Beef Quality

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Production Factors Affecting Beef Quality

Nutrition at finishing

Finishing feed is especially important in fattening systems, which only exploit the potential of cattle growth. The main effect of limited growth rate is a decrease in meat tenderness, which can be great. In fact, beef tenderness remains the most important quality factor, and is also the most problematic because it is not yet fully controlled. When fattening cattle on pasture, a maximum growth potential is frequently not achieved due to a deficiency in dietary energy. Generally, a finishing period induces compensatory growth or an increase in growth rate. An adequate feeding strategy in the finishing period will fully compensate for the negative effects on beef quality caused by prior growth restriction.

In the last few months before slaughter, an increase in dietary energy affects protein metabolism by increasing synthesis and turnover of proteins. Connective tissue (collagen) and myofibrillar proteins (muscle fibres, **Fig. 1a and 1b**), are two main components of muscle tissues that determine meat tenderness. Connective tissue determines the assembling mode and the cohesion of muscle fibre. Furthermore, there is important quantitative and qualitative variation in the collagen content and spatial distribution. Connective tissue is mainly composed of collagen, a fibrillar protein whose quantity and quality define the basal toughness of the muscle. Collagen quality is associated with the extent of polymerization (intermolecular linkages) of collagen fibres. The toughness of meat with a high collagen content will be increased as its collagen fibres become less soluble. Meat from animals with a high growth rate in the finishing period contains a large quantity of newly synthesized and heatproof collagen, and is more tender. This effect is more pronounced in muscle with a high collagen content.

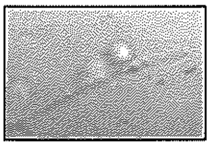

Figure 1a. Myofibril sampled 48 hours after post mortem viewed under microscope (original magnification x1500).

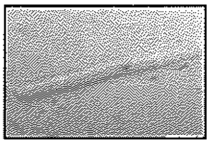

Figure 1b. Myofibril sampled 48 hours after post mortem viewed under microscope (original magnification x1500). The contraction state of the sarcomers, the myofibril contraction unit, in post rigour remains unchanged.

The effect of finishing on the myofibrillar component depends on the distribution of the muscle fibre types and on the activity of proteolytic enzymes during ageing. Muscle fibres may be differentiated by their speed of contraction into slow and fast contracting fibres or by their energy metabolism into oxidative and glycolytic fibres. Muscle contains mainly oxidative red-slow fibre (I), oxidative and glycolytic red-fast fibre (II A), and glycolytic white-fast fibre (II B). Each class of fibre differs in the content of myoglobin, glycogen, lipids, organelles and cytoplasmic proteins (e.g. enzymes). The total number of fibres in a muscle is determined at birth, and muscle growth is therefore the result of muscle fibre hypertrophy. The relative distribution among the 3 main fibre types can alter in response to different intrinsic or extrinsic factors, however these changes are reversible (I ↔ IIA ↔ IIB). The predominance of one or another fibre type in the muscle can affect parameters such as pH, water holding capacity, colour, flavour, rate and extent of ageing and tenderness. A high growth rate during finishing will increase the proportion of glycolytic white-fast fibres, which enhance tenderness.

An increased concentration of proteolytic enzymes in tissue is linked to increased protein turnover during the finishing period. Proteases, in particular calpains, act on some myofibrillar proteins. During ageing, calpains modify the cohesion and structure of the fibres resulting in increased in meat tenderness. It has also been shown, that an increase in growth rate decreases the activity of calpastatin, a calpain inhibitor.

After pasture, a finishing period with a high-energy feed also reduces the intensity of grassy flavour, an unpleasant flavour in meat. This seems to be caused by diterpenoids, which are derived from the breakdown of chlorophyll in the rumen. The finishing period also reduces the incidence of yellow fat, which is often badly perceived by consumers, because it is associated with old or unwholesome animals or unfresh products. In cattle, this pigmentation derives mainly from carotenoids in the diet, which are deposited in the adipose tissue. A long finishing period using feed with a low carotene content, such as corn, decreases yellow pigmentation in meat.

In conclusion, a finishing period of 2 to 4 months on a high-energy diet compensates for the negative effects of growth restriction on pasture. Furthermore, the occurrence of grassy flavour and yellow pigmentation of fat can be reduced.

Carcass leanness and meat quality

Leanness has little direct influence on meat quality, and on tenderness in particular.

Subcutaneous fat accounts for less than 2% of tenderness variability and intramuscular fat accounts for between 5 and 10%. Subcutaneous fat thickness and marbling are not reliable predictors of meat tenderness, both factors may determine beef quality because they act as an insulator and contribute to the visual quality. Subcutaneous fat acts as an insulator for carcasses and prevents muscle being in direct contact with the cold. During chilling, the decline of muscle temperature in the first few hours after slaughter is correlated with tenderness. Muscle temperature directly influences the rate of glycolysis and therefore the lowering of the pH. It also influences the activity of proteases, which are active during the ageing process. Furthermore, subcutaneous fat protects muscles from evaporative water loss and discoloration of the meat surface.

Without electrical stimulation or inadequate carcass stimulation, the insulator effect is particularly important if carcasses are chilled rapidly, when fat cover decreases the risk of cold shortening or cold toughening of outer muscle during the onset of rigor mortis. This phenomenon results in tough meat, which is irreversible. Further details on the effects of processing on beef quality are presented in **Toughness (effects of chilling systems and rigor mortis).**

A weak positive correlation exists between intramuscular fat and meat palatability, because the fat may contain the liposoluble aroma which creates flavour. The content of polyunsaturated fatty acids enhances the formation of Maillard reaction products, which spread during cooking. A positive but weak effect on tenderness is observed at an intramuscular fat content above 3%.

Marbling and colour of meat is one of the main components of visual quality, and can affect consumer preference. Some markets, such as in Japan, favour highly marbled meat whereas others demand less marbled muscle.

Growth promoters

Growth and performance stimulators are used to increase feed efficiency and growth rate in cattle, and use varies from one country to another. The current trend is to restrict use because of the fear that these substances incite in the public opinion. In Sweden and Switzerland, for example, all growth promoters except probiotics are prohibited.

The main groups of substances are:

- **Antibacterial agents**
- **Probiotics**
- **Steroids**
- **Growth hormones**
- **ß-agonists**

Antibacterial agents commonly used in livestock production are administered as dietary additives in low concentrations (subtherapeutical levels). Among the antibiotics used to improve performance, monensin (family of the ionophore) and flavomycin are authorized in the USA and the EU. Oral administration of these substances does not affect meat quality.

Probiotics are living microorganisms presented as an alternative to antibiotics. Studies indicate that these do not affect meat quality.

Steroids are used as growth promoters and are divided into androgenic steroids (such as testosterone or trenbolone acetate) and ovarian steroids (such as 17-ß oestradiol and progesterone). Generally, they are used as androgenic implants, as oestrogenic implants or as combined implants. Few effects have been observed on muscle composition, total and soluble collagen content, cooking loss and colour. Combined implants in steers and oestrogenic implants or reimplants in heifers increase stress response. The consequence is a higher ultimate pH and an increased incidence of abnormal dark and dry meat, which is known as dark-firm-dry (DFD) meat or dark cutting beef (DCB) (**Fig. 2b**). Several studies have shown an increase in meat toughness, especially in steers administered with oestrogenic or mixed implants whose meat had increased calpastatin activity.

Figure 2a. Normal quality beef, strip loin steak.

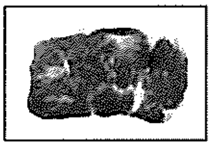

Figure 2b. DCB (Dark Cutting Beef) or DFD (Dark, Firm, Dry), strip loin steak.

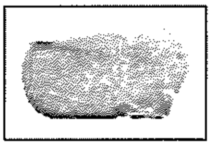

Figure 2c. PSE (Pale, Soft, Exudative), strip loin steak.

Growth hormones such as somatotropin and recombinant bovine somatotropin (rbST) alter nutrient deposition by increasing protein deposition and decreasing both fat deposition and intramuscular fat content. However, no effects have been observed on colour, glycogen content, ultimate pH, or sensory and muscle fibre characteristics.

ß-adrenergic agonists or **ß-agonists** reduce the adipose tissue by increasing lipolysis and reducing lipogenesis. They influence the muscle mass by increasing retention and reducing breakdown of proteins, which results in a hypertrophy of muscle fibre, an increase in proportion of fast glycolytic fibre and enhanced glycolytic metabolism. The intramuscular fat content is reduced at the same rate as a reduction in adipose tissue. Sarcomere length, water-holding capacity and colour are not affected by ß-agonists. Generally, meat is tougher if the animals receive ß-agonists, which is mainly due to a reduction of proteolitic activity and possibly effecting the calpain-calpastatin enzyme system. Collagen content of muscle does not effect meat tenderness. A stimulation of glycogenolysis by ß-agonists before slaughter may diminish the concentration of glycogen in muscle, thereby reducing the acidification of the meat. The ultimate pH will be higher, and hence the risk of dark cutting beef (DCB) prevalence is increased.

Stress susceptibility

Stress susceptibility is dependant on many factors such as sex, animal predisposition, environment, and the ability to adapt to changing environments.

In cattle, the main consequence of stress susceptibility is dark cutting beef (DCB), which occurs when the ultimate pH of the meat is greater than 6.00. Animals with an ultimate pH between 5.80 and 6.00, are considered as borderline DCB. The colour becomes darker, and water retention and tenderness are affected. The meat also develops a less intense flavour and preservation is affected.

The main factors leading to DCB are not well established, one cause is stress which is difficult to monitor. Excitable animals are more susceptible to stress and have a higher incidence of DCB, and their meat may also be tougher. Stressors may be the manipulation of animals, mixing of animals which results in the establishment of a new hierarchical order (especially in bulls), transport and new environments. These effects are also cumulative. Stress susceptibility is also dependant on animal sex: bulls are highly susceptible to stress due to their aggressive and mounting behaviour; heifers are less susceptible; and steers are the least susceptible.

Double-muscled animals are more sensitive to stress and therefore have a higher risk of dark-firm-dry meat (DFD). Double-muscled individuals of the Belgian Blue breed are known to frequently present pale, soft and exudative meat (PSE, **Fig. 2c**), which is caused by glycogen depletion and increased anaerobic metabolism before slaughter. This phenomenon also appears in breeds which lack important muscle development, such as those housed in tie-stalls. This housing system enhances susceptibility to stress before slaughter, and it is possible that a lack of physical activity in such animals may induce anaerobic utilization of glycogen in the muscle.

Exercise, fitness and muscle metabolism

Changes in physical activity alter the contractile and metabolic properties of muscle, because the distribution of fibre within the muscle is affected. Increased physical activity increases the oxidative capacity and the capillary supply to the muscle. After slaughter these muscles become less acidic. The meat may become tougher due to the effect of pH on the activity of some proteases; the ageing process is also slower, and the incidence of dark cutting beef (DCB) is higher. These effects have not been observed in grazing cows, which implies that pasturing does not represent an important physical activity.

Many questions remain unanswered: what type of activity, intensity and duration influences meat quality? When are these effects produced during the animal's lifetime? And at what time are they the most important? What influence is the sex of an animal?

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Transport and Handling Factors Affecting Beef Quality

This section deals principally with the problems associated with dark cutting beef meat (DCB), (see **Stress susceptibility**). DCB meat is a quality defect, which in extreme cases results in purplish-black meat. This meat is not suitable for sale, because the colour is not consistent with the customer's perception of fresh meat. The abnormally dark colour of DCB meat is similar to that of meat which has been cut and exposed to fresh air for a long time. On drying, good quality meat becomes black and must be trimmed for retail.

The other main problem of DCB meat is the risk of spoilage, its shelf life and the method of preservation. A carcass of DCB meat, which is well covered with subcutaneous fat, has a similar storage life to that of a normal beef carcass. Microorganisms only spread on the surface, and the risk of microbial contamination is only present when the carcass is cut.

High ultimate pH values of meat favour bacterial growth and protein breakdown. DCB meat has only small amounts of carbohydrates, and bacteria break down amino acids, which leads to the formation of ammonia and putrefactive amines. The shelf life of meat is closely linked to these processes, and meat with a pH above 5.80 should not be vacuum packed because of early putrefaction.

DCB meat has a higher water holding capacity in comparison to normal meat, its weight loss is lower in fresh meat, and after thawing and cooking. DCB meat does not require ageing, and the costs of stocking at chilled temperatures and corresponding weight loss are reduced. DCB meat is not without quality, because it is more tender than normal meat. However, it must be marketed separately to normal meat.

Nutritional status

Glycogen plays a crucial role in the transformation of muscle into meat, because it is the key substrate of postmortem glycolysis of muscle. Under anaerobic conditions, glycogen is converted into lactic acid and will determine the pH decline of muscle (final pH approximately 5.5). If the muscle is depleted of glycogen, the pH will remain above 6.00 resulting in dark cutting beef (DCB) meat.

Glycogen content in muscle can change according to the nutritional status of the animal, for example, increased adrenaline levels caused by fear or intense muscle activity will induce glycogen breakdown. A slow decrease in glycogen is also observed during a long period of food deprivation. The aim is to reach a high glycogen level in muscle just before slaughter, however, the effect of a high-energy diet for cattle is not pronounced nor linear, and depends mostly on the initial glycogen content of the muscle. The most effective response is obtained when glycogen content is low. It is also noted that castration does not modify muscle glycogen content or the response to a given diet.

Although high-energy diets do not always increase muscle glycogen content, they seem to slow down the rate of glycogen breakdown, and furthermore protect the animals against different stress factors. These effects can be seen after two weeks on a high-energy diet, and the glycogen content cannot be raised with the last meal before slaughter.

In cattle, degradation and repletion rates of glycogen are slower than in monogastric animals, and cattle are resistant to limited or complete fasting over quite a long period. However, if the muscle is depleted, it takes at least 2 days in the case of moderate depletion (about 25%) and at least 10 days in the case of a severe depletion to restore the initial glycogen content. Refeeding during 1 or 2 days at the abattoirs is of no use, and DCB prevalence is even more pronounced in these animals. Therefore animals should be slaughtered as soon as they arrive at the abattoir. A delay of 90 minutes in lairage increases the incidence of DCB, and the risk is even more pronounced when animals are slaughtered the following day.

Stocking density

Stocking density during transport is considered a stress factor before slaughter, response to stress during transport is similar for steers and bulls. The frequency of bruising increases with increased stocking density, and there is a positive correlation between dark cutting beef (DCB) meat and the number of bruises observed on the carcass. Bruises reduce the carcass quality and the visual quality of the meat, if severe bruising occurs, the meat is trimmed, resulting in economic loss.

The most important injuries have been noted at a stocking density of 600 kg/m², which corresponds to a maximum load which does not allow the animals to turn or lie down. Most recommendations suggest a maximum load of 360kg/m². Group and pen size also affect the density. If the stocking density is too low, animal welfare is also affected.

Body temperature and dehydration

Animals respond to handling between the farm and the abattoir, with increased heart rate, breathing rate, body temperature and perspiration, and they also urinate and defecate more frequently. Animals are deprived of water and food for quite long periods during transportation. Weight loss may reach up to 3 to 11% of the initial body weight. During the first 12 to 24 hours, the most important loss is that of body fluids from the intestine.

Dehydration during transportation to slaughter occurs frequently in warm climates and where the transport distance exceeds 1000 km. The loss affects the interstitial fluid in the muscle and may modify ante- and postmortem biochemical processes. Rapid rehydration is possible and will increase the carcass weight, this indicates that the gain is partially due to the increase in muscle water content.

The use of oral electrolytes of similar composition to interstitial fluids during transport can also reduce these effects. These solutions also diminish transport stress, have beneficial effects on body weight, and reduce the frequency of dark cutting beef (DCB) meat.

Pre-slaughter handling

From transportation up until slaughter, all unfamiliar handling is a source of stress, especially in grazing cattle which seldom have contact with humans and are sensitive to change. Dark cutting beef (DCB) meat is the direct result of stress generated before slaughter. More precisely, it is the result of over excitement accompanied by excessive effort, and is more the result of emotional rather than physical stress.

The principal sources of stress, especially in bulls, are:

- mixing of animals from different pens to form homogeneous groups on the farm and before transport;
- gathering and mixing of unfamiliar animals during transport and at the abattoir;
- waiting at the abattoir, especially if animals are slaughtered the day after arrival.

Other factors linked to handling before slaughter can also contribute to increased stress such as: duration of transport, stocking density, food deprivation, bruising during loading and unloading, handling or inadequate equipment at the abattoir. In order to reduce stress, some measures can be followed.

- Animals in a tie-stall barn system must be tied up during transport and in lairage.
- Loading and unloading stock must be conducted with ease, preferably without a ramp, or ramps should not be steeper than 20°.
- Lighting should not cause dazzling in the trucks during loading, and the unloading area should be well lit.
- During transportation, races should not have blind spots, noise and distraction should be reduced, and the use of electric goads should be avoided.
- Overhead electric grids are used to discourage mounting behaviour, but are not permitted in some countries.
- In some abattoir a shower is used to calm the animals.
- Keeping bulls in individual pens considerably reduces DCB incidence, using parallel races with separations every 3 m.

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Effects of Processing on Beef Quality

Stunning methods - meat quality considerations

Both mechanical and electrical stunning methods are used on cattle. The captive bolt or the free bullet are the most frequently used stunning techniques, where a metallic cane penetrates the cranial bone and the brain destroying the nerve centre. Electrical stunning requires a head restraint to enable reliable electrode placement for at least 4 seconds. If a cardiac arrest provoked by electrocution is also desired, a relatively long period is necessary. Sticking must be conducted within 60 seconds after the gunshot or within 20 seconds after electrical stunning.

All slaughter methods used in cattle involve violent and traumatizing processes. The effects on meat quality may be marked, and violent muscle contraction, increased blood pressure and catecholamin discharge are difficult to avoid. The main effects of slaughter on the carcass and muscle are:

- **Bruising**
- **Blood splash**
- **Blood speckle**
- **Broken bones**
- **Insufficient bleeding**
- **Modification of pH decline in muscle**

Bruising can occur between stunning and sticking, for example if stunned cattle fall heavily as they roll out of the stunning pen. If animals are bruised just before or after sticking, the effects will be modest.

Blood splash is the result of burst blood capillaries in the muscle, it appears as small spots in the tissue and may reach over 1 cm in diameter. Blood splash is caused by an increase in blood pressure in association with strong muscle contractions, as a result of electric stunning. It may occur in most muscle, especially the hindquarter.

Blood speckles are caused by haemorrhaging along the adipose tissue and muscle fascia (connective tissue). It may be also found in the sirloin and is trimmed off.

Broken bones followed by bleeding is not often seen in cattle. It tends to occur in the vertebral column during a spinal cord discharge as a result of an electrical current.

In cattle, **insufficient bleeding** can be the result of slaughter methods. Pithing is used to reduce the intensity of convulsions and kicking in the clonic phase, and is only conducted in cattle which have been stunned with a captive bolt or free bullet. A cane is introduced into the head through the hole created by the bolt or bullet, it damages the spinal cord and provokes a strong but short reaction of the hindlegs and the kicking stops rapidly. This operation is really a precaution to reduce the risk of accidents to the staff. Pithing is also conducted using compressed air insufflation with a gun, or a captive-bolt combined with direct compressed air insufflation. The worst bleeding results have been observed in the entire carcass and organs such as the liver, when using captive-bolt combined with compressed air insufflation at 12 bar. Stunning with compressed air insufflation results in brain cells and nervous system cells being scattered in the blood as well as in the respiratory system, and should not be practised in countries where bovine spongiform encephalitis (BSE) occurs.

Sticking while the animal is lying, is as efficient as sticking when it is hanging, however, in lying animals more blood is retained in the viscera. The efficiency of sticking can differ according to the type of pithing used, the use of compressed air tends to reduce the efficiency of sticking in comparison to the cane.

The intensity of convulsion following stunning effects the rate of **pH fall in muscle** and therefore effects meat quality. The extent and the nature of neurological damage may be partially responsible for the variation in the rate of glycolysis. Kicking which occurs during pithing does not affect the muscle metabolism in the longissimus dorsi, but it does accelerate the glycolysis in the psoas major.

Toughness (effects of chilling systems and rigor mortis)

During carcass conditioning, the muscle becomes inextensible and hardens. The onset of rigor mortis coincides with muscle contraction, and is dependent on temperature and the tension of the muscle. Muscle contraction induces meat toughness, i.e. the more the muscle contracts, the tougher the meat after cooking. It has been observed that the weakest contraction is obtained at 15°C during the onset of rigor mortis.

Muscle temperature during the onset of rigor mortis is one of the most important factors effecting meat tenderness. Maximum tenderness is achieved in the temperature range between 7 to 15°C in the longissimus muscle, and 10 to 15°C the semimembranosus muscle. Below and above these values, there is an increase in meat toughness, which is known as cold and warm shortening.

The different types of abnormal shortening are known as:

- **Rigor shortening**
- **Warm or heat shortening**
- **Cold shortening**

- **Thaw shortening**

Rigor shortening is the result of excessive shortening of muscle fibre at the time of rigor contraction. It occurs when muscle is removed from the carcass in the pre-rigor phase, such as hot deboning practice when the muscle is allowed to contract freely.

Warm shortening is a contraction which occurs at the onset of rigor mortis, during insufficient chilling when the muscle temperature is above 20°C and the pH is between 5.9 and 6.2.

Cold shortening is the result of chilling too rapidly at the onset of rigor mortis or a high chilling rate without freezing. The relationship with meat toughness is not linear, and excessive toughness is observed with 40% shortening. Above this value, tenderization occurs due to torn muscle fibres. Maturation of the meat does not overcome cold shortening. Muscle requires sufficient energy to contract, and in unstressed animals a pH decline from 7.1 to 5.5 reduces the energy available for muscle contraction. Below pH 6.0, the quantity of available energy is insufficient for contraction. For this reason muscle is not chilled below 10°C, before the pH has fallen below 6.0 in order to prevent cold shortening. In addition, electrical stimulation of the carcass activates glycolysis, increases the pH decline and therefore reduces cold shortening.

Thaw shortening occurs during thawing if the meat is frozen between pH 6.0 and the ultimate pH, or during rapid thawing and is accompanied by elevated drip loss. This type of shortening is more pronounced than cold shortening. Thaw shortening may be avoided if thawing is slow or if frozen meat is stocked for a long period. Glycolysis continues when the meat is frozen (at -12°C) and the muscle runs out of ATP, which is therefore unavailable for contraction during thawing. Faults in the handling of the cooling procedures are not irreversible. Thaw shortening is theoretically possible in beef, but does not represent a practical problem.

Preventive measures can be taken to avoid this type of shortening:

- **Muscle stretching**
- **Restrictive hot-fat trimming**
- **Electrical stimulation**

Muscle stretching is carried out to prevent muscle rigor contraction, and is achieved by altering the position of carcass suspension. Classic suspension by the Achilles tendon is vertical. In order to achieve muscle stretching, the carcass is suspended horizontally and is known as the tenderstretch or tendercut. Tenderstretch is the suspension from the pelvis or from the hole in the aitch-bone. Tenderstretch and the lying or horizontal positions (where the legs have the same position as a standing animal until rigor) significantly increase the tenderness of the longissimus dorsi, as well as important hindleg muscles. Tendercut is where the bones and connective tissues are cut at 2 positions in the mid loin and the round-sirloin junction. It is especially effective on the longissimus dorsi. The tenderness achieved after 1 or 2 days muscle stretching is comparable with tenderness of a normal suspended carcasses which has been aged for 2 to 3 weeks. However, these techniques are only efficient where there has been rapid carcass chilling.

Hot-fat trimming consists of partial or complete removal of the subcutaneous fat before the carcass is chilled (**Fig. 3a and 3b**). This may increase the efficiency of fat removal, due to the soft and pliable nature of the hot fat. The meat industry trims excessive fat due to consumer demand for leaner meat. However, fat removal before chilling results in lower muscle temperature and higher pH as well as increased toughness, especially with rapid chilling. Hence when rapid chilling is practised, it is necessary to remove only part of the subcutaneous fat and/or to combine hot-fat trimming with electric carcass stimulation.

Figure 3a. Subcutaneous fat trimming on a beef carcass (round and sirloin) made after weighing and before chilling.

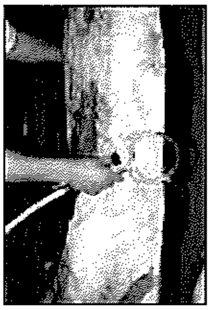

Figure 3b. Subcutaneous fat trimming on a beef carcass (round and sirloin) made after weighing and before chilling.

Electrical stimulation of the carcass is carried out shortly after slaughter. This promotes muscle contraction, utilization of muscle energy reserve, glycolysis and pH decline. The process of rigor mortis onset is also hastened, and the muscles enter rigor mortis before the temperature is sufficiently low to cause cold shortening due to rapid chilling. The voltage used varies from 32 to 3600 volts, where low stimulation is less than a 100 volt peak, and high stimulation is greater than a 200 volt peak. Low voltage must be applied rapidly (within 5 minutes) after slaughter to act via the nervous system, the shorter the time between stunning and electrical stimulation, the greater its efficiency. It is carried out manually by clipping the electrode on the nose or stick wound; the conveying rail is used as an earth. The efficiency is often weak in the hind leg. This problem may be overcome by using anal electrode as an earth. High voltages are usually used for automated systems, and stimulation may be conducted later for a shorter period. The response to this stimulation is more homogenous, and overcomes the variability found in low voltage stimulation.

Staff safety is crucial when using high voltage equipment.

Electrical stimulation increases the rate of tenderization. However, if the effect of cold shortening is not present, the final tenderness will be similar to non-stimulated muscle. Stimulation that is too intense, or various combined electric applications for stunning, immobilization, back-stiffening during hide pulling, in addition to the electrical stimulation can negatively affect meat quality.

In conclusion, it is necessary to have an overview and a global control of carcass conditioning in order to optimize all procedures. The aim is to maximize tenderness, by achieving rigor mortis with an approximate pH of 5.6, a muscle temperature of 15°C, at 10 hours postmortem.

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