
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Concluding Remarks

This work has shown that the weight to which lambs are grown has no significant effect on sheep meat flavour and odour but significant effects are observed due to the animal's growth rate, age, diet and possibly its sex. Overall flavour and odour intensity was much lower in corn/wheat fed animals compared to pasture fed animals slaughtered at 90 days. From the marketing view point, grain fed lambs about 90 days old are preferred for markets requiring milder flavoured meat whereas slow grown older animals (200 days) fed on pasture suit markets desiring more stronger flavoured sheepmeat.

Results from this work also supports the argument that an increase in meat ultimate pH, even to moderate levels, significantly alters the quality and quantity of odours and flavours of the cooked meat. This provides strong support for those who seek to control the variability and reduce the incidence of pre-slaughter stress induced high ultimate pH meat produced in New Zealand.

With due consideration to animal age, diet and control of pre-slaughter stress the New Zealand meat industry can produce consistent high quality sheepmeat tailored to specific discerning markets.

ACKNOWLEDGEMENTS

These experiments were supported by the Foundation for Research, Science and Technology (Young), and the Meat Research and Development Council of New Zealand (Braggins).

Processing for meat quality

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ABSTRACT

The factors which constitute quality of meat will vary according to its end use. In this sense, quality can be defined as 'fitness for purpose' and, to the extent that the purposes to which meat is used is highly variable, the properties of meat need to be controlled accordingly.

The quality of high value table meat required by the consumer can be defined in terms of tenderness, colour, juiciness and flavour. However, the processor has the facility to tailor his process to account for other important variables: these would include whether the product is chilled or frozen, the time interval before it reaches its intended destination and the packaging system used to get it there, whether the product needs a long shelf life for retail distribution or is intended for the HRI trade, and, of vital importance, the economic implications of the whole process. In many cases the processor needs to find the best compromise between conflicting requirements, and the equation needs to account for these background events which are not visible to the end user.

This paper discusses how processing can be used to modify the properties of meat so as to produce the 'best fitness for purpose' to the end user. A comparison is made between two extremes of processing conditions: slow chilling combined with electrical stimulation versus rapid chilling without stimulation. The outcome in terms of tenderness, water binding, colour and hygiene are compared.

INTRODUCTION

The concept of quality is a complex one. The intention here is to assess quality in terms of "fitness for purpose": in other words, to define and measure quality as the difference between the true performance of a product and the expectation of its performance.

Such a definition avoids problems associated with absolute measurement of meat quality, but it does place the onus on the industry to understand the expectations associated with meat and its various products. While expectations involve some degree of flexibility, modified particularly by price, there will always be a minimum requirement: the expectations associated with buying a Corolla are not identical to those of a BMW, but in either case, you expect transport. Absolute requirements will relate primarily to safety, appearance, eating experience (particularly tenderness, but also flavour and juiciness) and consistency.

Identifying these expectations is only part of the challenge. The expectations of the end users is the most visible purpose for which the product must be fit, rather like the visible 10% of the proverbial iceberg. The invisible 90% for which a product must be fit relate to the circumstances of the particular food chain which leads to the end user; meat products can be handled and stored frozen or chilled, in various forms of packaging and modified atmospheres and, perhaps of greatest importance, involving time intervals of just days to weeks from slaughter to consumption. And then, equally important, the process must be fit for the purpose of making a profit for the industry, without which all other considerations become pointless.

Finding the best compromise.

It is evident from what has been said so far that the purpose for which the process must be fit is not a single objective but an assembly of requirements. Central to the concept of tailoring a process to specific objectives is the recognition that the optimal requirements of some members of this assembly are incompatible. For example, optimum safety would require vigorous chilling followed by rapid distribution and sale in order to minimise microbial growth, but such an emphasis on only one member of the assembly would lead to an eating quality expected of leather rather than meat.

In this context therefore, processing for meat quality might be more accurately rephrased as finding the best compromise to attain a particular goal. The main players in the juggling act for table meats would be microbial growth, tenderness, colour and colour stability, water binding, and costs; for manufacturing meats, tenderness would be irrelevant (because the meat is ground anyway), but water binding and solubility of muscle proteins would become of greater importance.

With our present understanding, defining the best compromise is not a rigorous scientific exercise but involves the recognition of certain general principles and then refining the process by trial and error; the amount of hard quantitative data available to be able to predict the optimum process is insufficient. However, the future of efficient and effective meat processing will depend more and more on getting this hard data, in order to elaborate predictive models that can be used to define processing optima. Now that ample computing power is available in the ubiquitous desktop PC, a future can be envisaged where predictive modelling programmes are available to tailor the outcome of a meat production procedure to each processor's facilities and markets.

Steps have already been taken to this end. MIRINZ has developed two computer-based predictive modelling programs, one applicable to microbial growth, which relates the rate of growth to the time-temperature profile until 7°C is attained, and the other to the rate of tenderisation of meat, again according to a time-temperature profile, in the post-rigor period. These need to be developed and expanded further to incorporate other meat quality attributes.

Defining a process

Pre-slaughter process control

Typically, the choice of animal breed, sex and age would be viewed as a dominant form of process control. The choice of animal will have an important bearing on the fat and collagen content of meat. Some markets require high levels of intramuscular fat (marbling), and there is little doubt that the presence of marbling will increase the succulence of meat, particularly in conditions where the meat is cooked to high internal temperatures. Nevertheless, lean meats can reach very high standards of quality if processed in an appropriate manner, while also having the benefit of being viewed as a healthier product in many markets.

As animals grow older, there is also an increase in the amount of insoluble collagen, which can lead to toughening. This effect is however predominant in the low value cuts, whereas the increase in insoluble collagen in the high value cuts is relatively small (Shorthose and Harris, 1990). The choice of breed as the raw material for quality meat is minor, particularly within the range of European breeds.

Of far greater importance to quality is the management of animals before slaughter. The impact of muscle glycogen depletion, which results in elevation in the ultimate pH of the meat, is well known. An increase in the ultimate pH produces a darkening of meat colour, while storage life is reduced because the residual glucose concentrations in the post-rigor meat is reduced and the microbiological flora begin to break down proteins at an earlier stage. Tenderness is also affected, but in a rather more complex way; in the intermediate pH range (5.8-6.2), the process of tenderisation is dramatically slowed, so that there is a high likelihood that the resultant meat will be tougher than normal (Watanabe *et al*, 1995). At still higher ultimate pH levels, the rate of tenderisation is accelerated, but the texture and flavour of the meat is adversely affected.

The impact of poor pre-slaughter management and stress influence quality in other ways. It is important to keep the product free from defects such as of petechial haemorrhages and from bruises. Toughening effects independent of elevated ultimate pH have also been identified, which probably relate to changes in the *rate* of pH fall in the post-mortem period (Khan & Lee, 1973; Daly *et al*, 1995). Taken together, the effects of poor pre-slaughter management is reduced consistency in the outcome of the process. This highlights the vital importance of extending the process definition back to the farm, to include on-farm management of stock, their transport and their handling right up to the point of slaughter. Until these pre-slaughter issues are properly addressed, even the most sophisticated post-slaughter processing and marketing will be undermined.

Post-slaughter processing

Pre-slaughter process management is an absolute requirement for consistency and quality. In the post-slaughter process, options become available to tailor the outcome to specific needs. The two main tools for this tailoring process are the control of the rate of cooling of the carcass, together with the control of the rate of change of pH. These two variables are not independent since temperature will affect how fast the pH falls, but pH can also be manipulated independent of temperature by the use of electrical stimulation. How these two controls are managed is fundamental to processing for quality.

The opportunities available in the tailoring of the production process for specific usage can be effectively illustrated by comparing the outcomes of two extreme processing options:

Fast processing. In order to speed the biochemical events occurring in the post-rigor period, a 300 Kg carcass is electrically stimulated using high voltage (1150 V, 15 pulses/sec), then cooled at a rate just sufficient to reach an deep leg temperature of 10°C in 24 hours, as required by MAF.

Slow processing. In this example, the same carcass is subjected to a brisk cooling regime, using an air temperature of -5°C and air speed of 2 m/sec, without the use of electrical stimulation.

The impact of these differing processing conditions on the properties of the resultant meat are outlined in Table 1.

TABLE 1: Influence of processing conditions on meat quality.

	Process 1 *Fast process*	Process 2 *Slow process*
Time to surface temperature of 7°C	18 hrs	6 hrs
Time to deep leg temperature of 10°C	24 hrs	16 hrs
Time to ultimate pH	2 hrs	18 hrs
Time to reach 4 kg shear force[1]	12 hrs	175 hrs
Generations of E. coli[1]	8.3	3.3
Water loss[2]	14-16%	9-11%
L* value	46-48	42-44
End purpose	Rapid distribution to local market Frozen product	Chilled product with long storage life Manufacturing meat

[1] These values were calculated from the MIRINZ Tenderness model for shear force values, and the Process Hygiene Index for the generations of E. coli.

[2] Measured as fluid loss following centrifugation of 300g for 30 min at 10°C.

Tenderness

The ageing process begins as the muscle nears its ultimate pH (Devine & Graafhuis, 1995). Therefore the accelerated onset of rigor produced by electrical stimulation means tenderisation begins sooner and, since the carcass is on a cooling curve, at a higher temperature. The impact of these two extreme processes can be seen in Table 1, which shows the calculated development of tenderness in the MIRINZ Tenderness model: to reach 4 kgf shear force, which represents a high quality of tenderness, the slow process required 175 hours compared with 12 hours in the fast process.

Microbiology

The microbial consequences of these two processes are shown in Table 1. Again, this is based on a calculated number of generations of the E. coli bacterium from the Process Hygiene Index (PHI) model. The reproduction of this organism ceases at temperature below 7°C, unlike other bacteria of importance to storage life, but the present example gives an indication of the differences in microbiological activity under the different processing regimes. Based on surface temperature, fast process would allow 8.3 generations of E. coli, compared with 3.3 in the slow process.

Water binding

Methods of predicting the effects of processing conditions on the water binding of meat are still under development. As part of this process, data has been collected on water binding at different cooling rates, with and without prior stimulation. These studies used a method of centrifuging meat samples under constant conditions to measure how easily water can be released from the sample, and this provides a reflection of the amount of water which would be lost as drip or during cooking under more normal circumstances. By this method, water losses seen in the fast process would be 14-16%, compared with 9-11% in the slow process.

Colour

The effects of different processing conditions on colour are rather difficult to quantify at this stage, and only general comments can be made. Meat colour is generally assessed in two ways: as reflectance of light from the surface of the meat, which contributes to the brightness of the meat and tends to make the colour more pale in appearance; and in terms of the wavelength of the reflected colour, and here the amount of red is of particular importance in giving the meat the desired appearance. Fast processing produces an increase in the reflectance, and trials have shown that the L* value, a measure of reflectance, is 46-48, compared with 42-44 in the slow process.

The fast process also creates conditions conducive to oxymyoglobin formation so that, together with the increased reflectance, there is a more rapid development of the bright red colour needed in high quality meat when compared with meat produced by the slow process. In contrast, the colour stability in the slow process is generally been shown to be higher, which contributes to increased storage and shelf life. Most of these differences develop from the extent of protein denaturation to which the muscle is exposed, conditions characterised by high temperature and low pH; in other words, conditions of rapid pH fall relative to temperature rapidly promotes the desirable bright red colour, but the stability of the colour so produced is poor when compared to the slow process.

CONCLUSIONS

The effects of these two distinct processing conditions on the characteristics of the meat produced are clearly quite distinct. It is not a case of one being better than the other, but rather how their respective properties can be taken advantage of, and their disadvantages minimised.

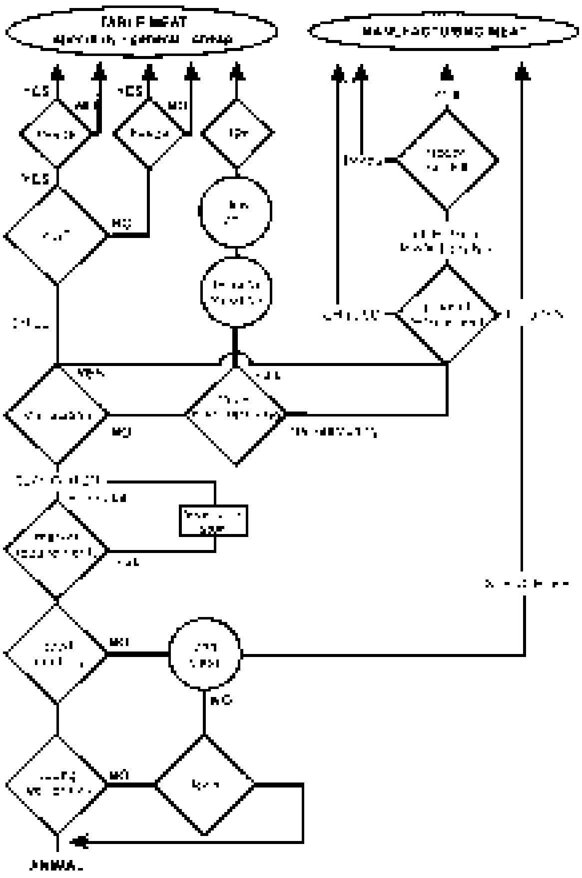
The fast process offers obvious advantages if the product needs to reach their end-user quickly. The rapid development of tenderness and colour are crucial for this purpose, while the disadvantage of weaker water binding and colour stability have little time to become fully expressed.

Alternatively, this process is well suited for a frozen product, and this fast process forms the basis for the Accelerated Conditioning and Ageing (AC&A) process developed for New Zealand lamb. In the frozen state, the meat enters a stasis with very limited changes occurring, including development of tenderness, so that there are important benefits in ensuring that tenderness rapidly reaches acceptable levels before freezing. Since freezing itself results in poor water binding and colour stability, the fact that the processing conditions are not optimal in these respects become relatively unimportant.

In contrast, the slow process are in many ways ideal for a chilled product which requires prolonged storage life. The faster temperature fall inhibits microbial growth, which, together with the slower pH fall, maximises water binding and thus limits drip losses during storage. A desirable level of tenderness can still be reached because of the prolonged holding time, applicable if the product is intended as an export item.

The slow process can be exaggerated still further to improve the processing characteristics of manufacturing meats. The characteristics of manufacturing meats are dependent particularly on water binding and myosin solubility, both primarily defined by the extent of muscle protein denaturation. By accelerating the cooling rate still further in the pre-rigor period, these characteristics can be maximised.

FIGURE 1: Process flow diagram



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