

New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](http://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for [commercial purposes](#).

NoDerivatives — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

development factors beyond those associated with breed and strain variation in fat content can give rise to differences in processing performance and eating qualities among animals of a similar age.

Genetic correlation estimates reported by Renand (1995) were variable and had high standard errors. Their average values tended to be much lower than those coming from his own more discriminating studies (e.g. Renand *et al.* 1994) in which a variety of indicator traits were evaluated, and those for pigs summarised by Wood and Cameron (1994).

While genetic influences have been shown to be important, the underlying basis of gene effects is only now starting to emerge, and at an increasing pace as genetic markers which impact on meat quality are revealed (Renand 1995). Improved understanding of the calpain system and its underlying genetic control has received much attention recently. Some important antagonisms with productive attributes affecting the efficiency of animal production are also emerging, and these are not necessarily the same for all muscles of the carcass and for all production and processing systems, as emphasised by Shorthose and Harris (1991). It is clear from their review, which stresses the complexity of inter-relationships among meat quality traits, that future genetic studies will need to embrace the reactions of different cuts and muscle products to different culinary methods as well.

Much work remains to be done to provide the genetic information needed to incorporate objectives for improved meat quality into selective breeding programmes for sheep and beef cattle. It is clear that multiple-trait selection indices will be needed to cope with the antagonisms that appear to be involved, a task that will require much extension effort and a consistent long-term focus on specified breeding goals if meaningful progress is to be realised. Even now, the important antagonism of leanness with fast growth is not well recognised in the breeding programmes currently being deployed by our sire-breeding industries. Generally, faster lean growth seems to be favourably associated with improved meat flavour, colour, juiciness and (sometimes) tenderness, although there is reduced tenderness in the case of the Callipyge gene and probably also for other genes involved in proteolysis. Fortunately, a number of quantitative trait indicators as well as genetic markers capable of being evaluated in the live animal are emerging from current research, and characteristic breed variations which can be exploited through crossbreeding are becoming identified. Muscle variations within the animal also offer opportunities to develop more specialised and better-matched meat production and processing methods capable of providing competitive sector-linked, "conception-to-consumption" delivery systems for an enhanced array of differentiated meat products.

Animal behaviour and stress: impacts on meat quality

J.F. CARRAGHER AND L.R. MATTHEWS

Animal Behaviour and Welfare Research Centre, AgResearch, Ruakura Agricultural Centre,
Private Bag 3123, Hamilton, New Zealand.

ABSTRACT

Animal behaviour can deleteriously affect meat quality through three different pathways: exertion/activity, physiological stress responses and perceptions of welfare. In this review of published work we will describe each pathway, and discuss methods for minimising their impacts on both the physicochemical and animal welfare aspects of meat quality. We conclude that whereas the physicochemical quality of meat can be improved by some post-slaughter carcass handling treatments, public perceptions of meat quality can only be enhanced by improved animal handling practices to reduce stress.

INTRODUCTION

Meat quality has usually been defined in terms of the physicochemical properties of meat (e.g. tenderness, flavour, colour, juiciness). However, many present day consumers have a broader definition of what constitutes meat quality. The physicochemical properties of meat are still very important, but issues such as food safety, food health and animal welfare will also influence which meat products customers will buy.

Meat quality: physicochemical aspects

The physicochemical properties of a piece of meat are determined by many factors from the farm to the plate. These include: the age of the animal, the particular muscle the cut the meat comes from, the manner in which the animal was slaughtered, the carcass processing methods employed, the duration and temperature of storage, and the cooking method employed. Of these, meat pH, plays a major role in determining the overall acceptability of the

meat by affecting tenderness, colour, flavour and odour (Devine, 1994).

pH is determined by glycogen in the muscle at the time of slaughter. A high muscle glycogen level will allow the muscle cells to metabolize after death, producing lactic acid and reducing muscle pH to around 5.5 (ultimate pH). Such meat will generally be tender, have a good red colour, and be suitable for table cuts. If, however, the muscle contains less glycogen at slaughter there will be less lactic acid produced and ultimate pH will fall less. An ultimate pH of 5.8 to 6.2 will tend to make the meat tougher, darker and unsuitable for table cuts. Meat with a pH between 6.2 and 7.0 will be very dark in colour, firm and dry until cooked (DFD), and will only be suitable for manufacturing purposes (MIRINZ, 1995).

Much research has been carried out worldwide to better understand the processes and mechanisms which result in DFD. The data have been extensively reviewed and discussed (e.g. Hood and Tarrant, 1980; Fabiansson *et al.*, 1989), and aspects dealt with in the present paper are reviewed.

Several factors affect muscle glycogen levels. Nutritional status is the primary determinant of the resting glycogen levels in the muscle (McVeigh and Tarrant, 1982a). And, as will be described in detail below, excessive or vigorous exercise and physical and/or psychological stressors deplete glycogen levels (McVeigh and Tarrant, 1982b; Apple *et al.*, 1995). Glycogen depletion is not permanent; levels can be restored if animals are allowed to rest, feed, and the stressor is either removed or the animals acclimate to it, but this may take days and depends on the quality of the feed supplied (Shorthose *et al.*, 1972; McVeigh and Tarrant, 1982b).

Meat quality: animal behaviour aspects

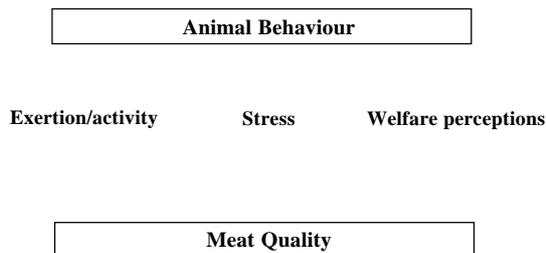
Kilgour and Dalton (1984) defined animal behaviour as “the patterns of action observed in animals which occur either voluntarily or involuntarily”. Not all animals, even within an apparently homogeneous group, exhibit the same behaviours either when undisturbed in the paddock, or when exposed to some sort of stressful handling procedure. A number of biological (e.g. genetics, sexual status, early experience) and environmental (e.g. facility design, handler competence, season) factors influence how an animal behaves.

The three pathways through which animal behaviour can affect both the physicochemical and animal welfare factors impacting on meat quality are shown in Figure 1.

1. Exertion/activity pathway

Exertion or activity can influence muscle characteristics and, therefore, the meat quality of animals. Relatively short periods of intense exertion will temporarily deplete glycogen levels in the muscles used; and if such activity occurs immediately before slaughter, the quality of the meat from those muscles will be poor. Thus, animals which mount frequently immediately pre-slaughter will produce DFD meat from the high value hindquarter and loin muscles, whereas the pH of the remainder of the carcass may be acceptable (Warriss *et al.*, 1984). Activity over extended periods can also affect meat quality. For example, the amount of exercise during on-farm

FIGURE 1: How animal behaviour can affect meat quality.



rearing will affect the mass, composition and/or metabolic status of the muscles involved. Leg and hindquarter muscles taken from sheep frequently exercised on a treadmill produced more tender meat than did unexercised animals (Aalhus *et al.*, 1991). This tenderness difference was attributed to lower levels of collagen and higher levels of myofibrillar protein in the muscles from exercised animals. It is not clear if activity patterns can explain differences in tenderness between extensively grazed and feedlot animals, because planes of nutrition, age or pre-slaughter handling procedures are not always controlled (Shorthose, 1989).

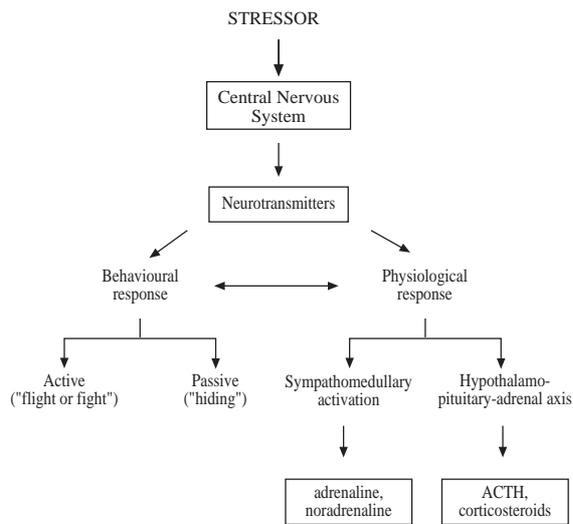
2. Stress pathway

Stress can affect muscle characteristics during both the on-farm rearing and the pre-slaughter management processes. The latter often have greatest impact upon meat quality; not necessarily because they are more stressful to the animal, rather that they are temporally close to slaughter, and therefore have most impact upon muscle metabolism in the carcass. Management procedures imposed on the animal can often conflict with the animal’s preferences; and, as a consequence, may result in physiological and behavioural stress responses (Figure 2). Such stressors can be: social (e.g. unfamiliar animals or isolation), physical (e.g. climate, facilities, procedures, handler), or psychological (e.g. social, facilities, procedures, handler); or various combinations of the three.

Both behavioural and physiological stress responses can produce decreased meat quality. Animals which respond actively to a stressor will tend to deplete glycogen levels in those muscles during resistance or escape. In addition, animals responding to a stressor can sustain injury, either from other animals, inanimate objects or from the actions of a handler; producing bruising and reducing meat quantity.

A fast acting sympathomedullary response will follow a stressful stimulus resulting in the secretion of adrenaline and noradrenaline which mobilize muscle glycogen reserves (by glycogenolysis) to produce glucose. If the stressful stimulus is not quickly removed or is severe, an hypothalamo-pituitary-adrenal (HPA) axis response will occur. The HPA axis response results in the secretion of glucocorticoid hormones (cortisol in most farmed species), which promote breakdown of muscle protein and fatty acid reserves to liberate glucose (a process called gluconeogenesis). Thus, although the two axes act over different time courses (sympathomedullary response is rapid; HPA response is slower), they both serve to maintain sufficient levels of blood glucose for use by the

FIGURE 2: Simplified diagrammatic representation of how animals respond to stressors.



muscles and the brain during periods of stress. Since both axes directly affect muscle metabolism they may impact upon meat quality. However, although adrenaline secreted during stressful pre-slaughter handling procedures can affect muscle metabolism and reduce meat quality (Tarrant and Lacourt, 1984), cortisol released in response to the same stressful procedures probably has little additional deleterious effect on product quality. Cortisol is more likely to affect meat quality or quantity when it is secreted in response to chronic or repeated acute on-farm stressors. Several studies have demonstrated that cortisol can decrease growth rate, either directly or indirectly, by affecting growth hormone levels (Klasing, 1985); but there is no evidence to suggest that chronic or repeated acute periods of cortisol elevation directly affect meat quality (e.g. Judge and Stob, 1963). The two axes also produce other effects that are outside the scope of this review.

Some of the factors that influence how an animal behaves and, via the stress pathway, affect meat quality, will be described.

Biological Factors

Genetics

Temperament refers to the ease with which an animal can be handled for routine farm purposes (Boivin *et al.*, 1992). Several studies have reported significant heritability (sire effect) values for docility in farmed species, suggesting that temperament traits can be effectively selected for (0.38 in pigs, Hemsworth *et al.*, 1990; 0.47 in dairy cattle, Dickson *et al.*, 1970). Certain species or breeds have a reputation for having especially good or poor temperament. However, because temperament is influenced by other factors including handler competence, yard design, and the animals previous handling experiences, there will always be exceptions to any generalisations about the docility of particular species or breeds (Le Neindre *et al.*, 1995). The importance of temperament to meat quality becomes most obvious during pre-slaughter handling when animals encounter novel situations, facilities and handlers. In such stressful situations docile ani-

mals are less likely to injure themselves or deplete significant amounts of muscle glycogen reserves (Vanderwert *et al.*, 1985).

There is no doubt that genotype and some of the other biological factors that can affect animal behaviour (e.g. age), can affect aspects of meat quality independently of their effect on behaviour (reviewed by Bray, 1988). Thus, *Bos taurus* usually gives more tender meat than *Bos indicus*, and young animals are usually more tender than older animals (Crouse *et al.* 1989, Jeremiah *et al.*, 1991). Reasons given for these differences include: different rates of *post mortem* glycogen metabolism, different amounts of connective tissue in muscles, and different amounts of intramuscular glycogen storage (Bray, 1988). However, differences in animal behaviour which are a result of the differences in genotype or age of animals in these experiments have rarely been considered as possible reasons for at least some of the observed variation in meat quality (e.g. Petersen, 1984)

Early handling experience

Boivin *et al.* (1992) and Le Neindre *et al.* (1995) reported that the management system animals were exposed to in early life had significant effects on the later temperament of the animal. Animals reared indoors from 3 months old to weaning were more docile when tested with novel handling situations at 10 to 16 months of age, than those raised outdoors. Although older animals exposed repeatedly to a particular stressful procedure may show some behavioural and physiological habituation, this habituation does not extend to exposures to different novel stressors (discussed in Lawrence, 1991). The implications of these findings are that animal temperament can be altered by early positive handling experiences, and these and novel situations are less stressful to the animal in later life. Thus, novel situations which arise during pre-slaughter handling procedures will be less stressful to appropriately experienced animals, and meat quality should be not be affected.

Age and sexual status

Most young, sexually immature farm animals have few behavioural characteristics which are likely to deleteriously affect meat quality e.g. they are not aggressive, territorial or sexually active. Even so, DFD rates of up to 15% in veal calves have been reported (in Warriss, 1990); but no reasons were given. Once animals reach sexual maturity they develop behaviour patterns which might affect meat quality. Young bulls and oestrous cows, in particular, exhibit high levels of mounting and riding behaviour which can lead to DFD in hindquarter and loin muscles (Kenny and Tarrant, 1984). Male animals castrated before puberty have a lower incidence of sexual and aggressive behaviour (Jago *et al.*, 1995). The effect on meat quality is dramatic: a recent New Zealand study showed that 60% of bulls had an ultimate pH >6.0, whereas only 6% of steers fell in the same category (Graafhuis and Devine, 1994). Therefore the majority of bull meat need not be such poor quality: up to 95% of bulls can produce low pH meat if precautions are taken to avoid mixing of stock, to reduce transport times and to slaughter animals

immediately on unloading (Price and Tennessen, 1981).

Social facilitation

Most farmed species live in social groups, and they tend to show synchrony in feeding and resting behaviours. Similar synchrony can lead to deleterious effects on meat quality. One flighty animal in a group of otherwise docile animals can raise the reactivity of the group to a sudden or stressful stimulus (Fraser and Broom, 1990).

Social stressors

Mixing different mobs of animals can significantly reduce meat quality. This can occur on-farm, on the transport vehicle, or at the abattoir (in lairage prior to slaughter). Mixing leads to high levels of aggressive activity, which will tend to deplete muscle glycogen reserves and DFD meat is often the result (Kenny and Tarrant, 1987; Warriss *et al.* 1984).

There are methods which can minimise effects on meat quality of mixing unfamiliar animals. Warriss *et al.* (1984) slaughtered animals at various times up to 10 days after mixing, and reported that ultimate pH values were >6 up to 2 days after mixing, with muscle glycogen content only returning to control levels on the fourth day. Clearly such a strategy would be possible on-farm, but not at a slaughterhouse. At the latter, mounting behaviour in lairage can be largely prevented by keeping individual animals in separate pens (impractical; Matzke *et al.*, 1985), or by fixing a low level electrified grid over a communal pen (Kenny and Tarrant, 1987). This latter approach would prevent mounting but not aggressive behaviour which may stress animals and could still affect meat quality.

Environmental factors

Climate

In a temperate climate the effects of temperature and season are difficult to separate and are usually considered together. Graafhuis and Devine (1994) suggest that the seasonal differences in the mean ultimate pH of sheep and beef reported in their extensive survey (more carcasses with pH>6.0 in spring), may be related to mob size, stock procurement procedures, farm management practices and/or changes in feed supply or weather. Most of these factors can influence how animals behave and respond to stressful stimuli; thus, some of the reported seasonal variation in meat quality may be a consequence of differences in animal behaviour under changing biological and environmental circumstances.

In another survey, Jago *et al.* (1996) examined 3 years of monthly carcass bruising data from one deer slaughter plant. Different patterns of bruising sufficient to cause downgrading were evident with stag carcasses being affected more often than hinds (8.6 cf 5.4%, respectively). Stag carcasses had significantly more bruising in the autumn. It was concluded that changes in body composition and behaviour related to the rut in stags, and stock procurement patterns were responsible for much of the seasonal variation.

Management factors

It is often difficult to separate the effects of the stressors which occur as a result of the pre-slaughter

handling facilities and handler competence, from those related to transport and social factors, but, as far as possible, this is attempted in the next two subsections.

1. Facility design and handler competence

The influences of facility design and handler competence on animal behaviour and stress responses are associated with animal temperament and early experience (discussed above). Even docile animals can become difficult to handle if yard facilities stop free flow of movement, or handlers are inexperienced in moving animals. Grandin (1987) has described handling facility designs which promote ease of animal movement. These include using curving raceways to avoid apparent deadends, avoiding steep slopes on loading ramps (particularly for offloading), and avoiding shadows across raceways. Facilities designed and built to take into account such principles are less stressful for the animals and produce more high quality meat (Warriss *et al.*, 1994).

Bruise scoring on sheep and beef carcasses has sometimes been used as an indicator of the pre-slaughter ease of movement. Surveys have shown that a large proportion of carcasses have bruising (lambs, 71%; ewes, 49%; Cockram and Lee, 1991; cattle, 97%; Jarvis *et al.*, 1995), with most carcasses having more than one bruise (range of median values: 3 to 5.8). Studies have shown that most carcass bruising is sustained in the 24 hr immediately prior to slaughter, with 43 to 90% (cattle) and 25% (sheep) occurring at the abattoir (McCausland and Millar, 1982; Cockram and Lee, 1991; respectively).

Warriss *et al.* (1994) subjectively scored pigs for stress prior to slaughter; for five abattoirs (covering the range of subjective stress ratings) the subjective scores were compared to levels of stress indicators taken from animals at slaughter, and meat quality data. There was a high positive correlation between the subjective assessment of stress in a plant, some of the blood indicators, and the incidence of poor meat quality. The authors reported that the more stressful slaughterhouses were larger, dealt with more animals at faster rates, had more mechanisation pre-slaughter (e.g. conveyors), and were noisier. This study suggests that experienced observers can accurately subjectively assess the stressfulness of different pig slaughter premises. These results suggest a similar approach using experienced observers could be applied to help beef or sheep slaughter premises identify and eliminate stressful elements of the pre-slaughter environment.

2. Transportation

The effects of transport stress on meat quality were reviewed by Tarrant (1990). Cattle studies have shown that short-haul road journeys should not significantly affect meat quality, providing loading density is within the recommended limits, and careful driving standards for different road types is maintained. In New Zealand, most journeys from farm to slaughter are short-haul. Graafhuis and Devine (1994), reported no significant effect of distance transported (up to 400 and 500 km for sheep and beef, respectively) on ultimate pH of carcasses. In contrast, Jago *et al.* (1996), found that deer transported more than 200 km to slaughter had a higher rate of carcass

downgrading due to bruising. Long distance road and/or rail transport of stock required from remote regions of Australia, can predispose animals to produce DFD meat if they are not sufficiently fed and rested before slaughter (Shorthose *et al.*, 1972; Wythes *et al.*, 1980). Animals that “go down” during short-haul transport, will yield poor quality meat (mean pH 6.3 vs 5.7 in controls; Warnock *et al.*, 1978).

Other pre-slaughter handling procedures

The effects of several other common pre-slaughter handling procedures on meat quality have also been investigated. Apple *et al.* (1994) determined the effect of a short period of intense exercise (up to 2.1 km over 20 min) on an inclined treadmill on lambs. This amount of exercise increased plasma lactate and glucose levels, and changed plasma levels of stress indicators (ACTH, cortisol). When the animals were slaughtered shortly afterwards, only one of the exercised groups had slightly decreased muscle glycogen. Twenty-four hours later meat pH values in exercised and control animals were 5.6 or less, and tenderness values were all good. Thus, short periods of exercise do not appear to significantly affect meat quality in sheep.

However, when exercise has a significant psychological or emotional component, some deleterious effects become apparent. For example, Chrystall *et al.* (1982) found that lambs exercised by dogs for approximately 5 km produced high pH meat. The impact of the psychological component of a stressor can be gauged from a study by Apple *et al.* (1995). Sheep were taken from their home environment and restrained on their side for 6 hr without visual or tactile contact with other animals and, less than 30 minutes later, slaughtered. Restraint and isolation significantly deleteriously affected meat quality compared to unstressed animals: muscle glycogen levels were lower (by approx. 50%) at slaughter, and ultimate pH was higher (6.4 vs 5.7 in controls). Another group of sheep was exposed to the same restraint and isolation stressor, but activity/struggling in the posterior body was inhibited by epidural anaesthesia. The carcass quality of this group was deleteriously affected to the same extent as in the restraint and isolation group. These data strongly suggest that the deleterious changes in carcass quality were a result of the psychological component of the stressor, probably via activation of the sympathomedullary axis, and that exercise contributed little to the observed changes.

Sumner (1984) reported that shearing lambs on the day before slaughter had no effect on meat pH (mean pH 5.53). Bray *et al.* (1989) compared the effects of a 20 day period of undernutrition, shearing and pre-slaughter washing stressors, singly and in combination, on lamb meat pH and tenderness. Applied singly there was no significant effect of any treatment on meat quality, but when combined, their effects tended to be cumulative. The mean ultimate pH from animals exposed to all three procedures was 6.25, with 80% of carcasses over pH 6.0. As the authors pointed out, under commercial slaughter conditions animals will often be exposed to several stressful stimuli, and the cumulative effects of such stressors can be detrimental to meat quality.

3. Welfare perceptions pathway

The image projected by a product is crucial to its acceptance and success in the marketplace. Advertisers often promote products with “clean and green” imagery to take advantage of growing concerns of consumers towards sustainability, reducing waste, and protecting the environment. Recently, the term “caring” has been added to clean and green, to reflect the growing concern of consumers who want the animal products they buy to come from animals reared and slaughtered according to high standards of welfare. The real or perceived animal welfare standards of a particular product become incorporated into the customers definition of product quality.

Increasingly, customer concerns toward animal welfare are widening to encompass the whole farming system from which the product is derived. Thus, some products are difficult to sell, because they are associated with a farming system perceived to be unfriendly to animals. Canned tuna is a very good example: labels on cans identify product caught using a technique which does not kill dolphins (it has nothing to do with the welfare of the tuna), and this product sells well.

These concerns have a substantial impact upon marketing of meat in Britain (e.g. the introduction of “Freedom Food” and similar labels to identify animal products raised under acceptable standards of animal welfare). The implications of this for New Zealand are very clear: British supermarket buyers have recently visited this country to determine if our animals are protected by animal welfare legislation and codes of conduct which they find acceptable. A number of issues which might need to be addressed were identified, including transport practices, care of newborn animals, and velvetting of deer.

CONCLUSION

Most animals destined for slaughter in New Zealand have the potential to yield table meat with high physicochemical and animal welfare qualities. To realize this potential we need to ensure that adequate precautions are taken during on-farm and pre-slaughter handling procedures.

Different strategies need to be utilised to protect the (a) physicochemical and (b) animal welfare qualities of meat:

- (a) Physicochemical properties: One strategy is to improve animal handling procedures and practices, both on-farm and pre-slaughter, to reduce the stress and behavioural responses which currently cause poor meat quality. The alternative is not to change pre-slaughter conditions, but to remedy some of the effects of stress post-slaughter by using certain carcass handling practices (e.g. electrical stimulation) to “salvage” some higher quality product from carcasses that would otherwise yield meat of poorer quality (Dutson *et al.*, 1982; Chrystall *et al.*, 1982).
- (b) Animal welfare perceptions: Unfortunately, the types of post-slaughter carcass treatments described above will do little to enhance the animal welfare perceptions of meat quality. The only way to improve the perceived welfare quality of meat is to refine on-farm and pre-slaughter animal handling practices to reduce stress.