Systems for quality venison

Joanne Stevenson-Barry

Abstract

Venison quality, as with other meats, encompasses a range of attributes including yield, safety, appearance, palatability and image Many of these attributes are affected by on-farm factors as well as transport, processing, packaging, storage and distribution Therefore, quality assurance systems are necessary from paddock to plate Although the New Zealand deer industry has developed very good quality assurance programs, there is room for improvement Recent research with venison indicates that the ultimate pH (pH_u) of the meat can influence meat quality profoundly. This research suggests that pH_u has a more significant effect on tenderness than other factors, including animal age, and it also impacts on juiciness, texture, flavour and keeping quality (shelf-life) of meat. Measurement of pH_u is used in meat quality grading systems around the world and could be a useful indicator not only of venison quality but of the effectiveness of the QA system, since pH_u is influenced by pre-slaughter events such as stress or over-exercise. Research results from a recent study measuring pH_u will be discussed, together with factors that influence quality

Introduction

Much of the research on venison quality has focussed on production traits and yield of meat produced There has been considerable focus on increasing or optimising yield However, in the eyes of the consumer, yield is probably one of the least important criteria As with other meats, palatability is the most important criterion Palatability, or eating quality, relates to the overall enjoyment of the eating experience and how good it tastes, smells, looks, and how juicy, tender and flavoursome it is. Mild flavour and consistent tenderness of New Zealand farm-raised venison are no doubt important characteristics and need to be ensured, but it is likely that the image of venison is also an extremely important criterion Image includes the consumers perception of safety, appearance, healthiness, and production aspects such as pasture-raised vs. feedlot, sustainability and, animal welfare In order to maintain or achieve high standards of palatability and image, some existing production practices need to be improved

Stress and pH

An indicator of livestock stress is the meat pH pH is a measure of the acidity of the meat. Under-nourishment, stress and over-exercise reduce an animals, muscle energy store (glycogen) After death, muscle glycogen is converted to lactic acid If the glycogen store has been reduced, less acid is produced which results in a difference in the ultimate pH attained. In the living animal, the pH is close to 7 and normally falls to around 5 5 at rigor mortis When the pH decline stops, it reaches a value called ultimate pH (pH_u) which is usually measured at about 24 hours after death If less acid is produced, because of less glycogen in the muscle at the time of slaughter, the pH does not fall as far and the pH_u is higher than normal It has been well-established that pH_u is an important indicator of quality as it affects the appearance, texture and shelf life of meat (McVeigh & Tarrant, 1981) and the measurement of pH_u is used in quality-based grading schemes for other livestock species around the world. A pH_u above 5 8 is cause for concern because it indicates that a stressful event has occurred pre-slaughter and it has profound effects on meat quality. But many cases pH_u above 6 and as high as 7 have been recorded in deer, and these values indicate severe stress, under-nourishment and/or over-exercise

The main objections to high pH_u meat are due to the dark colour and spoilage characteristics, but the consistency and eating quality are also considered objectionable Meat with very high pH_u (> 6 0) has

higher bacterial counts and approximately half the shelf-life than meat with normal pH_u (5.5-5 7). The economic consequences are· (1) rejection of the product at various stages of the marketing chain; (2) cost of disposal of product and substituting normal meat; (3) loss of reputation for quality, and (4) down-grading of non-affected cuts We have found a relationship between bruising and pH_u in that, when the obvious portion of a bruise is cut away, the surrounding meat, although of normal appearance, often has high pH_u and is of lower quality

Handling and meat quality survey

A survey carried out at a South Island deer slaughterplant where the handling was considered to be very good, indicated surprisingly high levels of elevated pH_u. We have surveyed over 7000 animals so far but have only analysed data from approximately 4000 animals from 142 consignments and derived from 101 farms Most of the deer were red or red x wapiti hybrids (94 %), with the balance made up of 3 % wapiti and 3 % fallow deer (the fallow deer were from two different farms, and were processed on one day) The red and red x wapiti hybrids were analysed as one group (referred to as red/wapiti) Sixty-one percent of the deer were stags and 39 % were hinds On average, deer were held in yards at the farm for 2 25 hours (ranged from 0-12 hours) and were transported on commercial deer trailers for 2 75 hours (ranged from 0-9 hours)

Muscle pH

We found that approx 70 % of fallow deer and 10.6% of red/wapiti animals had $pH_u > 5\ 8$ in the striploin (M. *longissimus dorsi*) (Pollard et al, 1998). The high frequency of unsettled behaviour and elevated pH_u levels recorded for fallow deer highlights the need for specific handling techniques and facilities to prevent problems with animal welfare and meat quality when processing this species (English, 1993; Fletcher, 1995) However, elevated pH_u does not appear to affect eating quality in fallow deer, but is a cause for concern in red/wapiti animals (Stevenson-Barry and Drew, 1988; Stevenson-Barry et al , 1999) The proportion of carcasses with elevated striploin pH_u in our survey (11 %) was much lower than that found in a survey of sheep and cattle slaughter premises in New Zealand (31 %, Graafhuis & Devine, 1994) However, sheep often undergo washing procedures that are stressful and known to increase pH_u, and dogs or electric prods are not used at the deer slaughter plant involved in this survey, factors that may have contributed to the better pH_u levels in deer.

Bruising and injury

Bruising and broken bones were also recorded in this study together with background history of the animals relating to handling on the farm, how far the animals were transported, weather conditions and behaviour Bruising and broken bones represents an economic loss due to discarding of the affected tissue (bruises and broken bones are cut out of carcasses before they are weighed), but also has animal welfare implications attributable to of poor handling prior to slaughter. In this study, 23 deer out of 3586 had broken ribs (0 6 %), of which 16 were old breaks that had healed, and clearly had not occurred in the immediate pre-slaughter period. Bruising occurred most frequently on the hocks (22 % of carcasses) followed by the hindquarters (19 %), forequarters (5 %), and loins (2 %) Overall 24 % of carcasses had bruising in some area other than the hocks The most common bruises (excluding those on the hocks) were small and less than 5 mm deep (12 % of carcasses; 48 % of all bruises were in this category) The frequency of bruising (in areas other than the hocks) differed greatly between farms, and ranged from 0 to 100 % of carcasses Bruising was found to be related to pH_u but no relationships were seen between behaviour (fighting in the overnight lairage pen or unsettled behaviour in the lead-in race) and either bruising or pH_u

Bruising differed between carriers (truck drivers), and a significant positive relationship was found between bruising and the weather index ($P<0.05$). Bruising increased as weather conditions deteriorated (weather scores were added together to give a weather index which increased as weather conditions deteriorated, i e as rain, cloud and wind increased and as temperature decreased). Bruising was positively related to load size, as in the study by Jago *et al* (1993) This could have occurred because deer in larger loads were more crowded and possibly climbed on top of each other However, in spite of this positive relationship, high frequencies of bruising sometimes occurred in

small loads. Possible reasons for the differences between days in bruising and pH_u include seasonal and climatic effects, and may become more apparent over the next year as more data is analysed.

Deer behaviour

Behaviour of the animals was recorded at the slaughter plant and high levels of unsettled behaviour were observed During overnight lairage a subset of the animals were monitored (just one pen of 9-15 animals for each slaughter date) by infra-red camera between 8pm and 4 am There were an average of 14 antagonistic encounters per hour, with a low of 3 per hour and a high of 34 per hour. These were mostly biting, followed by boxing and butting They tended to increase during the night and the number of encounters differed significantly on different nights Overall the amount of antagonistic activity (biting, boxing, butting etc) was similar across stags, hinds and mixed sex groups, but the mean agitation score (amount of movement/stepping around the pen) for stags was a relatively low 3 0, compared with 6 0 for hinds, and 5 6 for mixed sex groups For the one group of fallow deer that was monitored in lairage, the number of encounters was low (5), but the agitation score was a maximum 12 The percentages of antagonistic encounters involving 2, 3 or more deer, respectively were 44, 31 and 25 Biting was involved in 66 % of encounters, boxing in 37 %, and butting in 28 % Boxing tended to occur in encounters involving several deer rather than just two, and butting also became more prevalent as the number of deer involved increased. There was no clear seasonal pattern, or effect of the number of animals in the pen on the frequency of antagonistic encounters.

In the lead-in race prior to the stunning box, red/wapiti deer were more settled than fallow deer For both red/wapiti and fallow deer, the most commonly observed behaviour in the lead-in race was rearing, seen in 17 % of red/wapiti deer and 39 % of fallow deer Jumping was seen in only 7 % of red/wapiti deer but in a relatively large proportion (36 %) of fallow deer Lying occurred at similar levels in both species (8-11 %), as did climbing (3-4 %). Loads from different farms differed significantly in the proportion of deer which showed unsettled behaviour in the lead-in race, with the incidence of the specific activities rearing, climbing, jumping and lying down ranging from 0 to 55, 20, 40 and 40 %, respectively for each activity, for red/wapiti deer Unsettled behaviour also differed significantly between carriers. Deer that showed climbing, jumping or rearing were more likely to have been held in the race for a long time rather than for short periods. No relationship between antagonism or agitation score during lairage and unsettled behaviour in the lead-in race was evident.

Overall this data indicates that farm and carrier effects predominate for elevated pH_u, bruising and unsettled behaviour, although the high frequency of antagonistic encounters during overnight lairage, and the increasing frequency of antagonism over the eight-hour observation period, suggest that holding deer over this period may be undesirable. A relationship between antagonism in lairage and bruising could be expected but none was found in our survey. This suggests that the impacts during antagonistic behaviour in the lairage were not sufficient to result in bruising, and that bruising occurred at other stages in the pre-slaughter process. As yet, we are unable to quantify what practices on farms and in transport are affecting meat quality and behaviour of the animals. It is believed that perhaps stockmanship is a contributing factor In discussing these results with farmer groups and veterinarians, it has been suggested that perhaps a good predictor of the stress-level of the deer would be a measure of stress-level of the handlers (farmers and transporters).

Influence of pH_u on venison quality

Muscle pH_u is known to influence eating quality (tenderness/texture, flavour/odour and succulence/juiciness), functional properties (water-holding capacity which affects drip/purge, and water-binding capacity in processed meats) and safety (microbiological spoilage) in beef, lamb and pork. Studies have shown that, as meat pH_u increases from the ideal of 5.5 there are undesirable consequences to tenderness, texture, flavour, odour, colour, microbiology and hence, shelf-life and consumer acceptability (McVeigh & Tarrant, 1981) A complex relationship has been shown to exist between pH_u and tenderness in both beef and lamb, such that toughness increases as the pH_u rises to between 5 8 and 6 0, then decreases as the pH_u rises above 6 0 However, this relationship does not appear to exist for fallow deer or reindeer, which are reported to be uniformly tender regardless of

pH_u (Drew, 1988; Wiklund et al, 1997) We have done two studies with red deer venison confirming similar effects of pH_u on tenderness and darkening of meat colour as reported for lamb and beef (Stevenson-Barry and Drew, 1998, Stevenson-Barry et al., 1999). It is highly likely that, since high pH_u venison has similar tenderness and colour trends to other species, the undesirable consequences on other meat attributes (texture, odour, flavour and microbiology) will also occur.

Toughness is an important issue in un-aged venison, lamb and beef, and also in meat in the "intermediate" pH_u range (5.8-6.2). Under these conditions, even meat from a young animal is likely to be tougher than old stag meat However, the extent to which these tenderness problems can be "aged" out is different for lamb compared to beef and is worth noting. Studies with lamb have indicated that the toughness related to intermediate pH_u (5 8-6 2) could be reduced during ageing so that eventually the meat reached an acceptable tenderness level (Watanabe et al., 1996, Devine, 1994), the effect of the intermediate pH is to substantially reduce the ageing rate. In beef however, studies have shown that samples did not attain an acceptable standard of 8 kgF even after 49 days of ageing at 4°C (Simmons and Cairney, 1997). Our studies with red deer venison demonstrated that the tenderness profile change after ageing at 4°C was similar to that reported for lamb, in that all of the striploin samples eventually tenderised to an acceptable level. But intermediate pH_u muscles still tended to be tougher than the normal pH_u muscles and were more variable in tenderness (i e less consistent quality) than normal pH_u muscles This is why we have now focussed considerable attention on identifying causes of pH_u problems.

Effect of nutrition level on pH_u

There is a well established relationship between pH_u and stress, as physical stress results in depletion of muscle glycogen, in turn reducing the amount of lactic acid produced in the muscle following slaughter (McVeigh & Tarrant, 1981). However, our survey found that the only variable related to pH_u was bruising There was no indication of a relationship between pH_u and fighting or agitation in lairage, or unsettled behaviour in the lead-in race This may be due to other factors besides physical exertion at the slaughter plant affecting pH_u, for example the fitness of the animal or its nutritional status can also affect muscle glycogen levels (Gregory, 1996, Malmfors & Wiklund, 1996) In addition, behavioural measurements were restricted to only two stages in the pre-slaughter process, and did not include, for example, an evaluation during transit and during yarding at the farm. However, there is some indication that pH_u levels for the summer of 1998/9 were elevated compared to the previous year. In the previous year, the incidence of elevated pH_u ranged from 0-25 % in the loins and averaged about 10 % but in 1999 ranged from 6 to 68 % and averaged 19 %. It is believed that under-nutrition caused by a severe drought in the region reduced muscle glycogen levels, raised pH_u levels and consequently reduced meat quality.

Body condition

Jago et al. (1996) conducted a study of bruising of red deer carcasses at a deer slaughter plant in New Zealand during 1991-93. They concluded that carcass quality and deer welfare could be best protected by careful driving, by only transporting animals in good condition, and by avoiding transporting males during the rut We have recently seen a relationship between condition score and pH_u In a very recent study involving hinds from a commercial deer farm which were being culled due to body condition and for being dry (non-pregnant) based on pregnancy scans Those animals that were in very poor body condition (almost emaciated) had significantly higher pH_u values than those of animals with better body condition score. In the survey work we also observed a relationship between fatness and pH_u Animals with very low fatness (GR measurements), particularly emaciated animals, were found to have higher pH_u and as GR increased, pH_u decreased.

Effects of lairage

Previous studies on deer have revealed mixed effects of lairage on meat quality Jago *et al* (1993) reporting a greater frequency of bruising in deer held overnight than in those slaughtered soon after arrival at a DSP, but there was a negative relationship between lairage time, plasma glucose and

carcass pH_u, suggesting a recovery from the effects of transport. Grigor *et al* (1997) studied deer held in lairage with hay, water and straw bedding, for 0, 3, 6 or 18 hours. In that study there was an increase in antagonistic behaviour and a decrease in liveweight over 18 hours of lairage, but an increase in liver glycogen and a decrease in plasma creatine kinase activity, again suggesting of recovery from transport The lowest pH_u values (5 52 in the loin) were seen in the deer held for 6 hours (Grigor *et al*, 1997) It was concluded that because behaviour was unsettled, the deer should be slaughtered as soon as possible after arriving at the plant (Grigor *et al.*, 1997). Nevertheless, in New Zealand, it is still common practice to hold deer overnight before slaughter, to reduce gut-fill to avoid carcass contamination It may also be argued that at late afternoon and evening the slaughterplants tend to be quieter, therefore it may be a better time to deliver animals, rather than amid the noise of an operating plant Also, having animals delivered before the kill starts provides some certainty as to the number of animals to be killed that day

Temperament

Dr Temple Grandin, and her colleagues (Voisenet et al , 1997a) found that cattle with the most excitable temperament ratings produce carcasses with tougher meat and a higher incidence of intermediate pH_u than cattle with calm temperament ratings. In preliminary work with a group of 50 animals from Invermay, we found that two animals that were reported to be difficult to handle (flighty/skittery) also had correspondingly high pH. These observations suggest that selecting or culling based on temperament may be a good practice both from an animal handling and meat quality point of view. Selecting for temperament may also have additional benefits since other work, by Voisinet et al., (1997b), found that cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments

Conclusions

Recent evidence suggests that, as with other meat-producing animals, deer behaviour and pre-slaughter stress affect venison appearance, palatability and shelf-life. Animal behaviour and stress can affect the meat ultimate pH (pH_u), which influences tenderness profoundly. Normal pH_u is around 5 5 and as pH_u increases, toughness increases to a maximum around 6.0 Beyond pH_u 6 0, toughness decreases, but meat with pH_u above 6 0 is darker in colour and has decreased shelf-life due to more rapid microbial spoilage The toughness associated with intermediate pH_u can be modified somewhat with conditioning and ageing of product (i e chilled storage), but even after 21 days chilled storage, intermediate pH_u meat is still tougher than normal pH_u meat Often intermediate pH_u meat (pH 5 8-6 2), even if it is from a young animal, will likely be much tougher than old stag meat

pH_u is influenced by animal stress and farmers can contribute to venison quality by controlling and/or limiting the stressors. However, there is research in other animals that suggest that the animal's intrinsic behaviour may play a role Since pH_u influences venison quality, the incidence of high pH_u meat needs to be reduced or eliminated. pH measurement of carcasses is relatively simple and is about as easy, and it takes about the same time as carcass weight and GR measurement. pH measurement should be incorporated into grading systems to allow payment based on quality and to provide the feedback needed by farmers to improve quality This is already being done in the beef and lamb industries

References

Devine, C E , 1994 Incidence of high pH beef and lamb I Implications for meat quality *Proceedings, Twenty-Eighth Meat Industry Research Conference* 125-129

Drew, K R , Crosbie, S F , Forss, D A , Manley, T R and Pearse, A J 1988 Electrical Stimulation and Ageing of Carcasses from Red, Fallow and New Zealand Wapiti-type Male Deer *J. Sci Food and Agric* 43· *245-259*

English T 1993 Fallow deer farming-Animal welfare issues in Australia *Proceedings, First World Forum on Fallow Deer Farming* 225-228

Fletcher J 1995 Handling farmed deer *In Practice* 17 30-37.

Graafhius A E and Devine, C E , 1994 Incidence of high pH beef and lamb II. Results of an ultimate pH survey of beef and sheep plants in New Zealand *Proceedings, Twenty-Eighth Meat Industry Research Conference.* 133-141

Gregory N G 1996 Welfare and hygiene during preslaughter handling *Meat Sci* 43 S35-S46

Grigor P N , Goddard P J , Macdonald A J , Brown S N , Fawcett A R , Deakin D W and Warriss P D 1997. Effects of the duration of lairage following transportation on the behaviour and physiology of farmed red deer *Veterinary Record* 140 8-12

Jago J G , Matthews L R , Hargreaves A L and van Eeken F 1993 Preslaughter handling of red deer implications for welfare and carcass quality *Proceedings Deer Branch of the New Zealand Veterinary Association* 10 27-39

Jago J. G , Hargreaves A L , Harcourt, R G and Matthews L. R 1996 Risk factors associated with bruising in red deer at a commercial slaughter plant *Meat Sci* 44 181-191

Malmfors G and Wiklund E 1996 Pre-slaughter handling of reindeer-effects on meat quality *Meat Sci* 43 S257-S264

McVeigh J and Tarrant, P 1981 The breakdown of muscle glycogen during behavioural stress in normal and beta-adrenoceptor blocked young bulls *In* The Problem of Dark-cutting in Beef Eds D. E Hood and P V Tarrant *Current Topics in Veterinary Medicine and Animal Science* 10. Martinus Nijhoff, The Hague pp 430-439

Pollard, J C , Stevenson-Barry, J M and Littlejohn, R P. 1999 Factors affecting behaviour, bruising and pH_u in a deer slaughter premises *Proceedings New Zealand Society of Animal Production* 59 148-151.

Stevenson-Barry, J and K Drew (1998) Venison pH *A Report on the Incidence of High pH Venison and Its Influence on Quality Research Report prepared for the Technical Committee of the Game Industry Board* 15p

Stevenson-Barry, J M , Carseldine, W J , Duncan, S J and Littlejohn, R P 1999 Incidence of high pH in venison implications for quality *Proceedings New Zealand Society of Animal Production* 59 145-147

Simmons, N J and Cairney, J M 1997 Relationship between ultimate pH and tenderness in beef *Prepared for The New Zealand Meat Producers Board* 17pp

Watanabe, A , Daly, C C and Devine, C E 1996 The effects of ultimate pH of meat on tenderness changes during ageing *Meat Sci* 42 133-144

Wiklund, E , Barnier, V M H ; Smulders, F J. M , Lundström, K and Malmfors, G 1997 Proteolysis and tenderisation in reindeer (*Rangifer tarandus tarandus* L) bull longissimus thoracis muscle of various ultimate pH *Meat Sci* 46 33-43

Voisinet, B D, T Grandin, S F O'Connor, J D Tatum and M J Deesing 1997a Bos Indicus-Cross Feedlot Cattle with Excitable Temperaments have Tougher Meat and a Higher Incidence of Borderline Dark Cutters. *Meat Sci 46 pp 367-377*

Voisinet, B D, T Grandin, J D Tatum, S F O'Connor and J J Struthers 1997b Feedlot Cattle with Calm Temperaments have Higher Average Daily Gains Than Cattle with Excitable Temperaments *Journal of Animal Science, volume 75, pp 892-896*