ACCELERATED PROCESSING OF PORK LOINS

A.J. MØLLER and E. KIRKEGAARD
Royal Veterinary and Agricultural University, Department of Meat Technology and Process Engineering, Howitzvej 11, DK-2000 Copenhagen F, Denmark.

SUMMARY: The effect of chilling rate and pH before boning of slow resp. fast glycolysing pork loins were evaluated as regard to tenderness and muscle fibre contraction. As compared to a conventional cold boning procedure, hot boned loins at 5.9, 5.8 and 5.7 from both slow and fast glycolysing muscles resulted in significant toughening when a fast chilling procedure was used, although to a less degree by decreasing pH value. At a moderate chilling rate, air chilling at 2-4°C, no significant toughening was observed in hot excised loin sections, irrespectively to pH at boning but significant sarcomere shortening was found.

INTRODUCTION: The relationship of early post mortem pH and temperature of pork muscles has mainly been considered and associated to the occurence of PSE (pale, soft and exudative) meat (Bendall & Swatland, 1988). Another aspect dealing with the pH and temperature during rigor is cold contracture, i.e. the ability of excised muscles with high ATP levels to contract when exposed to low temperatures (Locker & Hagyard, 1963). Honikel et al. (1984) reported that the development of rigor in porcine muscles occurs at pH 5.9 which implies that muscles could be rapidly chilled at this point without excessive muscle shortening. Although pork is generally believed to be less prone to cold shortening, tough pork has been reported to occur more recently probably due to increased chilling procedures being used by the industry (James et al., 1983; Dransfield & Lockyer, 1985; Barton-Gade et al., 1987; Møller & Vestergaard, 1987). The effect of chilling rate on meat palatability, particularly tenderness, may be even more critical for pre rigor excised muscles because of less restrictions to shortening. Most studies on hot boning procedures have been carried out with beef and lamb. Pork muscles, however, differ greatly from those species in that post mortem glycolysis occurs in pork faster (Honikel et al., 1984). Additionally, pork muscles are well known to vary substantiously in their pH decline post mortem. Consequently, pork muscles especially from slow glycolysing carcasses are more prone to cold induced toughening (Møller & Vestergaard, 1987; Møller, Kirkegaard & Vestergaard, 1988). The purpose of this study was to extend our previous studies on the relationship of early post mortem pH and temperature to meat tenderness. The M. longissimus dorsi were excised at various pH levels from slow and fast glycolysing carcasses and used for evaluating the effect of chilling rate on tenderness.

MATERIALS AND METHODS: 87 Danish Landrace or Yorkshire pigs reared at the same progeny station to approximately 90 kg live weight were stunned with carbon dioxide and slaughtered conventionally. At 45 min. post stunning, the pH value (pH_1) was measured in M. longissimus dorsi (LD) at the 15th rib from both sides. This measurement was used to allocate the carcasses into a slow ($pH_1 \geq 6.3$) respectively a fast ($5.7 < pH_1 \leq 5.9$) glyco-

lysing group. The slow glycolysing carcasses were further assigned into four subgroups (A, B, C & D) while the fast glycolysing carcasses were assigned into three subgroups (E, F & G) according to their pH values at time at boning, table 1. The left sides of carcasses were used as controls and transferred to the chilling tunnel, operating at -18°C, at 1 hr post stunning. The carcasses were conveyorized through the tunnel in 60 min. and then placed into a conventional chilling room at 2-4°C, 0.2 m/s. At 24 hr post stunning a section (700-800 g) of the LD muscle was removed at the position of the 12th to 15th rib. The right sides were transferred directly to the chilling room and a corresponding loin section was excised from group A, E, F and G at 1 - 1.5 hr post stunning. Sampling from group B, C and D was not performed before their pH values had dropped to respectively 5.9, 5.8 and 5.7. All early excised samples from the right sides were divided into two equal subsamples, placed in polyethylene bags and randomly assigned to be rapidly cooled in ice water or more moderately cooled in the chilling room at 2-4°C until 24 hr post stunning. All samples were then vacuum packed and kept at -20°C for 8-12 weeks until further analysis. Temperature and pH were measured in the LD muscles from both sides at intervals during the initial chilling period. The pH values were measured using a Knick Digital model 653 and direct insertion probe electrode, Ingold Lot 406-M3. Perchloric acid extracts were produced and used for measuring the R-value as an estimation of the degree of transformation of ATP to IMP (Honikel & Fischer, 1977). A cross section was cut 10 mm thick from each subsample and a helium-neon laser with a wavelength of 632.8 nm was used for measurements of sarcomere length (Weber et al., 1989). From each subsample, 6-8 blocks (20 x 20 x 50 mm) were taken for Warner-Bratzler (WB) shear force measurements. WB samples were individually heated in 0.9% NaCl at 80°C for 25 min. Samples of rectangular cross-section (10x10 mm) were cut from the cooked meat and sheared at right angles to the fibre axis, using a Warner-Bratzler shear blade with a triangular slot angular cutting edge. An Instron Universal testing machine model 4301 was used to measure the peak shear forces (N/cm^2). A total of 12-15 measurements were obtained from each loin section for calculating the average WB values.

RESULTS AND DISCUSSION:

Temperature

Mean values of loin temperatures during the initial chilling period from controls and early excised samples (group A, E, F and G) are illustrated in Fig. 1. The fastest cooling samples, in ice water at 0°C, cooled to about 4°C within 3 hr post stunning. By this chilling procedure, the aim was to obtain maximum muscle fibre contracture from residual cold shortening ability in regard to the pH level at time of boning. A much reduced and more reasonable chilling rate for the early excised loin sections was obtained by chilling in air at 2-4°C. These

loin sections took approximately 5.5 hr to be cooled below 10°C. The chilling rate for loins in intact sides (controls) is almost intermediary to the fast respectively moderate chilling rate used for the right sides excised loin sections.

R-values

Mean R-values from early excised loin sections as influenced by pH at time of boning are given in table 1. Previous work has shown that R-values are highly correlated to the ATP concentrations in pre rigor muscles (Honikel & Fischer, 1977). From this study, loins from the high pH group, i.e. $pH_1 \geq 6.3$, show an R-value of .97 which according to our earlier measurements (Møller et al., 1989) corresponds to an ATP concentration of about 4.0 µmol/g. For the slow glycolysing high pH_1 muscles, the R-values increase as expectedly by decreasing pH level at time of boning. Approximately 50, 25 and 12.5% of the initial ATP concentration appears in these muscles when excised at respectively 5.9, 5.8 or 5.7. At the same pH levels, however, obtained at 1 hr post stunning from the fast glycolysing muscles, the R-values tended to be higher which may indicate a somewhat higher degree of ATP depletion as compared to slow glycolysing muscles when same pH level is considered.

Shear force measurements

Mean WB values are given in table 2. The shear force measurements of early excised loins were evaluated by t-test calculations on differences in WB means between left sides controls and the corresponding right sides representing different pH at boning and chilling rate. The most severe degree of toughening appeared especially in loins boned at pH 6.3. As compared to the controls in that group of carcasses, the extent of cold toughening represents a 70% increase in WB values. This is a somewhat higher cold toughening potential than we previously observed (Møller & Vestergaard, 1987) where samples, however, were excised at 3 hr post stunning. At decreasing pH level at boning from loins with initial high pH values (≥ 6.3), the degree of cold toughening decreased but even at 5.7 followed by fast chilling in ice water a significant ($P < .05$) increase in WB values is seen. The effect of fast chilling on cold toughening caused a higher degree of significance among the groups of slow glycolysing muscles (treatments B, C and D) as compared to the fast glycolysing groups (E, F and G) although the level of WB values is somewhat higher in the lattergroups. From this study, a pH level above 5.7 may present a considerable risk of cold shortening if a rapid chilling procedure is used. This result differs from earlier studies (Honikel et al., 1984; Frye et al., 1985) from which pH 5.9 in loins has been suggested as a useful guideline for performing hot boning. When hot boned loin sections are cooled more slowly at 2-4°C by the air chilling procedure (table 2), no significant differences between controls and early excised loins irrespectively of pH at boning are observed from this study.

Sarcomere lenghts

Mean values of sarcomere lengths in the various groups of treatment are given in table 3. As compared to the controls

which show a mean sarcomere length at approx. 1.80 µm, both the moderately and fast cooled excised loin sections showed reduced sarcomere lengths as an indication of muscle fibre contraction. The ice water chilled samples obtained, however, generally a higher degree of muscle fibre contraction and especially so for the samples belonging to the slow glycolysing muscle group in accordance to our earlier results (Møller & Vestergaard, 1987). Also the moderately cooled excised loins do show significantly shorter sarcomere length but without a concomitantly toughening effect as compared to the controls (table 2). Apparently, a certain degree of an ageing effect due to a higher muscle temperature during the initial post mortem period may have caused a tenderizing effect as revealed by the non significant difference in the shear force data between controls and moderately cooled excised loin sections.

Table 1.-Mean R-values at time of boning and experimental groups for the right sides early excised loin sections

pH Group	R-value	Number of sides[3]
(S-Muscles)[4]		
A. 6.3[1]	.97 ± .09	16
B. 5.9[2]	1.14 ± .07	16
C. 5.8[2]	1.21 ± .09	16
D. 5.7[2]	1.25 ± .10	15
(F-Muscles)[4]		
E. 5.9[1]	1.13 ± .11	8
F. 5.8[1]	1.26 ± .10	8
G. 5.7[1]	1.31 ± .12	8

[1] Muscles excised at 1 hr post stunning.

[2] Muscles from high pH_1 group ($pH_1 \geq 6.3$) when excised at the indicated pH values.

[3] Following boning, loin sections were cut into two subsamples, chilled in air at 2-4°C (moderate chilling rate) or in ice water at 0°C (fast chilling rate).

[4] S- = slow and F- = fast glycolysing muscles.

Table 2.-Effect of pH and chilling rate of early excised pork loin sections on Warner-Bratzler(WB) shear force values.

	Mean WB values N/cm^2 ± s.d.		
		Excised loins / Chilling rate[3]	
pH Group	Control	Moderate	Fast
A. 6.3[1]	62.4 ± 14.6	63.6 ± 15.3^{ns}	103.5 ± 25.6^{xxx}
B. 5.9[2]	51.1 ± 8.9	55.0 ± 8.4^{ns}	71.1 ± 15.4^{xxx}
C. 5.8[2]	51.6 ± 12.5	51.4 ± 10.3^{ns}	61.8 ± 15.6^{xx}
D. 5.7[2]	47.7 ± 11.6	49.0 ± 9.9^{ns}	56.2 ± 18.1^{x}
E. 5.9[1]	60.3 ± 9.9	62.0 ± 10.7^{ns}	94.7 ± 27.7^{xx}
F. 5.8[1]	56.4 ± 12.8	58.4 ± 13.9^{ns}	68.3 ± 12.1^{x}
G. 5.7[1]	62.9 ± 22.5	62.0 ± 11.3^{ns}	70.7 ± 19.6^{ns}

[1], [2], [3] see table 1; ns = non significant; x, xx and xxx = significant at 5%, 1% and 0.1% level.

Table 3.-Effect of pH and chilling rate of early excised pork loin sections on sarcomere lengths.

	Mean sarcomere lengths, µm ± s.d.		
		Excised loins / Chilling rate[3]	
pH Group	Control	Moderate	Fast
A. 6.3[1]	1.80 ± .07	1.71 ± .07^{xxx}	1.63 ± .11^{xxx}
B. 5.9[2]	1.80 ± .10	1.75 ± .06^{x}	1.69 ± .10^{xxx}
C. 5.8[2]	1.80 ± .10	1.73 ± .06^{x}	1.72 ± .07^{xx}
D. 5.7[2]	1.85 ± .07	1.76 ± .06^{xx}	1.72 ± .06^{xxx}
E. 5.9[1]	1.77 ± .12	1.67 ± .12^{x}	1.64 ± .11^{xx}
F. 5.8[1]	1.81 ± .08	1.69 ± .04^{x}	1.71 ± .11^{xx}
G. 5.7[1]	1.81 ± .08	1.73 ± .07^{ns}	1.69 ± .06^{x}

[1], [2], [3] see table 1; ns = non significant; x, xx and xxx = significant at 5%, 1% and 0.1% level.

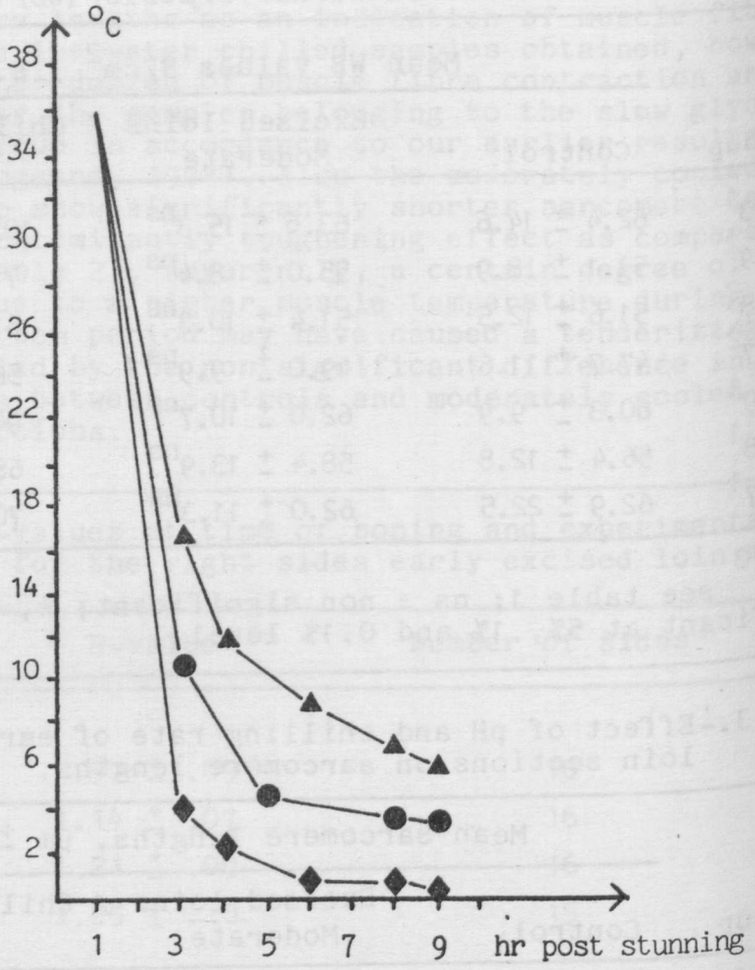

Fig.1.- Temperature in hot or cold boned pork loins during the initial chilling period 1 to 9 hr post stunning.
● = cold boned (controls) at 24 hr post stunning
▲, ◆ = hot boned at 1 hr post stunning, then cooled in ice water at 0°C (◆) or in air at 2-4°C (▲).

REFERENCES:

- Barton-Gade, P., Bejerholm, C. and Borup, U. (1987) Proc. 33rd Int. Cong. Food Sci. and Technology, 181, Helsinki.
- Bendall, J.R. and Swatland, H.J. (1988) Meat Science 24:85.
- Dransfield, E. and Lockyer, D.K. (1985) Meat Science 13:19.
- Frye, C.B., Calkins, C.R. and Mandigo, R.W. (1985) J. Food Science 50:1560.
- Honikel, K.O. and Fischer, C. (1977) J. Food Science 42:1633.
- Honikel, K.O., Kim, C. and Hamm, R. (1984) Proc. 30th European Meeting of Meat Res. Workers, 95, Bristol.
- James, S.J., Gigiel, A.J. and Hudson, W.R. (1983) Meat Science 8:63.
- Locker, R.H. and Hagyard, C.J. (1963) J. Science Food Agric. 14:787.
- Møller, A.J. and Vestergaard, T. (1987) Meat Science 19:27.
- Møller, A.J., Kirkegaard, E. and Vestergaard, T. (1989) Proc. 33rd Int. Cong. Food Sci. and Technology, 1149, Copenhagen.

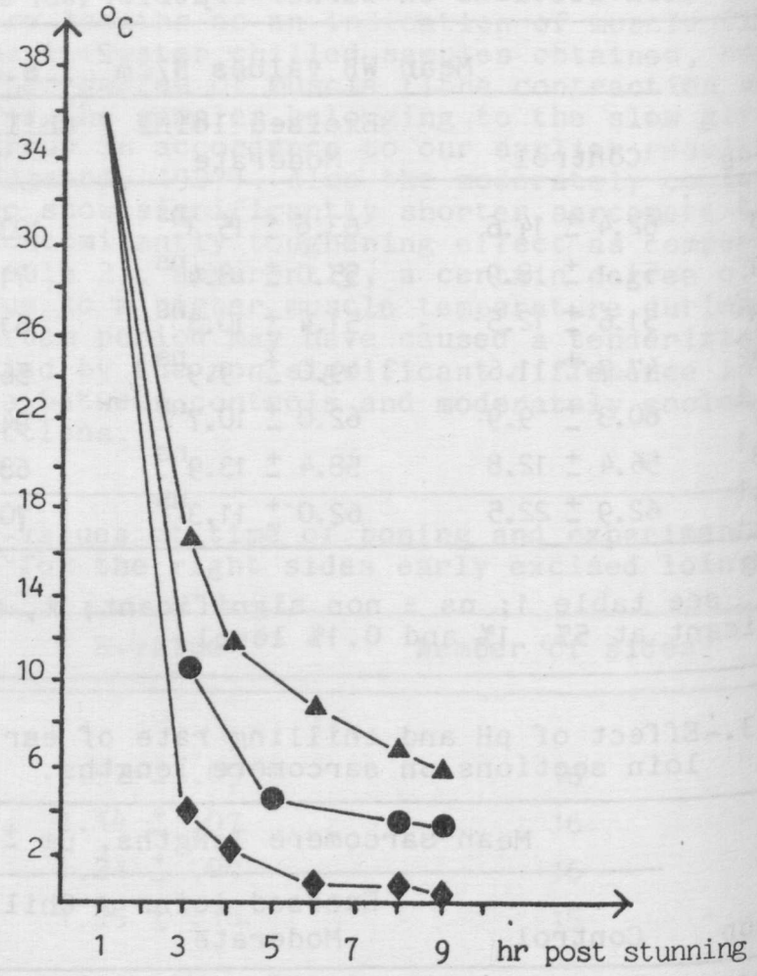

Fig.1.- Temperature in hot or cold boned pork loins during the initial chilling period 1 to 9 hr post stunning.
● = cold boned (controls) at 24 hr post stunning
▲, ◆ = hot boned at 1 hr post stunning, then cooled in ice water at 0°C (◆) or in air at 2-4°C (▲).

REFERENCES:

- Barton-Gade, P., Bejerholm, C. and Borup, U. (1987) Proc. 33rd Int. Cong. Food Sci. and Technology, 181, Helsinki.
- Bendall, J.R. and Swatland, H.J. (1988) Meat Science 24:85.
- Dransfield, E. and Lockyer, D.K. (1985) Meat Science 13:19.
- Frye, C.B., Calkins, C.R. and Mandigo, R.W. (1985) J. Food Science 50:1560.
- Honikel, K.O. and Fischer, C. (1977) J. Food Science 42:1633.
- Honikel, K.O., Kim, C. and Hamm, R. (1984) Proc. 30th European Meeting of Meat Res. Workers, 95, Bristol.
- James, S.J., Gigiel, A.J. and Hudson, W.R. (1983) Meat Science 8:63.
- Locker, R.H. and Hagyard, C.J. (1963) J. Science Food Agric. 14:787.
- Møller, A.J. and Vestergaard, T. (1987) Meat Science 19:27.
- Møller, A.J., Kirkegaard, E. and Vestergaard, T. (1989) Proc. 33rd Int. Cong. Food Sci. and Technology, 1149, Copenhagen.