

Effects of Pre-slaughter Stress on Carcass/meat Quality: Implications for Botswana

Molebeledi HD Mareko

Department of Animal Science and Production,
Botswana College of Agriculture P/bag 0027, Gaborone, Botswana

Abstract: The study will discuss the effects of pre-slaughter stress on meat animals and consequently, on the end product which is the carcass/meat. Meat consumers nowadays are increasingly demanding that animals be reared, handled, transported and slaughtered humanely. In Botswana animals submitted to processing plants for slaughter are usually exposed to a lot of stressful situations immediately before slaughter. They are transported in trucks and/or trekked on foot for very long distances even during extremes of weather, with minimal chances of grazing, drinking water and resting. The stressful conditions through which the animals undergo have been proven to have deleterious effects on the quality of the animals' carcasses and/or meat. These conditions according to a lot of literature lead to dark, firm and dry and pale, soft and exudative meat. Although physiochemical quality of meat can be improved through post-slaughter carcass handling treatments, the general consumer perception of carcass/meat quality (shelf life, visual appearance and palatability) can only be enhanced by improved animal handling practices such as reducing pre-slaughter stress. Based on literature, recommendations are made from which animal handlers in Botswana can learn, so that where possible, stressful situations on animals are avoided or minimised during periods immediately prior to slaughter.

Key words: Antemortem handling, carcass/meat quality, dark-firm-dry (DFD) meat, pale-soft-exudative (PSE) meat, pre-slaughter stress

INTRODUCTION

According to Warriss^[1], proper handling of animals antemortem has been highlighted for two reasons; firstly, in an increasingly competitive market with emphasis on quality of the final product, the economic losses caused by poor handling are becoming more important. Secondly, consumers in many countries have become more aware of the ethics of meat production and thus meat should be produced in ways that take account of animal welfare. The slaughtering industry in many countries is becoming centralised into fewer, larger plants and thus marketing times and the distances animals travel to slaughter have increased^[1]. Additionally, larger slaughter plants often operate at higher line speeds than in small plants. The need to move and process animals rapidly inevitably leads to more stress in the period immediately before slaughter. Even when carried out with due care and consideration, the marketing process is inherently stressful. Animals are removed from their home environment, loaded and unloaded from transport vehicles, subjected to often long journeys (on rail, road and trekked) and held in unfamiliar surroundings. During this period they get exposed to various stressors such as noise, unfamiliar smells, deprivation of feed and water, vibrations, extremes of temperatures, breakdown of social groupings, close confinement, overcrowding, increased human contact and improper stunning^[1-3]. Although Botswana is exporting

beef to the European Union (EU), a body that critically encourages consumption of good quality meat from well cared for animals, some stressors mentioned above are still very common in the local meat animal handling environments. And above all these, caning (ie. use of whips/sjamboks) of animals and the reckless use of aiding animals to chase slaughter animals such as dogs, horses and donkeys are still prevalent practices in Botswana. The combined impact of these stressors can lead to losses in meat quality and quantity and this in turn is governed by the stress intensity, duration of each stressor and the susceptibility of the individual animal to stress.

Stress can affect muscle characteristics during both on farm rearing and pre-slaughter management processes. Pre-slaughter management practices usually have the greatest impact upon meat quality, not necessarily because they are more stressful to the animal, but rather due to their proximity to the point of slaughter and therefore greatly affect muscle metabolism post slaughter. The adaptive mechanisms by which animals resist stress influence muscle characteristics in ways that contrast to the immediate stress effects. However, the gross response by the tissue depends on the ability of the animal to cope with stress and the mechanism by which homeostasis is maintained. There are profound differences in these attributes among animals of different species, different breeds and among individuals. These differences are

easily recognisable in the tissues of the dark-cutting beef and pale, soft, exudative muscle. The objective of this paper is to highlight, using literature, effects of pre-slaughter stress on slaughter animals and their carcasses and also offer advice on best ways of handling slaughter animals to the Botswana meat industry.

Stress Pathway: Management procedures imposed on the animal can often conflict with the animal's preferences and as a consequence may end up causing physiological and behavioural stress responses. According to Lefcourt^[4] and Schaefer *et al.*^[3] an alternative definition of stress is a comparative departure of physiological factors from 'normal'. Stress responses usually lead to decreased meat quality. Animals that respond actively to a stressor will tend to deplete glycogen levels in their muscles during resistance or escape^[7]. An active response can lead to injury, either from other animals, inanimate objects or from the actions of a handler, producing bruising and consequently affecting meat quality. According to Carragher and Mathews^[2], a fast acting sympathomedullary response will follow a stressful stimulus resulting in the secretion of adrenaline and noradrenaline which mobilise muscle glycogen reserves (by glycogenolysis) to produce glucose. If the stressful stimulus is not quickly removed or is severe, a Hypothalamo-Pituitary-Adrenal (HPA) axis response will occur^[2]. The HPA axis response results in the secretion of glucocorticoids hormones (cortisol in most farmed animal species), which promote breakdown of muscle protein and fatty acid reserves to liberate glucose (a process called gluconeogenesis). Transport and handling evoke an increase in circulating cortisol and in this context transport and handling are thus viewed as stressors^[5]. Though the sympathomedullary and HPA responses act over different time courses (sympathomedullary response is rapid, whereas HPA response is slower), they both serve to maintain sufficient levels of blood glucose for use by the muscles and the brain during periods of stress. Since both axes directly affect muscle metabolism they impact negatively upon carcass yield and meat quality. Lean meat quality is affected through the production of Pale, Soft, Exudative (PSE) or Dark, Firm, Dry (DFD) meat and consequently, in a way influencing eating qualities of meat negatively.

Stress effects on Live and carcass weight: 3.1 Live weight According to Warriss^[1], loss of live weight can be partitioned into loss of urine and faeces and loss of carcass and offal. Loss of potential carcass yield could be caused by loss of protein and fat and by loss of water (dehydration). An animal that is deprived of food (fasted) will mobilise body tissues to provide energy for maintaining the vital functions of the body^[1]. Tarrant

^[6] reported that live weight begins to be lost almost immediately after feed withdrawal at a rate of about 0.12 to 0.20% per hour, more especially with pigs. A large part of this loss, particularly in initial stages is attributable to loss of urine and faeces^[6]. More loss is possible if the animal is subjected to greater energy demands such as those needed to maintain balance or for thermoregulation during transportation. Thermoregulation may involve greater loss of body water through sweating or panting and in longer transport particularly, animals can become dehydrated^[3]. This situation is likely to occur in Botswana where animals are commonly transported to slaughter plants over long distances even in very hot days. According to Schaefer *et al.*^[3] when the effects of fasting are combined with the effects of transport and handling, the animals typically lose more weight than is observed with fasting alone. These authors also pointed out that transit shrink in beef steers represents as much as 68% of the shrink resulting from the combined effects of fasting and transport within 46 h. Wythes and Shorthose^[7] reported that live weight loss tends to be greater when both food and water are unavailable under conditions of high ambient temperature. This is typical of Botswana conditions where animals hardly have any access to water and feed during the period of transportation even when transported over long distances and exposed to high ambient temperatures. Wythes and Shorthose^[7] produced a relationship showing mean losses of live weight of about 7% after 12 h, 9% after 24 h, 10% after 48 h and 11% after 72 h due to with-holding both feed and water. In Botswana, a lot of animals are transported from distant areas such as those in the western part of the country to the Botswana Meat Commission (BMC) slaughter plants mainly in the eastern part of the country (in Lobatse and Francistown). These animals, in terms of live weight, are likely to fall in Wythes and Shorthose^[7]'s range of 7 – 11% live weight loss because their transportation and handling mostly occurs over 1 - 3 days with no feed and water. Warriss *et al.* (1990) also reported that in journeys ranging in length from 500 to 2000 Km animals lose between about 6 and 12% of their live weight and these are typical distances in Botswana for animals from ranches and cattle-post to abattoirs.

In ruminants, because of their proportionally larger guts and the fact that the rumen acts as a store of nutrients and water, cattle in particular are generally less susceptible than pigs to feed deprivation^[7]. The gut contents of adult cattle can account for over 20% of the live weight and form a major component of live weight losses over the initial 24 h of food deprivation. Previous diet and access to water are therefore important factors influencing the patterns of live weight loss in ruminants^[1]. According to Warriss *et al.*^[8], even if feed is offered there is evidence

that under conditions of stress some ruminants may be reluctant to take it and this may extend effective fasting times under commercial marketing conditions. And if feed is unavailable, water consumption may also be reduced to very low levels in sheep. Warriss *et al.*^[8] have reported average live weight losses in sheep ranging from 0.09 to 0.34% per hour and rates of carcass loss varying from 0.08 to 0.5% per hour, with the onset of carcass loss occurring between 12 and 24 h after deprivation of food. These workers also found an apparent linear rate of carcass loss (0.085% per hour) up to 72 h of fasting. Less loss was recorded in fatter and heavier lambs and transportation for up to 6 h had no extra effect above that of fasting^[8].

Carcass weight: Regarding carcass weight, Tarrant^[6] points out that it is less clear when carcass weight loss begins, but probably between 9 and 18 h after the last meal. According to Warriss *et al.*^[8] and Warriss^[1], rates of carcass weight loss determined over fasting periods of 48 h or more, vary between 0.06 and 0.14% per hour. The variation is said to be attributable to those factors that also influence live weight loss and one of the most important is whether water is also withheld, in which case carcass weight loss appear to be up to three times higher^[1]. Carcass weight loss accounts for up to about one third of total live weight loss over the first 24 h of fasting and up to one and a half between 24 and 48 h^[1]. The loss in carcass weight is largely attributable to loss of protein and to a lesser degree fat, rather than loss of water. This is supported by evidence that the reduced yield is maintained after meat curing^[1]. In an experiment conducted in summer^[9], transportation of pigs for 1 hour resulted in a nonsignificant loss of 0.6% carcass yield, while a journey lasting 6 h reduced it by 2%. When subjected to long journey, pigs showed evidence of dehydration, suggesting that in contrast to those caused by fasting, transport yield losses are also attributable to tissue water loss^[9]. The study concluded that it is ideal to rest pigs for 1 – 3 h before slaughter. High temperatures such as experienced in Botswana during the larger part of the year, more especially during transportation, will obviously lead to increased carcass weight loss in animals through loss of moisture.

Fernandez *et al.*^[10] working with Friesian-Holstein calves (veal) reported that long transport (11 h) increased loss in live weight and dressing percentage. It has always been difficult to separate the effects of fasting and transport in cattle. Jones *et al.*^[11] looked at effects of withholding water, feed and thereafter have the animals transported for a short possible time to the slaughter plant. Live weight was lost most rapidly initially and amounted to 10.6% at 48 h, while carcass losses were observable at 24 h and at 48 h were up to 6.5%^[11]. These losses were high compared to those found in studies by

Warriss *et al.*^[8] and Warriss^[1] where only feed was withheld, illustrating the importance of dehydration in reducing yields. Long periods without food or water have various other undesirable effects on carcass quality^[1]. With longer deprivation periods the stomach contents of ruminants become more watery, increasing the chances of head, tongue and carcass contamination either through regurgitation or through accidental cutting of the gut wall during dressing. Long periods of fast also lead to significant losses in the weight of edible offal, particularly the liver and the removal of the hide or fleece may become more difficult because of dehydration of the subcutaneous tissues^[1]. These considerations must be balanced against the problems associated with too short a pre-slaughter fasting period; for instance very full guts make the operation of dressing the carcass difficult, because the gut contents may pose effluent disposal problems^[1].

Effects of stress on lean meat quality: Meat quality attributes that are primarily affected by animal handling procedures include; colour, pH, texture and palatability of the lean. However, other meat characteristics such as spoilage potential (shelf life) are also negatively affected by poor animal handling. Stressful marketing may predispose animals to produce pale, soft, exudative or dark, firm, dry meat or may reduce quality by other, less understood mechanisms^[1,3]. According to Anderson *et al.*^[12], present problems with excessive drip loss, DFD and PSE meat are a consequence of relatively low ultimate pH in the meat. Low pH depends on the initial glycogen level in the muscle at the time of slaughter and the level of stress induced on the animals during transportation and pre-slaughter procedures. The most important factors affecting PSE and DFD incidences occur after the animal has left the farm^[13]. Larger slaughter plants such as BMC often operate at higher line speeds and the need to handle animals faster may not be matched by improvements in facilities and practices. Higher speeds and the need for coercion may then result in greater stress suffered by the animals and consequent poor meat quality.

Handling facilities: The influence of facility design and handler competence on animal behaviour and stress response is associated with animal temperament and early experience^[2]. Rough handling may be more detrimental and stressful to animals with an excitable temperament compared to animals with a more placid temperament^[13]. Increasing problems have been recorded with pigs that appear to be very excitable^[14]. These pigs are difficult to move without inducing considerable stress and with PSE meat resulting from them. It is important that considerations in the lairage do allow the animals to rest. Mixing groups of unfamiliar pigs leads to fighting and the

problem has been found to be more acute with uncastrated males. The physical exertion associated with fighting depletes muscle glycogen stores and leads to DFD meat, which has poor keeping quality^[14]. Innovative handling systems are necessary and according to Barton-Gade *et al.*^[16], workers in Denmark have developed new designs of lairage that improve the practical handling of pigs. To enhance the quality of the booming pork industry in Botswana, use of innovative handling facilities such as discussed by Barton-Gade *et al.*^[16] should be implemented by the local pig processors. These designs incorporate smaller pens holding up to 15 individuals and with automated push gates to move the animals. It has been observed that the automatic moving gates are less stressful than the actions of human beings and make the pigs easier to move^[16]. This has led to reduced incidences of DFD meat and the amount of bloodsplash and speckle, but not PSE pork. Bloodsplash refers to the occurrence of spots of blood in the muscle, whereas speckle refers to the small pinpoint bleedings in fat or connective tissue overlying the muscle^[18]. These unsightly quality defects most often occur in pigs and sheep and result in lowered commercial value for the affected regions of the carcass. Blood splash and speckle can be affected by a number of different factors including; farm of origin, day of kill, the time from stunning to sticking, type of stun and electrode placement^[1]. In extensive farming systems of Botswana, where cattle see stockmen less often, animals are likely to be excitable leading to difficulty in handling. This will induce stress, especially with tropical breeds that are more temperament than European breeds.

Transportation: In a study by Van der Wal *et al.*^[19] in which Dutch Yorkshire pigs were transported for 15 Km, rested and then slaughtered, an optimum resting period of 3-4 h was observed. Fortunately, in terms of distance, most of Botswana piggy farms and slaughter plants are very close to towns and cities and this makes it easier to get the pigs to the processing plants quickly. So for pork quality to get enhanced in this manner, care should be taken to avoid locating piggy farms in distant areas so that attention can be paid to improving other quality parameters. Van der Wal *et al.*^[19] also observed that within the distance of 15 Km, there were no negative effects on meat quality caused by fighting in the lairage and behaviour in the stunning pen. Despite this, the researchers noted that muscular contractions during and after stunning had a negative effect on pork quality, causing a more rapid drop in pH, a faster development of rigor-mortis and a reduced water-holding capacity. Imperfect stunning was also found to cause an increase in muscular contractions and a decrease in meat quality. Wenzlawowicz *et al.*^[20] transported hybrid pigs (4806) for <60 to 180 minutes before slaughter from 232 fattening

groups, it was noticed that high loading density and high humidity during transportation for >2 h had adverse effects on meat pH. And pigs with a waiting period of >60 minutes before slaughter showed a lower meat pH than those slaughtered within 1 hour.

Comparatively, ruminants seem to be more resilient than pigs. Nevertheless, evidence is available that ante-mortem stress is detrimental to beef palatability, although the effects vary in size and the actual mechanisms not very clear^[8]. Research in Australia by Wythes *et al.*^[7] has demonstrated that steers trucked for 125 Km and rested for 26.5 h quietly with feed either in transit or in lairage, compared with only 2.5 h, improved tenderness by 15%. Resting for 52 h, compared with 4 h improved tenderness of meat from cows transported 1390 Km by road and rail by 13%. A 96 h rest improved tenderness of meat from bullocks transported 650 Km by rail by 23% when compared with animals rested only 24 h^[7]. Nonetheless, the beneficial effects of longer holding periods were lost if the animals were not allowed to rest but were periodically disturbed. These studies prove the importance of resting during transportation, so it would be very advisable for farmers and transporters in Botswana to rest and feed their animals during both transportation and lairage so as to improve carcass/meat quality. Jones *et al.*^[11] and Jeremiah *et al.*^[21] also demonstrated that pre-slaughter stress (feed withdrawal and mixing unfamiliar animals) lead to beef which is less tender, less juicy, has poor flavour, increased pH and dark cutting. Mixing of unfamiliar animals during transportation in Botswana is a common practice, done so as to share costs of transport. But this can be re-considered given the negative effects on meat quality brought about by this factor. Importantly, it was also observed that a progressive increase in instrumentally measured toughness of meat from steers given no food or water for 48 hrs had shear force values 22% higher than those from control animals slaughtered directly off food and water^[20]. Fernandez *et al.*^[21] observed that long transport resulted in decreased liver weight, glycolytic potential and pH at 4 hrs post-mortem in the *longissimus lumborum* (LL). This was accompanied by decreased tenderness scores in the LL and semimembranosus muscles. It is evident from literature that long transport has unfavourable effects on the sensory quality of meat.

With the prevalence of Dark-Firm-Dry (DFD) beef, the most susceptible animals are young bullocks and old cows, followed by steers and heifers being the least affected unless they are on oestrus^[2,13,22]. Warriss *et al.*^[8] reported that lean meat quality of sheep is less influenced by pre-slaughter fasting for up to 72 h or transport for up to 6 h, although muscle glycogen levels are progressively reduced with longer food deprivation. Jarvis *et al.*^[22] observed that in terms of distance and transport, sheep

from distant markets had a significantly greater plasma osmolality than those from local farms and markets and this can be accounted to loss of moisture by sheep coming from distant places. Sheep from local markets carried significantly higher cortisol levels than those from farms and this was probably due to the fact that sheep from closer markets had recently been handled. It has been observed in New Zealand^[1] that lambs are made to swim through a tank of water for cleaning purposes and this is repeated at times for dirty ones. This has been found to lead to depleted glycogen stores, with carcasses of raised ultimate pH resulting. Carcasses from shorn, underfed and repeated washing showed 80% of ultimate pH values (>6) compared with 12% in carcasses from control lambs^[1].

Bruised carcasses also have been reported as one of the big problems in the meat industry, this associated much with pre-slaughter ease of movement. Grandin^[24] observed that in the United States of America 50% of the occurrences that contribute to bruising of cattle occur prior to the time the cattle arrive at the packing plant (at feedlots and during hauling) while errors at the packing plant (rough handling, facilities and equipment problems) are responsible for the other 50%. Other surveys have shown that a large proportion of carcasses have bruising (lambs, 71%; ewes, 49%; and cattle, 97%), with most carcasses having more than one bruise^[25]. These bruising are sustained mostly in the 24 h immediately prior to slaughter with 43 to 90% (cattle) and 25% (sheep) occurring at the abattoir^[2,22]. In the case of Botswana where caning of animals is common and stockmen are not conversant with animal welfare procedures, these figures might be significantly higher. According to Eldridge and Winfield^[24], space allocation for cattle during transportation can significantly affect the level of bruising, carcass weight and risk of injury to animals. Farmers and transporters in Botswana don't necessarily take the issue of space allocation into account, they are mainly concerned with hauling as many animals as possible per trip to reduce transport costs.

Stunning: According to Warriss^[1], electrical stunning produces more blood splash and speckle than captive bolt, which in turn produces more blood splash than percussion. Contrary to this, Grandin^[26] argues that electric stunning is used with great success in New Zealand in cattle, pigs and sheep and to prevent blood-splash in the meat, electrodes needs to be held firmly against the animal to provide constant amperage. Electrical stunning at the head only produces more blood splash whereas head to back stunning produces more blood speckle^[1]. However, Warriss^[1] also pointed out that despite a considerable amount of research, the actual mechanisms causing blood splash and blood speckle

have not been conclusively proven. Nonetheless, regardless of the type of stunning or the species of meat animal, cellular metabolism is affected by stunning and exsanguination. In Botswana both the electrical and captive bolt stunning methods are used, but like literature points out, processors should be careful and use whatever method properly.

According to Wood *et al.*^[14] animal welfarists prefer electrical (because it is sudden) rather than captive-bolt (because it fails too often) or carbon dioxide immobilization (because animals struggle excessively). Literature^[1,14,26] has documented disadvantages more especially in pork quality from electrically stunning pigs, because it increases the rate of muscle pH decline, sometimes excessively leading to PSE pork. Grandin^[26] also states that the increased reliability of electrical stunning (failure rate of <1%) compared to captive bolt stunning (failure rate of 1% to 5%) provides a definite advantage from the humane standpoint. To facilitate handling pigs rapidly for electrical and Carbon dioxide gas stunning, most of the large plants use races leading to restraining conveyors that direct pigs into individual compartments of the stunning unit^[15]. Channon *et al.*^[26] observed that genotype, pre-slaughter handling and stunning method (CO₂ vs electrical) had an interactive effect on the pH, tenderness and drip loss of pork. These authors advised that pig processors should optimise their handling systems and techniques, especially if pigs carrying the halothene-n gene are being processed. Processors should also minimize exposure to unfamiliar environments and pre-slaughter stressors in order to improve the quality of their pork products. This advice will also be applicable in Botswana, where a booming piggery industry is being realised. It can also be applied across different meat animal environments.

CONCLUSION

Animals industries are currently undergoing substantial rationalisation with fewer but larger production units and processing plants and longer distance between them. This condition often oblige longer transport and handling exposure of animals, which in turn can cause loss of weight, degradation of meat quality and alterations in some physiological stress parameters. Evidence from literature shows that prolonged feed withdrawal and transportation cause loss of live weight, carcass shrinkage and negatively affect carcass/meat quality. If an animal is deprived of food, it mobilises body tissues to provide energy for maintaining the important functions of the body. Stress does affect lean meat quality through colour, water-holding capacity, palatability and shelf life. Combinations of different sorts of stress, together with varying reactions of muscle fibers of

different metabolic types, probably explain the occurrence of the two-toning phenomenon, in which parts of a muscle apparently show both PSE and DFD meat features.

It has always proved difficult to substantiate effects brought about by an individual stressor due to interactions between the effects of different handling procedures and genotype. In this paper, recommendations based on literature have been drawn and Botswana meat industry can learn from them without having to duplicate the same work, also given the monetary constraints of a third world country for such type of research work. Recommendations are; animals need to be rested quietly with water just before trucking and prior to slaughter, over-loading animals during hauling and mixing of unfamiliar animals during transportation and lairage should be minimised as much as possible. During hot weather, animal hauling should be done at night or in early morning and that there should be rest-stops in case of long trips. More effort must be put into improving handling and management facilities and teaching and management protocol. Facilities should be designed with an idea of imposing less stress to the animals and such designs may include curving raceways to avoid apparent dead ends, avoid steep slopes on loading/off loading rumps and avoid shadows across raceways. Of particular reference to Botswana, aiding/driving animals should be used with utmost care on animals destined for slaughter and the canning/whipping of meat animals should be stopped immediately as these lead to bruised carcasses.

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