the extent of the others (Table 2). Thus, even after 7 days of ageing, P2 and P3 were rather tough and gave quite a large chewing residual.

Conclusions

* MFI accounts for about 66% of the variation in sensory tenderness of beef and about 40% of the variation of pork of normal meat quality.
* Pork has a higher initial MFI-value and a shorter ageing time than beef.
* Determination of MFI is one valuable way of studying the tenderising process in meat.
* MFI cannot be used as an absolute measure of sensory tenderness.
* There are individual variations in the relationship between sensory properties and MFI, probably due to differences in meat quality, breed and sex of the slaughter animals.
* In meat of normal quality a low initial MFI-value indicates that the meat will be tough after ageing.

Acknowledgement

I wish to thank Mr Björn Holmquist (M.Sc.) for his very valuable help with the statistical analysis and Ms Gertrud Larsson for excellent technical assistance.

References

Calkins, C.R, Davis, G.W. & Sanders, W.L. (1980) Fragmentation index of raw muscle as a tenderness predictor of steaks from USDA commercial and utility carcasses. J. Food Sci. 45, 111.

Davey, C.L. & Gilbert, K.V. (1969) Studies in meat tenderness. 7. Changes in the fine structure of meat during aging. J. Food Sci. 34, 69.

Davis, G.W., Dutson, T.R., Smith, G.C. & Carpenter, 7. L (1980). Fragmentation procedure for bovine longissimus muscle as an index of cooked steak tenderness. J. Food Sci. 45, 880.

Dransfield, E., Jones, R.C.D. & MacFie, H.J.H (1980-81) Tenderising in M. longissimus dorsi of beef, veal, rabbit, lamb and pork. Meat Sci. 5, 139.

Fjelkner-Modig, S & Rudérus, H. (1983) The influence of exhaustion and electrical stimulation on the meat quality of young bulls. Part 2 - Physical and sensory properties. 8, 203.

Jeremiah, L.E. & Martin, A.H. (1978) Histological and shear properties of bovine muscle and their alteration during post mortem aging Meat Sci. 2, 169.

MacBride, M.A & Parrish. Jr, F.C. (1977) The 30.000 dalton component of tender bovine longissimus dorsi. J. Food Sci. 42, 1627.

Møller, A.J., Vestergaard, T, & Wismer-Pedersen, J. (1973) Myofibril fragmentation in bovine longissimus dorsi as an index of tenderness. J. Food Sci. 38, 824.

Olson, D.G., Parrish Jr., F.C. & Stromer, M.H. (1976) Myofibril fragmentation and shear resistance of three bovine muscles during post mortem storage. J. Food Sci., 41, 1036.

Reagan, J.O., Dutson, T.R., Carpenter, Z.L. & Smith, G.C. (1975) Muscle fragmentation indices for predicting cooked beef tenderness. J. Food Sci. 40, 1093.

Skelley, G.C., Handlin, D.L. & Bonnette, T.E. (1973) Pork acceptability and its relationship to carcass quality. J. Anim. Sci. 36, 488.