Accelerated Processing; Achievements, Drawbacks and the Reconciliation of Sensory and Microbiological Meat Quality

F.J.M. SMULDERS

Department of the Science of Food of Animal Origin, Faculty of Veterinary Medicine, The University of Utrecht, The Netherlands

Introduction

The ways of slaughtering animals and processing their meat is likely to change in the near future. The traditional way of processing meat, i.e. the chilling of carcasses and sides, boning of high and low valued (sub) primals after a certain holding period and then re-heating and re-chilling of large quantities of meat for the manufacturing of meat products is not economical from an energy point of view and it has distinct disadvantages in terms of meat quality. Consequently one has looked for alternative ways of processing, relying on a more rational way of treating meat. However, in spite of promises for such a rationalisation the application of so-called accelerated processing procedures is still limited in practice.

The growing pains associated with the introduction of these new techniques have only partly been overcome and meat researchers are constantly searching for solutions for problems encountered in accelerated processing.

Naturally the processing of meat- and slaughter-byproducts may also be influenced by accelerated processing. However, these will not be dealt with in this paper. Purpose of this contribution is to outline the achievements and drawbacks of accelerated processing. Attention is particularly focused on the impact on fresh meats. Finally a dilemma is discussed which arises from the attempts to satisfy both sensory and microbiological quality of meat.

Accelerated Processing and Sensory Meat Quality

Ever since the phenomenon of cold shortening and the concomitant toughening was recognized (Locker & Hagyard, 1963) one has looked for ways to overcome the adverse effects of rapid chilling on the sensory meat quality. The problems mainly concerned beef and lamb. Several methods such as tenderstretching (Hostetler et al., 1970) and high temperature conditioning (Smith et al., 1971) were introduced, but particularly electrical stimulation was shown to be useful and less complicated for preventing cold shortening (Carse, 1973). Electrical stimulation, conducted roughly within 1 h post mortem (Smulders, 1984a) accelerates the breakdown of ATP and glycogen and thus effects a rapid pH decline preventing toughening by excessive myofibrillar contraction. In addition electrical stimulation may improve tenderness through other mechanisms such as physical disruption of myofibrils (Savell et al., 1978), increased lysosomal enzyme activity (Dutson et al., 1980), and diminution of collagen crosslinks (Judge et al., 1980).

Through mechanisms possibly involving a deeper oxygen penetration (Sleper et al., 1982) or an increased denaturation of sarcoplasmic proteins (Eikelenboom and Smulders, 1986) the colour becomes brighter. The latter

Conventional processing	Accelerated processing
exsanguination	exsanguination
	electrical stimulation
dressing	dressing
	(*decontamination*)
refrigeration	
cold boning	*hot boning*
	(*decontamination*)
cold packaging	*hot packaging*
	high temperature conditioning
	refrigeration
expedition	expedition

Fig. 1. The main features of conventional and accelerated processing of fresh meat.

mechanism may also be responsible for the slight increase in drip loss of meat having been subject to overstimulation. On the other hand is was demonstrated that cold shortening as such adversely affects water holding capacity (Honikel et al., 1981, Smulders et al., 1986a). Electrical stimulation, by preventing cold shortening, may thus succesfully counteract loss of water holding capacity.

Last but certainly not least, electrical stimulation has paved the way for an increased interest in hot boning. Through the acceleration of rigor onset it promises the possibility of deboning a warm, yet firm, product and a reduction of any required conditioning period.

Besides the economically deprived areas of the world there has, to some extent, been a tradition of hot processing in Eastern Europe, which was primarily directed at the manufacturing of meat products. Since the early seventies, hot processing of high valued primals became a point of renewed interest. Hot boning on any

important level is currently practiced on a commercial scale in the Scandinavian countries (Buchter, 1982). In the USA hot boning has been adopted by some plants which pack cow-meat for further manufacturing. Moreover, the bulk of "whole hog sausage" is manufactured from pre-rigor pork. Nonetheless, a wide-spread application of hot boning has not been realized sofar, in spite of possible economic benefits (e.g. energy savings up to 50%, faster throughput of carcasses). Henrickson (1982) indicated industrial impediments such as investment-costs of retrofitting conventional plants, current industry segmentation and increased demands for adequate sanitation and packaging systems, to be the reason for this.

Pre-rigor excision of muscles theoretically results in a shortening that may adversely affect meat tenderness. Since hot boned, vacuum packaged, primals chill faster than carcasses an additional shortening may occur. Electrical stimulation was shown to largely overcome tenderness problems. However, recent experiments showed that even when electrical stimulation is applied, some negative effects may still occur in hot boned, rapidly chilled, meat (Smulders et al., 1981). These can be minimised by superimposing high temperature conditioning on the stimulation treatment (Chrystall and Devine, 1982). For hot boned beef, temperatures around 15°C were shown to be suitable for this purpose (Smulders et al., 1984). Yet, complete elimination of tenderness problems after hot boning is not always fully achieved in some muscles (Smulders, 1984b).

Possibly through a faster post mortem cooling hot boned meat tends to be slightly darker than cold boned meat. Because of more uniform cooling the colour of hot boned cuts will be more similar (Cuthbertson, 1980). Fat colour becomes slightly more white and less stained through a reduced percentage of purge in the vacuum pack (Smulders, 1984b). The latter feature reflects the increased waterbinding capacity of hot boned meat, which in fact is one of the major advantages claimed for hot boning (Cuthbertson, 1980). Taylor et al., (1980-1981), however, showed that the application of electrical stimulation may partially override the improvement in water holding capacity after hot boning. The mechanisms involved in this have already been discussed (*vide supra*). It appears that, as regards the use of electrical stimulation, one should compromise depending on the destination of the hot boned meat. If carcasses are to be hot boned to produce high valued primals, electrical stimulation seems wise. When hot boning is conducted with the main purpose of producing pre-rigor beef for the immediate use as manufacturing meat one may wish to omit electrical stimulation.

Most of the research just overviewed only partly applies to pork. There has been little interest in the introduction of electrical stimulation in the pork processing line. The faster onset of rigor mortis in pork muscle largely overcomes the tenderness problems associated with pre-rigor excision or cold shortening. Yet rapid chilling after hot boning may indeed toughen pork slightly (Honikel et al., 1984). Even more important is that electrical stimulation of pigs would most probably increase the incidence of PSE in pork.

Accelerated Processing and Microbiological Meat Quality

Traditionally in most meat producing countries carcasses are chilled rapidly to effect a temperature decline to below 7°C. It is generally assumed that this chilling procedure, besides reducing weight losses and shortening the in-plant residence time, will adequately limit growth of pathogenic and spoilage flora on meat. The treatment of carcasses may in the near future be directed more and more to accelerated processing. Over the years the attention of researchers has been focused on the effects of accelerated processing on economic, sensory and technological characteristics of meat. Thus the impression may have arisen, unjustly, that microbiological problems are not under discussion. Yet, there are clearly bottle-necks which should be coped with adequately.

Before looking in detail to the more specific problems related to accelerated processing it should once more be stressed that the keeping quality of meat, be it hot or cold boned, is determined by the nature and the degree of initial contamination of the carcass surface. Consequently prevention of contamination is by far the most important factor in safeguarding the microbiological quality of meat. The recommended Code of Hygiene Practices for Fresh Meat (Codex Alimentarius Commission, 1976) describes the Good Manufacturing Practices during slaughter. It is attainable to produce meat with the lowest possible microbiological contamination, only if the whole process is strictly controlled. This is an essential responsability of the management. Adherence to GMP will reduce (cross) contamination in general and, in particular, reduce the probability of carcass contamination with pathogens such as *Salmonella*.

The introduction of accelerated processing entails very special microbiological problems. Using Fig. 1 as a guideline let us look at the major points of concern.

Electrical stimulation may be assumed to hardly affect the bacteriological condition of meat. Although one would expect some reduction of bacteria due to the reduced pH in an early post mortem stage, the published data indicate no important effects (Kotula, 1981). Van Logtestijn et al. (1983) state that it is more likely that the method of stimulation affects the microbiological condition of meat. "Hide-on" stimulation systems will cause no essential hygiene problems, whilst application of "hide-off" stimulation seems acceptable provided electrodes are frequently cleaned and sanitized. The insertion of pin electrodes is discouraged in view of microbiological risks.

Hot boning in any form increases the surface-area/volume ratio of a carcass in a very early post mortem stage when the meat is still warm and more sticky than after refrigation. Under such conditions the cutting table constitutes an even more important source of cross contamination than in cold boning. Particularly carcass areas such as the chuck and round, which are used for pivoting fore- and hindquarters run the risk of being increasingly inoculated with scrapings from the cutting table. One of our more recent experiments showed that the aerobic colony count (3d, 30°C) of beef primals boned "on the table", assessed after 21 d of vacuum storage at 2°C, was 5.9 $\log_{10}$ CFU/cm² in cold boned, and 6.8 $\log_{10}$ CFU/cm² in hot boned beef; boning "on the rail" reduced the counts by approximately 1 logarithmic unit (Smulders and Eikelenboom, 1986). Hot boning especially "on the rail", requires some skill. Knife handling in hot boning procedures is considered to be difficult particularly by tradition-bound butchers. However, a more lengthy experience tends to reverse their concerns. To maintain grip on the hot meat most boners wear steel mesh gloves. Unless thoroughly cleaned in every break these gloves may contain *Enterobacteriaceae* colony counts (1 d, 37°C) as high as 10^8 CFU/g tissue. It is essential that appropiate cleaning techniques are used to avoid contamination of primal cuts through gloves. Ultrasonic cavitation proved to be very effective for this purpose (Van Klink and Smulders, unpublished).

Hot meat is more difficult to vacuum pack than cold meat. Firstly the sticky surfaces of hot meat tend to increase the risk of "air-trapping" (Apple and Terlizzi, 1983). Moreover, from hot meat of e.g. 30°C water will evaporate readily at residual air pressures of 31.8 mbar, whereas in cold meat of e.g. 3°C this will happen not earlier than at approximately 5.7 mbar. The increased evaporation may jeopardize the sealability of some films and prevent an adequate "skinning". Sofar a satisfactory solution has not been found.

Undoubtedly one of the most serious drawbacks is the necessity to include high temperature conditioning to satisfy the requirements of sensory quality (*vide supra*). It is obvious that elevated holding temperatures will increase the risk of microbial proliferation. Model experiments with beef show that after 7 d of vacuum storage at 2°C aerobic colony counts (3 d, 30°C) and *Enterobacteriaceae* colony counts (1 d, 37°C) of beef primals conditioned at 15°C were approximately 1 logarithmic unit higher than those kept under strict refrigeration, i.e. at 0°C (Smulders and Eikelenboom, 1986). Experiments conducted under more practical conditions indicated that conditioning hot boned, vacuum packaged beef for 5 h at 15°C before further storage at 2°C, resulted in significantly higher microbial loads than cold boned counterparts not having been subject to high temperature conditioning; this in spite of the fact that initial counts had been similar or even lower (Smulders and Eikelenboom, 1986). Table 1, taken from latter study, illustrates this point; for comparison a similar experiment with hot boned pork, not subjected to high temperature conditioning has also been included. It should be noted that hot and cold boned pork loins chilled at 2°C immediately after vacuum packaging show no significant differences. Both in beef and pork the microbial load of retail cuts prepared from hot and cold boned primals is similar. It is obvious that part of the surface flora has been removed in the course of trimming. Hence cutting tables and eventually also retail cuts will become cross-contaminated to a greater extent.

Here we clearly face a dilemma: we have compromised wholesomeness to yield a product of satisfactory sensory quality. Reversing the situation, i.e. safeguarding wholesomeness at the cost of sensory properties, seems equally unwise. Possibly this problem should be tackled by applying more strict refrigeration at lower temperatures than 2°C. Danish experience indicates this to be a solution (Hermansen, 1986). Techniques for additional sanitation of carcasses and meats, e.g. terminal decontamination by organic acids, are available but, sofar, not allowed in many meat producing countries (Smulders et al., 1986b). Yet such a terminal processing may turn out to be a prerequisite when accelerated processing is to be applied in such a way that sensory and microbiology meat quality are reconciled.

Conclusion

In evaluating the feasability of accelerated processing, one must give attention to all possible aspects of meat quality. The requirements for obtainment of an adequate sensory/technological and microbiological quality of meats produced by means of accelerated processing may occasionally be conflicting. In such cases one must look for solutions which will not compromise the Good Manufacturing Practices of meat production. Provided these solutions are adopted by the meat industry, accelerated processing will provide an attractive alternative for conventional procedures.

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Table 1 The effect of hot boning on the bacteriological condition of beef (conditioned 5 h/15°C before chilling at 2°C) and pork (chilled at 2°C immediately after packaging) as compared with cold boned, not conditioned counterparts; % of plates appropriate for colony assessment (≥7 CFU's per plate) and mean bacterial counts and standard deviations (log_{10} CFU/cm²).

	SUBPRIMALS								RETAIL CUTS			
	Day 0/1 (before packaging)				Day 12 (12/11 d vacuum storage at 2°C)				Day 15 (after 3 d at 5°C in O_2 perm. packs)			
	hot boned		cold boned		hot boned		cold boned		hot boned		cold boned	
Colony Counts	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
ON BEEF ROUND (n=7)												
Aerobic (3d, 30°C)	100	3.5^{a}	100	3.9^{b}	100	6.1^{b*}	100	4.8^{a}	100	3.7	100	3.6
Aerobic (10d, 4°C)	100	2.4^{a}	100	3.4^{b}	100	6.0^{b}	100	4.9^{a}	100	4.0	100	3.9
Enterobacteriaceae	29	1.3^{a}	100	2.2^{b}	100	3.7^{b}	71	3.1^{a}	14	1.7	14	2.2
ON PORK LOINS (n=10)												
Aerobic (3d, 30°C)	90	2.5	90	2.2	100	2.8	100	3.2	100	4.9	100	5.6
Aerobic (10d, 4°C)	40	2.0	80	2.4	80	2.4	90	2.8	100	5.2	100	4.8
Enterobacteriaceae	10	1.4	0	< **	10	2.8	20	1.8	90	3.0	70	2.6

* In rows, within subclass comparisons, figures with different superscripts differ significantly ($p<.05$).
** Below limit of detection (Enterobacteriaceae <1.3).