OF GLYCOLYSIS, CHILLING RATE AND BEEF QUALITY; AN INVENTORY OF POTENTIAL CONSEQUENCES

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led data from two series of experiments conducted in two beef production operations with similar electrical mulation, but different refrigeration conditions (plant A: moderate chilling; plant B: rapid chilling), were d to evaluate the effects of glycolytic and chilling rate on beef quality. Whereas in slow glycolysing cle the correlation coefficient between sarcomere length and Warner Bratzler shear force was highly nificant ($r=0.78$; $p<.05$), this was not the case for fast glycolysing muscle ($r=0.25$; $p>.05$). Fast glycolysis ulted in markedly higher drip losses, which effect was significantly more pronounced in the slower chilling ine. Beef carcasses with an ultimate pH value in the 5.8 - 6.1 range were significantly tougher than those the 5.4 - 5.5 range. The pH/temperature profile of a large number of beef carcasses from both plants (plant n=400; plant B: n=780) was subsequently monitored, serving as the basis of a risk assessment for current cessing conditions in The Netherlands. This 'inventory' indicated that electrical stimulation practically minated the risk of cold shortening under both chilling regimes, that faster glycolysis markedly increased risk of excessive drip loss by protein denaturation at moderate chilling rates, and that the prevalence of DFD condition was around 3.5 - 4.0 %.

oduction

present, electrical stimulation of beef carcasses is widely used to prevent excessive post mortem muscle traction at low temperatures, better known as cold shortening. This phenomenon results in tough meat with drip loss (Honikel et al., 1986). These adverse effects are observed when pre-rigor muscle is rapidly lled, while glycogen stores and hence pH values are still high enough to allow muscle contraction. nsequently, chilling rate and rate of pH fall are major determinants of beef quality, where high post mortem mperatures are known to accelerate, and low temperatures to delay glycolysis (Marsh, 1954; Bendall, 1978). by applying different forms of electrical stimulation, it was demonstrated that tenderness was optimal when ycolysis had proceeded at an intermediate rate (pH_{3h} about 6.1) and decreased at both sides of this value rsh et al., 1987). Further investigations by Smulders et al. (1990) substantiated these findings; in dition, it was shown that high correlation coefficients ($r=0.84$) between panel tenderness scores and comere length only existed for the slow glycolysing muscles, whereas at fast pH decline this correlation was diligible. This implies that tenderness depends on shortening only in slow glycolysing muscle.

Besides glycolytic rate, ultimate pH values seem to be related with beef tenderness. Based on the pH values bulls and steers, Purchas (1990) demonstrated that the highest shear force values were found at an mate pH of 6.1 and then decreased on both side of this pH range. Jeremiah et al. (1991) came to similar clusions after having evaluated data sets obtained over a 10 year period; segregation of beef carcasses sed upon ultimate pH values between 5.8 and 6.2, was effective in removing the majority of tough carcasses in sex groups, regardless of breed.

The present contribution attempts to analyse the risks of cold shortening and the resulting toughness and ssive drip loss during conditioning of beef carcasses in two major beef processing operations. Over the years useful information had been collected in these slaughterplants, both of which use the same ctrical stimulation procedure but apply different chilling rates. Evaluation of several data sets and of ditional measurements allowed for estimating the risks of various chilling rates on pH and temperature cline and ultimately of beef quality.

terials and Methods

ta sets from two series of experiments on the sensory quality of beef longissimus muscle, performed in 1982- 83) (plant A) and 1990-1992 (plant B) were used for comparison. Both plants relied on similar stimulation ocedures (low voltage stimulation, 85V, 14 Hz; Mitab, Simrishavn, Sweden), but applied different chilling ing. In both studies pH (ultimate values assessed at 48 h post mortem) and temperature decline, tenderness ther-Bratzler shear force, 7 and/or 14 days p.m.), sarcomere length and drip loss during vacuum storage at 2

± 2°C were assessed at 7 days post mortem. Cooking of the samples and shear force measurements were performed according to Smulders et al. (1981). Sarcomere lengths were assessed by measuring the first order laser diffraction band using the procedure described by Koolmees et al. (1986). Drip losses were assessed by weighing samples before and after vacuum storage.

More recently both plants were revisited several times to monitor the pH and temperature decline of a mixed population of 1,180 electrically stimulated bull and cow carcasses; in the following these measurements are referred to as the 'pH/temperature inventory'. Measurements were done at 45 min, 3 h and 20 h post mortem in the centre of the M. longissimus between the 5th and 6th rib. The pH and temperature were measured with a portable pH meter, type CG818 (Schott Geräte, GmbH D6238 Hofheim, Germany) equipped with a combined (glass, reference) electrode type Lo406-M6-DXK-S7/25 (Ingold) and a digital thermometer type Impac tastotherm D700 (Leuvenberg Test Techniek b.v., The Netherlands). A 'risk analysis' was conducted based on the following suppositions: cold shortening risk at pH>6.0 at temperatures < 10-12°C (Bendall, 1972), rigor (heat) shortening risk at pH_{45min}<6.0 at temperatures >25°C (Honikel et al., 1986), risk of excessive drip loss when pH_3<6.0 at temperatures >30°C (Honikel et al., 1986), least favourable ultimate pH 5.8 - 5.9 (Purchas, 1990), DFD at ultimate pH values >6.0 [being the median value of the pH range considered hazardous (Tarrant, 1980)].

Results and Discussion

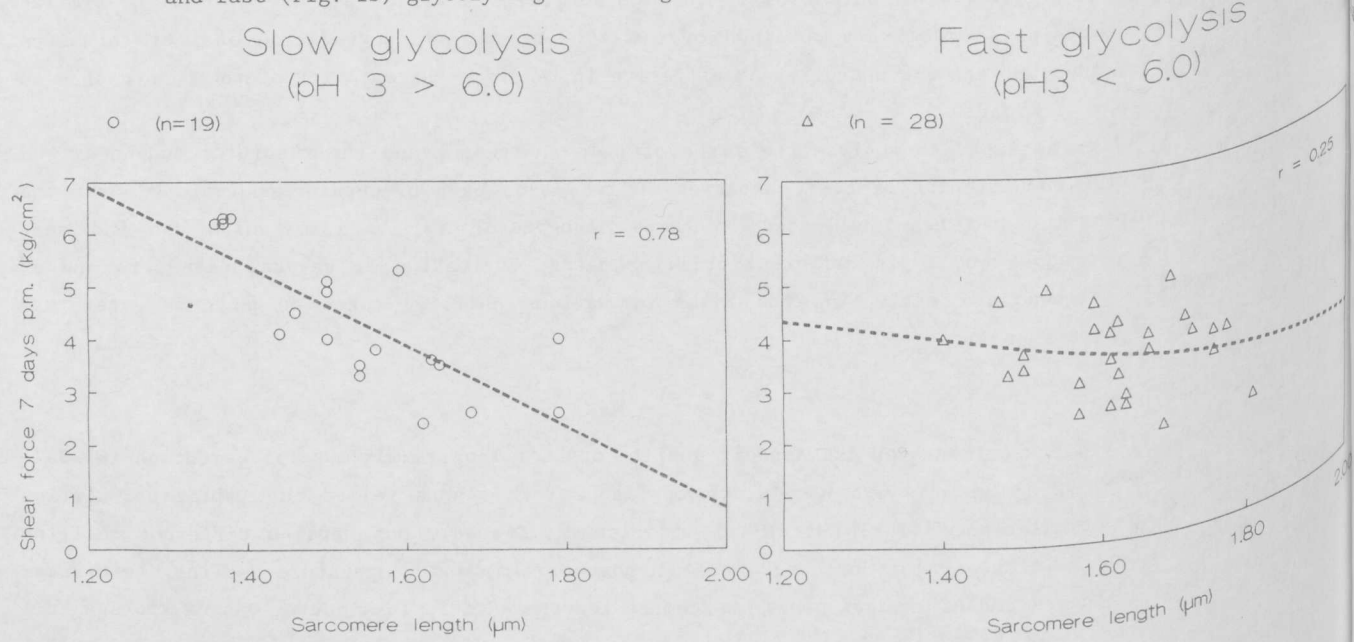
As opposed to the most recent (1991-1992) studies, the 1982-1983 animal population had a wide range of glycolytic rates, allowing for calculation of several interrelationships. Figures 1a and 1b, taken from the latter study are graphic presentations of the relation between sarcomere length and shear force values of beef longissimus muscle at 7 days post mortem.

Whereas in slow glycolysing muscle (defined as having a pH_3 value >6.0) this correlation coefficient was 0.78 (p<.05), the correlation was negligible for the fast glycolysing (pH_3 <6.0) subpopulation (p>.05). This finding substantiates earlier observations (Marsh et al., 1987; Smulders et al., 1990, Pike et al., 1992). The latter studies also suggested that early post mortem muscle pH (pH_3) has some value for predicting ultimate tenderness and that a moderate post mortem pH fall would yield better results for tenderness and drip loss than an excessively fast or slow one.

Based on this concept, in Figure 2 the effects are presented of fast vs. slow glycolysis on the drip loss of similarly electrically stimulated beef longissimus under conditions of fast chilling (plant B, 1982-1983) and slow chilling (plant A, 1991-1992). Under both chilling conditions fast glycolysis resulted in significantly higher drip losses. As this effect was significantly more pronounced in the slower chilling regime, protein denaturation (Eikelenboom and Smulders, 1986) is the most probable cause for this phenomenon.

Our results also allow for testing if ultimate muscle pH to some extent determines the ultimate tenderness,

Figure 1 The relationship between sarcomere length and Warner-Bratzler shear force values of slow (Fig 1a) and fast (Fig. 1b) glycolysing beef longissimus lumborum muscle.



suggested by data of Purchas (1990) and Jeremiah (1991). As the shear force measurements of the 1982-1983 opulation were done slightly differently (cylindrical samples excised with a cork borer as opposed to ctangular strips in the more recent study) and because the range of ultimate pH values in the earlier periments was less wide, we have only classified the data of plant B (Figure 3); few muscles with pH values .0 were excluded because muscles with a DFD character are subject to aberrant ageing conditions (Geesink et 1992).

As shown in Figure 3 marked differences exist in the tenderness of muscles with various ultimate pH values. se with values in the range 5.8 - 6.1 were significantly tougher than those in the 5.4 - 5.5 range. Hence, data support the findings of Purchas (1990) and Jeremiah (1991).

ure 2 The effect of glycolytic and early post mortem chilling rate on % drip loss of longissimus lumborum muscle assessed after 7 days of vacuum storage at 2±2°C.

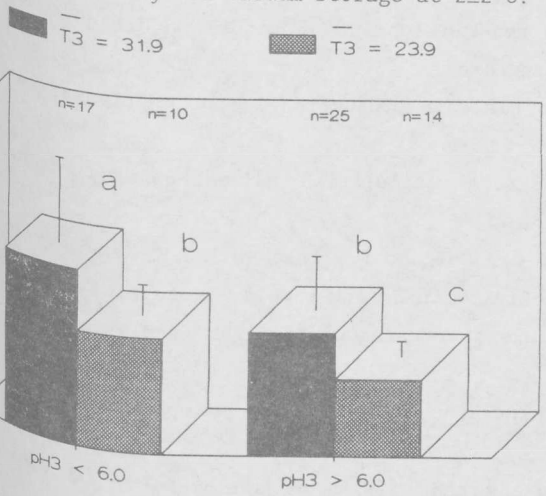
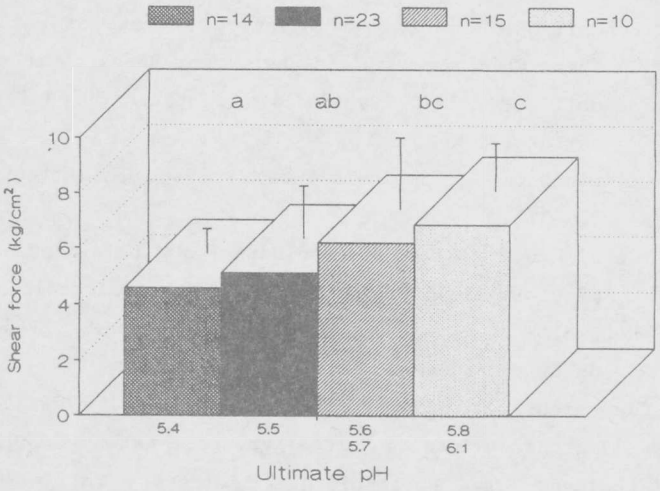


Figure 3 The effect of ultimate pH_{24h} on Warner-Bratzler shear force values of beef longissimus lumborum muscle assessed after 7 days of vacuum storage at 2±2°C.



The results of the pH/temperature inventory are given in Figure 4. Although both slaughterplants used trical stimulation, there was a large variation in the speed of pH decline, measured as pH at 45 min and 3 post mortem. Part of the variation can be explained by differences between the slaughterplants, but even thin the individual slaughterplants a large variation was observed. Differences in conductivity of the tric current largely explain such variations.

Table 1 lists the pH/temperature profiles for both plants, as well as the 'overall' picture, which may serve an indication for the current situation in The Netherlands. It is an attempt to estimate the effects on ory beef quality of certain pH/temperature combinations, encountered in commercial beef production erations.

ure 4 The pH/temperature profile of 1,180 beef carcasses at various times post mortem, measured in 2 beef processing operations

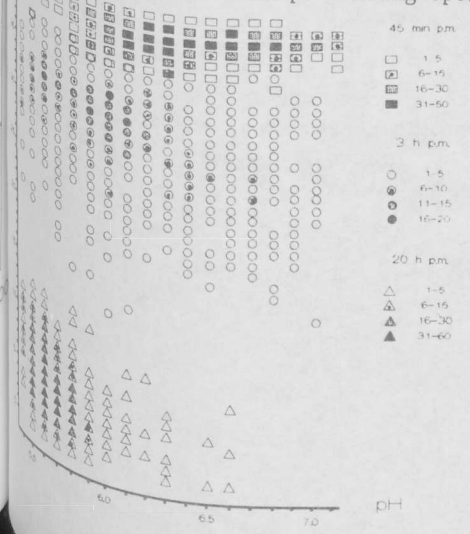


Table 1 An analysis of potential risks for meat quality based on a pH/temperature inventory in 2 plants with different initial chilling rates.

		Moderate initial chilling plant A (n=400)	Fast initial chilling plant B (n=780)	Pooled population (n=1180)
Muscle pH	45 min	6.5	6.5	6.5
	3 h	5.9	6.2	6.1
	20 h	5.6	5.6	5.6
Temperature (°C)	45 min	38.8	39.8	39.4
	3 h	32.5	28.8	30.2
	20 h	5.9	4.3	4.9
Risk subpopulation (%)				
- Cold shortening		0	6	4
- Heat shortening		0.5	5.9	4.1
- Excessive drip (protein denaturation)		44	22	30
- pH_{ult} range 5.8-5.9		7	19	15
- DFD condition		2	5	4

The variation in temperature decline can be largely explained by differences between the slaughterplants the differential chilling rate being a major factor. The 'risk analysis' showed that electrical stimulation practically elimates the risk of cold shortening under both chilling regimes. This conclusion is corroborated by the sarcomere lengths measured in the two more extended data sets. Rigor (heat) shortening [observed in recent experiments with slowly chilled stimulated veal to be more than a theoretical risk (Smulders and van Laack, unpublished)] might occur in 4.1 % of the population. Yet, in none of the 1,180 animals from the 1982-1983 and 1991-1992 populations which exhibited the afore-mentioned riskful pH/temperature combination sarcomere lengths indicated excessive muscle contraction. Risk analysis further indicates that fast glycolysis induced by stimulation markedly increases the risk of protein denaturation, particularly when moderate chilling rates are applied and, finally, that (provided normal transport conditions are adhered to) the proportion of relatively high pH beef carcasses approximates the 3 and 3.5% reported for Dutch beef in similar surveys by van Logtestijn (1965) and van Laack et al. (1989), respectively.

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