Pre-slaughter animal handling and fresh meat processing; an update

FRANS J.M. SMULDERS and RIËTTE L.J.M. VAN LAACK
Department of the Science of Food of Animal Origin, Faculty of Veterinary Medicine, The University of Utrecht, P.O. Box 80175, 3508 TD Utrecht, The Netherlands

INTRODUCTION: In converting muscle to meat, things can go wrong at many stages from farm to consumer. Unfortunately, we still lack sufficient knowledge to always devise the right solutions. On the other hand, many critical points *have* been identified and *can* be effectively controlled, provided an approach is chosen similar to the HACCP strategies that are currently being introduced to safeguard meat safety (van Logtestijn, 1991). For different animal species, problems vary and they suggest different control options. Space limitations dictate that we address only major ones in this contribution. The interested reader is referred to other publications for a more complete account (e.g. Tarrant, 1989; Smulders et al., 1991).

Before we can begin to address quality control options peri mortem, it is imperative to more precisely define what meat quality is. Apart from the traditional concepts (nutritive value, hygienic/toxicological, technological and sensory aspects) today's consumer perceives meat quality to include emotional aspects related to animal welfare and animal handling: not only palatability of meat, but also 'pat-ability' of the animal providing the meat play an increasingly important role in modern meat production (Kauffman and Rutgers, 1991). Fortunately, as a rule, the eating quality of meat benefits greatly from treating animals well. Conflicts may arise when novel (bio)technological developments in primary production or slaughter procedures are perceived by the consumer as interfering with the animal's well-being. We will not extensively discuss these conflicts. Instead, some attention will be paid to those developments that have some relation with eating quality and which have been the subject of recent controversies.

ANTE MORTEM TREATMENT: For some years this conference has seen invited speakers addressing this important subject. Yet, it must be conceded that all of us have discussed more or less the same topics; unfortunately we have not seen a major breakthrough in the past decades. This is not to imply that much can not still be improved: major improvements are to be expected if we are to succeed in improving the logistics of animal production, transport and pre-slaughter handling and if traditional recommendations are to be met. We will now look at the different stages and illustrate some major concerns.

On-the-farm

The fact that the market share for alternatively produced meat [e.g. 'group grown' veal, free-range pork ("scharrelvarkensvlees")] is growing has prompted several farmers to contemplate changing their production methods. For instance, in The Netherlands 48,000 free-range pigs were slaughtered in 1989 (Netherlands' Commodity Board for Livestock and Meat, 1990), which corresponds to a *per capita* consumption of 3.8 kg. At least some consumers are willing to pay extra for the increased costs of production. In a recent Dutch study (van der Wal et al., 1991) carcass conformation, sensory quality traits and fatty acid composition of free-range (n=79) and traditionally produced (n=78) pork were compared. Although shear force measurements were significantly higher in muscle samples from free range-pigs (p=.030), panel evaluation did not reveal any appreciable difference in tenderness. Also, differences between colour, juiciness, odour and flavour were negligible. In another Dutch study (te Nijenhuis and Bon, 1988) consumers were confronted with traditional and free-range pork. The sensory ratings were influenced considerably by the label the meat carried. Free-range pork was offered to the consumer both labelled and unlabelled. As soon as it was labelled 'free-range', sensory ratings increased markedly. This illustrates the significance of the emotional aspects of animal handling on the consumer's perception.

At least in Northwestern Europe, the consumer also objects against the use of anabolic agents, beta-agonists and somatotropins. Moreover, the use of these agents is not advisable as these interfere with the aging response of meat, which may lead to problems with regard to tenderness and/or waterholding capacity (e.g. Ouali et al., 1991; Smulders et al., 1991, Geesink et al., 1991).

The influence of genetic make-up of slaughter animals on eating quality is well-known, particularly for pigs. Although breeding programmes relying on the halothane test have markedly reduced the incidence of stress-susceptible pigs (currently less than 1% of the Dutch Landrace population are halothane reactors), it is a misconception that this allows for making less efforts to reduce pre-slaughter stress (e.g. see Barton Gade, 1984). According to Grandin (1988) a more frequent contact of the farmer with the animal, or providing the pigs with some means

of distraction, will reduce problems at loading and transport. The fact that free-range pigs allegedly have less inclination to fight (Barton Gade and Blaabjerg, 1989) seems to substantiate this observation.

During transport

The loading of animals in transport vehicles where they are mixed with other animals and rough treatment by the driver constitute major stressors. Pigs are particularly sensitive to such circumstances. Loading is preferably done with hydraulic lifts, and it is important that the slope of the loading dock is not too steep (<20°), that animals from the same farms are kept together as much as possible and that the use of electric goads is avoided whenever possible. Stocking too many animals in a truck markedly increases the risk of hyperthermia and thus of PSE. Lambooy and Engel (1991) recommend a stocking density for pigs of about 235 kg/m2 as a reasonable compromise between animal welfare, rentability of transport and meat quality.

Although cattle are not as sensitive to stress as pigs, muscle energy stores are depleted quite easily, which might lead to DFD sometimes even after short transport. In one of our unpublished experiments, 6 out of 15 young bulls, transported over a distance of less than 60 km, developed DFD and had to be excluded from further experimentation. Van Laack et al., (1989) reported that depending on transport time the prevalence of DFD in young bulls was 3.4 vs 27.3%. Similarly, Lambooy and Hulsegge (1988) found that long transport of pregnant heifers in trucks markedly decreases muscle energy levels; in this study the authors further showed that keeping heifers penned within the truck, although leading to skin lesions at the hipbone, resulted in 1.6% less weight loss and markedly less water uptake than when animals were stocked loose.

The reactions to handling and transport of veal calves, housed either in isolation in crates or in groups of 15 to 30 animals, were recently investigated by Trunkfield et al. (1991). The crate-fed calves reacted to handling and transport with a significantly higher plasma cortisol level than group-grown animals.

During lairage

The effects of pre-slaughter treatment on meat quality depend on the energy stores in the muscle at the time of death. Fasting prevents pigs from vomitting, on which they may choke (Guise, 1987). Generally, increasing the interval between last feed administration and slaughter, by lengthening the period of food withdrawal, transport and lairage, increases the ultimate pH and reduces the prevalence of PSE. Eikelenboom et al. (1991) recently reported that fasting 16-24 h before delivery resulted in darker and firmer meat than control animals that had not fasted; although the incidence of DFD may slightly increase, feed withdrawal for 24 h also reduced drip loss and thus constitutes an important ante mortem quality control option. Additional advantages of fasting are that intestines are lighter. This facilitates evisceration and reduces the risk of puncturing of the viscera. On the other hand, one must keep in mind that fasting of young animals does increase the risk of shedding of enteropathogens such as *Salmonella* (Linton and Hinton, 1987).

Upon arrival at the abattoir pigs are best rested for several hours, during which showering is very useful to lower the incidence of PSE (Smulders et al., 1983; Long and Tarrant, 1990). The importance of inclusion of a resting period in lairage was nicely illustrated in a recent study by Eikelenboom and Bolink (1991;these proceedings). One of two batches of pigs was slaughtered immediately after arrival. Animals from this batch showed inferior meat quality traits (paler meat with more drip) than those of the other batch slaughtered after the usual resting period of 2 h. The fact that the difference in meat quality between the batches was even larger than those generally found between halothane-positive and halothane-negative pigs illustrate the importance of pre-slaughter handling.

STUNNING: The methodology of stunning of slaughter animals has for the past decade been the subject of debate. A Seminar organised in 1982 clearly showed the controversy that existed between the advocates and opponents of CO_2 and electrical stunning (Eikelenboom, 1983). Objections against electrical stunning are that this procedure results in more haemorrhages and broken bones. Major objections against CO_2 stunning were that the time that elapses between the administration of CO_2-gas to the animal and full unconsciousness is too long (15 to 40 s). The fierce movements of the animal following exposure to gas are interpreted by some as a symptom of the animal's anxiety. Others argue that such movements are nothing but symptoms of the excitation phase, i.e. part of a normal narcosis. Although still some difference of opinion exists between experts, at least experts seem agree that: a) post stunning convulsions (seen both after electrical and CO_2 stunning) are not necessarily an indication of consciousness and therefore not always a cause for concern, b) that during the induction period before unconsciousness the pig probably experiences

CO_2 as mildly unpleasant at best, c) that the new Combi-systems for CO_2 stunning allows for better handling of the pig than the compact stunner, and that modern CO_2 stunners produce less PSE, less blood splash and less broken bones (Lambooy, 1990). Troeger (1991) recently reviewed the major pro's and con's of stunning and has listed major recommendations.

New developments on the stunning front are scarce. Lambooy and Ring (1989) mention that direct stimulation of the brain with only 25 V will produce an effective stunning. More work needs to be done to devise a feasible method by which such could be achieved in meat industry practice.

A most interesting stunning option was recently reported by a group of Swiss investigators (Schatzmann et al., 1990). Their method relies on so-called 'jet-injection' of approximately 2 cm^3 water frontally into the brain at pressures of around 3000 to 4000 bar during 20 to 50 ms. Instantaneous unconsciousness ensues. More work is in progress.

The technique of bleeding is reported to have some impact in the prevalence of haemorrhages. Exsanguination in a lying position is advocated by some as resulting in a marked reduction of blood splash (e.g. Troeger, 1991). Others (Hölscher et al., 1989) did not observe any such effect.

Stunning of cattle still relies on captive bolt stunning. Trials with electrical stunning of veal calves in a V-shaped restrainer have not yielded the desired results. Major objections include that the animals recover too rapidly, and that their convulsions endanger the operators while they shackle and stick the animal (Lambooy, 1986).

SLAUGHTER AND FRESH MEAT PROCESSING: The whole area of slaughter and fresh meat technology is too wide-ranging to be covered within the frame-work of this presentation. Moreover, during last years' ICoMST some promising developments (e.g. new packaging options) were already reviewed in some detail (Taylor, 1990). Therefore, to avoid unnecessary overlaps, we have chosen to discuss those processing options that have attracted particular attention of several research groups.

Electrical stimulation

Since the early 1970's meat scientists the world over have investigated the effects of electrical stimulation on meat quality. It is commonly agreed that stimulation: a) accelerates post mortem glycolysis, b) improves tenderness by prevention of cold shortening and by other mechanisms (e.g. mechanical disruption of the myofibrillar structure or enhanced lysosomal enzyme release), c) makes muscle colour appear lighter, and d) may have an adverse effect on the water-holding capacity of muscle proteins, unless the stimulation process is strictly controlled (see Smulders et al., 1991).

Studies in the United States (Marsh et al., 1987; Smulders et al., 1990) have shown that tenderness probably attains its highest value when glycolysis proceeds at an intermediate rate (corresponding to a pH at 3 h post mortem of about 5.9) and declines at both faster and slower rates. The explanation for this phenomenon is that stimulation not only depletes muscle glycogen reserves, but may also incapacitate calpains, which are the endogenous muscle enzymes thought to be mainly responsible for meat aging (e.g. Etherington et al., 1990). The results of these studies suggest that electrical stimulation is currently applied incorrectly at many abattoirs, which prompts paying more attention to fine-tuning and subsequently controlling stimulation procedures (Smulders, 1991).

The prevalence of blood splash in veal calves has been associated with electrical stunning (e.g. Lambooy, 1986). Hence processors have suggested that through similar mechanisms (rupture of blood vessels caused by high voltages) blood splash might result from electrical stimulation during exsanguination. However, it was clearly demonstrated that there is no reason whatsoever for this fear (Smulders et al., 1989). In the latter study it was also shown that shackling veal calves by one or the other hindleg does not appreciably affect the response to stimulation.

Electrical stimulation is applied particularly for slow glycolysing muscles, e.g. beef, veal, mutton and lamb and goat meat. Lately, more attention is being paid to the use of electrical stimulation to prevent cold shortening in extremely rapidly chilled pig carcasses (e.g. Møller and Vestergaard, 1987). Many pork producers are reluctant to use electrical stimulation for this purpose as they have problems enough trying to prevent PSE resulting from the accelerated glycolysis after stress and the concurrent hyperthermia. Yet, our own studies with halothane negative Dutch Landrace/Large white crossbreds (van Laack and Smulders, 1989), as well as experiments in England (Taylor and Tantikov, 1990) and Denmark (Møller et al., 1989) seem to refute these concerns. In collaboration with scientists from the Institute of Animal Production "Schoonoord" at Zeist, we recently studied the effects of 85 V/60 s electrical stimulation of three lines of Belgian Landrace pigs which differed in their genetic susceptibility to

halothane (nn, Nn, and NN). Although glycolysis was accelerated significantly in the stimulated carcass sides, electrical stimulation did not cause appreciable aberrations in meat quality in any of the three groups. Since all these animals had been anaesthesized prior to slaughter to allow for muscle biopsies (see Klont, 1991; this conference), we are not entirely sure how to interpret these results. More work is in progress.

As an alternative to electrical stimulation pelvic suspension has been recommended to overcome possible effects of rapid chilling of pig carcasses. Taylor (1990) discussed this option at last year's ICoMST. In The Netherlands we have been unable to show detrimental effects of rapid chilling of pre-rigor excised bone-in pork loins (see van Laack and Smulders, 1991d; this conference). On the other hand, in recent experiments we have observed marked reductions in shear force and considerably improved panel tenderness ratings after pelvic suspension of blast-chilled pig carcass sides (Smulders et al., unpublished results).

Finally, it has been suggested by British scientists to decide upon inclusion of electrical stimulation and/or selecting chilling rates, according to pH measurements in individual carcasses (Dransfield, pers. comm.). In our opinion, such a scenario would indeed be ideal provided that robust and reliable pH probes became available and slaughterline logistics allowed electrical stimulation at a fairly late stage.

Hot processing

An extensive and updated overview of the effects of hot processing on the sensory, microbiological and functional properties of beef, veal and pork has recently been prepared (van Laack and Smulders, 1991c). The interested reader is referred to this review for a more complete account of the effects of accelerated processing. As the impact on slaughterhouse logistics, the investments involved in retrofitting existing facilities into hot boning operations, and some marketing problems of hot boned meat currently discourage an immediate adoption of accelerated processing in many countries, we will restrict ourselves to discussing some recent findings.

Troeger and Woltersdorf (1987) observed a better water-holding capacity in skinned as compared with scalded pig carcasses. They stress that the positive influence of skinning as a factor affecting meat quality should not be overrated. They do suggest, however, that skinning may have a marked effect on meat quality in hot boning operations. The latter option was investigated recently in The Netherlands (van Laack and Smulders, 1991a). Under the experimental conditions of our study (halothane-negative pigs, scalded or skinned, hot boned or cold boned after overnight chilling, vacuum packaged and storage for 13 days at 1°C), the method of dehairing did not affect pH/temperature fall in hot and cold boned pork loins, nor were meat quality traits (colour, water-holding, tenderness) or the microbiological condition significantly affected. Hot boned loins and hams were slightly superior in waterholding, regardless of method of dehairing.

It has been suggested that very rapid chilling in the early post mortem phase might be helpful to reduce the prevalence of PSE (e.g. Honikel et al., 1984; Woltersdorf and Troeger, 1989). However, in commercial practice, it is extremely difficult to achieve the rate of temperature decline in pig carcass sides that is necessary to slow down glycolysis and thus prevent PSE. The latter might only be attained when smaller portions of meat are chilled, because heat is obviously removed more quickly from smaller pieces of meat. One of our recent studies was dedicated to investigating the effects on PSE prevalence of hot and cold boning of fast glycolysing (pH40<6.0; Fibre Optic Probe values>50) and slow (pH40>6.2; Fibre Optic Probe values<50) glycolysing carcasses from a halothane-negative pig population (van Laack and Smulders, 1991d). Although in hot boning pork loins were chilled at 1°C immediately after excision at approximately 50 min post mortem, it neither prevented nor limited the adverse effects of fast glycolysis. It appears that, to appreciably limit drip losses even faster chilling rates are necessary than the one achieved in our study. We are currently investigating how differential chilling rates of (hot and cold boned) pork impact on sensory meat quality characteristics (e.g. see van Laack and Smulders, 1991d; these proceedings).

Novel options for meat tenderisation

A pressurisation treatment of meat cuts for several weeks in plastic vessels at pressures around 4 atm (Aemig, 1990) is currently being advertised for commercial use in butcheries. Allegedly, colour and tenderness improve considerably, whilst spoilage and pathogenic flora is outcompeted by lactic acid bacteria. It is most likely, that the tenderising effects of this so-called 'TenderTainer' treatment relies on extended storage enabling full expression of the endogenous aging enzymes rather than on the effects of pressure as such. Pressures in the order of 1500 atm at elevated temperatures are necessary to induce tenderisation through pressure (MacFarlane, 1985). Until scientific reports on the TenderTainer procedure become available, scepticism is timely. Stanton and Light

(1990) recently suggested that pre-rigor injection of lactic acid in muscles might weaken the lysosomal membranes, cause a faster release of cathepsins post mortem and thus increase the proteolytic activity. More research is necessary to substantiate if such a method might appreciably improve tenderness.

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