REVIEW OF RESEARCH CONDUCTED IN FRESH MEAT SCIENCE IN AN AFRICAN CONTEXT

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Contents

1. INTRODUCTION

South Africa has both formal and informal livestock sectors. Although both these sectors have their own unique marketing systems and strategies, there are a number of areas of overlap, i.e. some livestock produced by the informal sector is marketed in the formal sector, and visa versa to a lesser extent. This review will focus on the formal sector. Within the formal sectors, fresh meat quality is of utmost importance. One of the quality attribute's that the consumer places a high value on is the eating experience, and more specifically the tenderness of the fresh meat product that is consumed. Although there are a large number of extrinsic and intrinsic factors that influence meat quality, this review will be more focused on the general factors that are associated with all livestock as they proceed down the value chain – from transport, lairage, slaughter and interventions that follow thereafter on the carcass so as to improve and/or maintain its quality. As it is argued that even if an animal has been genetically selected for tenderness, the wrong *ante mortem* treatment can negate the genetic potential and result in tough unsuitable fresh meat.

Although the main focus of this review is on beef, where relevant, reference is also made to the other red meats found in South Africa, namely lamb, pork, ostrich and game. There is also a bias in the review in that emphasis is placed on research that has been conducted at Stellenbosch University's Meat Science Research team. A more detailed account of the outputs (publications and post graduate students graduated) can be found on the University's web page (Web: http://academic.sun.ac.za/Academic/Agric/Animal_Science/index.htm).

2. LIVESTOCK HANDLING

2.1 Transport

The stressors associated with transport and handling cause physiological changes and the combination of different stressors will lead to decreased welfare, reduced meat quality and therefore economic losses to the industry. Psychological stress is caused by novel environments and regrouping, which can lead to increased social interaction and result in physical exhaustion. Furthermore, the event of transportation involves the withdrawal of feed and water for extended periods leading to weight loss and dehydration (Knowles, 1999). Poor welfare in addition to the cost to the animals also results in inferior meat quality, such as decreased tenderness, poor water-holding capacity and colour stability. Any form of handling, and transport is associated with physical damage which is manifested in bruising, torn skins and broken bones and in extreme cases can lead to the death of an animal.

Transportation starts at the farm and progresses either directly to the abattoir or via livestock market(s) to the abattoir. Eldridge *et al.* (1984) found significantly fewer and smaller bruises in cattle transported directly from the farm than those sold through livestock markets. This was confirmed by Hoffman *et al.* (1998) in a study on mature beef cows. This emphasises the importance of evaluating the entire transportation cycle and how these differ between countries.

Prior to and during transportation, feed and water are withdrawn from the animals, resulting in weight loss. The degree of loss varies, due to factors such as time off feed, time off water, ambient temperature, diet, duration of transport as well as the sex, age and temperament of the animals all playing a significant role (Lühl, 2009). Shorthose & Wythes (1988) estimate weight loss to amount to 0.75% of an animal's initial weight per day. The majority of weight loss occurs in the initial 24-48h of fasting and is ascribed to excretion of gastrointestinal contents and urine, which accounts for 12-25% of the animal's live weight (Grandin & Gallo, 2007). After 48h off feed and water, tissue catabolism and dehydration lead to increased weight loss, with water deprivation having a more profound effect (Ferguson & Warner, 2008). Species react differently to transportation stress. Ostriches for instance have been found to lose 10-17% of initial weight during transport and lairage (Sales & Oliver-Lyons, 1996). Goats lost an average of 10% live weight during transport of 2.5h and 18h lairage (Kannan *et* al., 2000). Literature does conclude that ruminants cope better than monogastric animals with feed and water deprivation (Ferguson & Warner, 2008). The treatment of steers and heifers with an electrolyte before transport resulted in a significant decrease in weight loss (Scheafer *et al*., 1997), implying that the weight loss could be minimised by the correct pre-treatment of the animals. Further research is required to assess if this treatment is effective in other animals and under local conditions.

There are various stressor associated with transport and lairage. It is difficult to assess them separately as they are co-dependent in many instances (see for example the MSc thesis of Lühl, 2009 that evaluated these factors in Namibia), but the major meat quality problem associated with stress is a high final pH, sometimes resulting in DFD meat. Crowther *et al.* (2002) found that transportation of ostriches at night decreases stress dramatically, resulting in a lower final pH that translated into improved meat quality. This is attributed to the elimination of many of the stressor from the transport environment. However, livestock are seldom transported at night in South Africa for various reasons, amongst these the cost of labour after hours - this aspect of night transport warrants further research.

The actual design of the transportation vehicle is unique to each species and it is essential that the design be such that the animal's welfare is not jeopardised. Grandin (1980b) is the world leader in the field of animal behaviour studies and how to incorporate these into transportation, lairage and slaughtering facility design. In a South African context, little work has been done on animal behaviour for ostriches and game species. Our climate and distribution channels are also widely different in certain instances from those of other countries which open the field to research (see results of Lühl, 2009). Much can also be done to train the animal handlers from farm to abattoir, as in South Africa most of these labourers are unskilled. It has become clear in the past years that temperament of the individual animal plays a major role in the animal's ability to cope with a stressor (Grandin, 1997a). A link has been identified between the environment that the animal is reared in, earlier handling experiences, contact with humans and degree of tameness to the ability to cope with stressors and ultimately the meat quality. From a South African point of view, this is essential and research is required to establish if animal behaviour and welfare can be used to improve meat quality.

The length of travel and conditions of the road have also been found to have significant effects on the meat quality, with animals that have been transported for a prolonged period of time on a rough road more inclined to DFD (Tarrant *et al.*, 1992; Honkavaara *et al*., 2003; Gallo *et al.*, 2003). The incidence of bruising and or injuries also increases as the travelling time increases due to animal fatigue and the likeliness of the animals trying to lie down and being trampled on, especially if the stocking density is not correctly calculated (Kent & Ewebank; 1985; Knowles, 1998; Warriss, 1998; Lühl, 2009).

The time animals spend in lairage is determined by a country's legislation and/or code of practice. In some countries, animals are slaughtered on the day of arrival while in others animals they have to stand overnight (Ferguson & Warner, 2008). The original intent of lairage after transport was to allow for rest and recovery from the journey, while also ensuring a continuous throughput on the slaughter lines. However studies have shown that lairage can be detrimental to meat quality if the lairage time is too long, as the glycogen reserves are depleted even further as it is not feasible to replenish these during lairage (Warner *et al.,* 1998; Matzke *et al.,* 1985), but availability of water has proven to decrease the occurrence of DFD (Whytes, 1982). The rate of glycogen depletion is species specific, it has been shown by McVeigh & Tarrant (1982) that the rate in cattle is rather slow (1.3 µmoles/g.day) which explain why cattle are less sensitive to prolonged fasting periods.

The Stellenbosch Meat Science research team has already evaluated the effect of transportation on ostrich weight loss and meat quality, and found that *ante-mortem* stress during transportation and lairage, lead to live weight losses. The purpose of this study was to compare the effect of different transport distances on the quality of meat, live weight losses and dressing percentage. Ostriches were transported for 0, 60 and 600 km respectively before being slaughtered. There was a significant difference in the percentage live weight loss during transport and lairage between the groups that travelled 60 (2.4 ± 2.185 %) and 600 km (8.13 ± 1.156 %) respectively. There was also a significant difference in dressing percentage (farm weight to cold carcass weight) between the two above-mentioned groups. Treatments also had a significant effect on pH_u with the ostriches that didn't travel exhibiting the lowest pH_u (5.77 ± 0.053) and the birds that travelled 600 km having the greatest pH_u (6.11 ± 0.053). No differences were found in shear force and percentage cooking loss between the treatments, although all three treatments differed significantly from each other in drip loss. Significant differences were found for L*, b* and hue angle between the three treatments, whilst there were no differences in a* and chroma values between the treatments. A significant correlation was found between hue angle ($r = 0.528$; $P = 0.008$) and pH_u. Of specific interest to the meat industry, at the time of slaughter, meat drip loss and s-CK (creatine kinase) was significantly correlated ($r = 0.484$; $P = 0.022$), which indicates that CK levels may be used as a predictor of meat quality prior to slaughter.

As pertaining to the traditional farmed species, Lühl (2009) from Stellenbosch University conducted an intensive investigation into the farm handling, transport and lairage conditions of cattle in Namibia. Namibia by nature is very well suited for livestock production and is a net exporter of meat. Meat is currently exported to South Africa, the European Union (EU) and Japan while market access to the United States of America is being explored. Food safety, traceability and lately animal welfare are all aspects which are requested by Namibia's trading partners when exporting meat to those countries. The first two aspects have been addressed with the introduction of the Farm Assured Namibian Beef scheme (FAN Meat) which also provides basic guidelines for animal welfare.

Beef in Namibia is produced from extensively managed enterprises which are privately owned and managed, or state owned and communally utilized. The events of handling and transport are considered stressful to all animals but especially so to extensively raised animals and their reaction to these events has the potential to severely infringe on their welfare. The aim of Lühl's (2009) study was to determine the effect of pre-, during, and post-transportation handling on animal welfare status under Namibian transport conditions. The study also investigated the influence of breed on the meat quality of Namibian beef.

The level of bruising recorded on slaughter was used to measure animal welfare. Interviews with producers were conducted to describe the pre-transport handling. Questionnaires that included variables considered as important indicators of animal welfare during transport were distributed to truck drivers. Observations of the off-loading event and animal behaviour were completed in lairage at the export abattoir in Windhoek. The variables that were identified as high risk factors and had a significant influence on the level of bruising under Namibian transport conditions include animal factors (i.e. breed type, age, sex, condition and subcutaneous fat cover), pre-transport handling (i.e. re-branding of animals), transport related risks (loading density and animals lying down during transit) as well as lairage factors (i.e. fit of truck floor to off-loading ramp, the way animals moved to holding pens, pen size and minimum environmental temperatures).

The difference in pH is significant from a shelf life view as the higher pH would significantly influence the keeping quality of the product. More research is necessary to establish this, also to investigate the effect of lairage times and animal behaviour in relation to meat quality.

From these results (Lühl, 2009), Stellenbosch University (SU) research team was able to establish a set of good manufacturing procedures (GMP) for handling and transport of cattle. The following results obtained from the study considering animal welfare aspects is considered for drafting an outline for a code of practice for handling and transport of cattle in the African context:

- Re-branding of animals in order to facilitate legible brands increased bruising ($p < 0.05$).
- Loading densities in square meter per animal ($p = 0.06$) affected bruising negatively and poor welfare due to too high densities was further reflected in the increased bruising resulting from animals going down during transport.
- Vehicle and facility design became important when on and off-loading. The fit between off-loading ramp and truck floor ($p < 0.05$) forced animals to step up or down and resulted in more slips and falls compared to level fits.
- The size of holding pens in lairage was implicated in increased bruising ($p < 0.05$), with the larger pens having higher levels of bruising (this was most probably caused by free range animals running around more due to their unfamiliar surroundings).
- Minimum temperature changes from 8 - 16º C (during winter) saw a concomitant increase in the number of bruises observed on slaughter ($p < 0.0001$).
- Animal factors which had an influence on bruising included sex ($p < 0.0001$) and age of the animals, as well as live weight ($p < 0.0001$), the visual condition ($p = 0.005$) and fat score ($p < 0.05$). The presence of horned animals in consignments further influenced bruise levels observed in this study ($p < 0.05$).

2.2 Injuries & Bruising

The distribution of the locations of the bruises as well as the frequency in which the bruising is present arise primarily from transport, loading and lairage practices as these steps are the most likely to cause harm to the animals (Grandin, 1990, 1991). Information from the bruising patterns can indicate what practices should be better managed to minimize bruising on carcasses. Bruises or contusions are described as superficial discoloration due to haemorrhage into the tissue from ruptured blood vessels beneath the skin surface, without the skin being broken. In the contusions the blood accumulates in surrounding tissues, producing pain, swelling and tenderness (Blood *et al.*, 1983). The bruising can be caused by a physical blow from a stick or stone, a metal projection or when an animal falls (Chambers *et al.*, 2004).

There are regulations that govern the treatment of animals during transport and pre-slaughter practices, to prevent unnecessary bruising or damage to the animals. The ostrich industry is governed by strict welfare codes (SAOBC, 2009) to ensure that the birds remain calm, and these include guidelines related to stocking density, handlers on the transportation vehicles, and experienced drivers. These codes of practice also prescribe the layout of the lairage pens. Similar codes exist for different species but still bruising, lacerations and more severe injuries occur (Wotton & Hewitt, 1999). Separating animal welfare from meat quality, tremendous losses occur due to bruising in the livestock industry (Hails 1978; Grandin 1980a; Wythes & Shorthose 1984; Eldridge & Winfield 1988; McNally & Warriss 1996), due to loss in carcass weight, wasted time in trimming which increases labour costs and slows down the line speed (McNally & Warriss 1996). Bruising is used as a measure of animal welfare, but as it is only evaluated post mortem and the exact point of occurrence cannot be determined from the bruise (Strappini *et* al., 2009) – more novel methods to evaluate animal welfare should be developed.

According to the FAO (Food and Agricultural Organisation), bruised meat is wasted because it is “aesthetically” unacceptable to consumers and spoils more rapidly due to the fact that the bloody meat is an ideal growth medium for bacteria during storage (Chambers *et al*., 2004). Primary meat inspection on carcasses takes place in export abattoirs by a meat inspector of the Department of Agriculture, within one hour after slaughter (Anonymous, 2004). During the meat inspection, the inspector has to trim away all the bruises on the hot carcass. According to Hoffman *et al*. (2010), warm trimming of ostrich carcasses can lead to average losses of 300g per bird. Hoffman *et al*. (2010) found that the most prominent areas of bruises were the neck and thighs in birds. They believed that if there was multiple bruising over the body, it was probably due to trampling. They proposed that cold trimming could reduce the losses in meat yield and that cold trimming could lead to a reduction in the microbial load of primary meat, increasing the shelf life of these meat cuts. This (removal of small bruises on chilled carcasses) has since become the norm (standard operating procedures) in the abattoir with significant financial savings.

The research team has evaluated the causes of cattle bruising during handling and transport in Namibia. The variables which were identified as high risk factors and had a significant influence on the level of bruising under Namibian transport conditions include animal factors (breed type, age, sex, condition and subcutaneous fat cover), pre-transport handling (re-branding of animals), transport related risks (loading density, and animals lying down during transit) as well as lairage factors (fit of truck floor to off-loading ramp, the way animals moved to holding pen, pen size and minimum temperatures). However, no single factor could be pin pointed as the driving force behind bruise levels and the overall impression is that these risks have a cumulative effect on bruising (Lühl, 2009).

The degree and age of bruises were recorded in a separate investigation at the same abattoir and results reflect that the overall incidence of bruising is very high, with the highest levels seen on the hips, around the butt and pin areas. It was speculated that the latter were caused by incorrect use of the stunning box. This all indicates that training of staff working in lairage and on the killing floor is insufficient – it would be of value to identify the level of training of these key personnel as well as the development of good training material. Typically, the perception exists amongst the slaughter personnel that the “dirty” work is that in lairage and on the killing floor.

The results of this study (Lühl, 2009) indicate that in the event of animals transported to slaughter in the central areas of Namibia, conditions surrounding transport are more important than distance transported or journey duration. However, in South Africa, a large number of animal slaughtered are moved short distances from feedlots and thus transport bruising should not be a major factor. However, no research has been done on the effect of bruising (and transport stress) on weaners being transported to the feedlot.

The supply chain for sheep differs in that most of the lambs destined for slaughter are transported from the farms directly to the abattoir (although feedlotting of lamb close to the abattoirs is on the increase). Frequently, transport trucks will also stop enroute to load sheep from different producers and the effect of this transport (and mixing of animals from different groups) has not been quantified.

Bruising on ostrich carcasses and the implications on the microbiology and losses in utilizable meat when removing them post evisceration or post chilling was evaluated at a South African abattoir by the SU Research Team. It was found that one reason for the loss of utilizable meat in the ostrich industry is sustained bruises. In ostrich abattoirs, these bruised areas are removed as part of the primary meat inspection, performed directly after evisceration. The bruises on the carcasses were also investigated to determine their frequency and distribution to try to establish causes of bruising and subsequently possible preventative measures. The bruises on the necks represented 52.58% of all bruises found; with the high side railings of the transport vehicles the most probable cause of the injuries. Large and multiple bruising seen on the carcasses were probably from ostriches trampling on birds sitting down. Implications of removing the bruises at primary meat inspection or after overnight cooling of the carcasses (0-4°C), were investigated and it was found that when the bruises were trimmed on the warm carcasses the total aerobic viable counts on the trimmed surfaces increased significantly during overnight chilling. However, when the bruises were left on the carcasses during overnight chilling, counts decreased after cold trimming. The cold trimming of minor bruises together with better management of trimming practices also led to a decrease in meat yield losses. From both a microbiological and an utilizable meat yield point of view, it is advantageous to remove the bruises after overnight cooling (note that a distinction is made between a bruise and a wound). This practice needs to be evaluated in other species as well. An aspect highlighted in this research is that the incorrect design of transport vehicles results in more bruises. This aspect warrants further research in cattle and sheep transport truck design.

Personal observations (Hoffman) would seem to indicate that the use of rBST in dairy cows may result in excessive bruises at the point of administration – this results in a significant decrease in carcass yield.

It has been established that up to 65% bruised meat can be incorporated into meat products such as salami and Devon without a negative effect on product quality as assessed by a sensory panel (Rogers *et al*, 1993). This opens research possibilities into the manufacturing of processed products such as salami with bruised meat, thereby increasing the meat yield from the carcass even more.

2.3 Stress responsiveness / glycogen loss

Handling, transportation and lairage of livestock all cause a stress response in the animals, this stress response manifests as a physiological changes in the animal in order to maintain homeostasis. The changes include increase in body temperature, heart and respiration rate. Any form of fear activates the pituitary-adrenal axis, resulting in increased circulating levels of cortisol, glucose, and free fatty acids. Transport is also associated with muscle exertion (cattle stand during transport) which is manifested in increased levels of muscle enzymes, especially creatine kinase, in the blood (Broom, 2003). Table 1 gives an overview of the stressors associated with transport and handling and the affect it has on the physiological state of the animal. Many of these physiological variables are used in research to measure animal welfare status.

Table 2.1 Commonly used physiological indicators of stress during transport (adapted from Broom, 2003)

Stressor	Physiological variable
Measured in blood or other body fluids	
Food deprivation	↑ FFA, ↑β-OHB, ↓ glucose, ↑ urea
Dehydration	↑ Osmolality, ↑ total protein, ↑ albumin, ↑ PCV
Physical exertion	↑ CK, ↑ lactate
Fear/arousal	↑ Cortisol, ↑ PCV
Motion sickness	↑ Vasopressin
Other measures	
Fear/arousal and physical pain	↑ Heart rate, ↑ heart rate variability, ↑ respiration rate
Hypothermia/hyperthermia	Body temperature, skin temperature

FFA = free fatty acids; β-OHB = β-hydroxybutyrate; PCV = packed-cell volume; CK = creatine kinase.

In addition, stressors during transport can be categorised as either "irritant" or "intermittent" (Crowther *et al*., 2001). Irritant stressors are defined as stressors that occur over long periods of time, continually, such as vibration, noise, novelty, confinement, movement and heat exposure, and these stressors could have a long-lasting effect on the animal. Flashes of light and the noise of passing cars are seen as intermittent stressors and are able to provoke an immediate stress response, but only for a very short duration. Crowther *et al*. (2001) postulated that it was the irritant stressors that were responsible for the greatest effect on stress levels during transport.

The level of stress an animal experiences during transport and lairage can be determined by analysing blood samples taken at intervals during transit, as increases in red blood cell count, haemoglobin, total protein and packed cell volume are indicators of dehydration in animals (Blood *et al.*, 1983). Kent & Ewbank (1983) and Tarrant *et al.,* (1992) reported increases in the number of white blood cells and neutrophils and a decrease in the numbers of lymphocytes, eosinophils and monocytes in transported cattle. The changes in these blood constituents indicate that the stressors alter the immune system of animals. The concomitant loss of resistance to infection is believed to cause bovine respiratory disease complex, also referred to as 'shipping fever' which often leads to deaths in feedlot cattle after transport (Irwin *et al*., 1997).

In birds, the heterophil:lymphocyte (H:L) ratio is a very reliable indicator of stress (Gross & Siegel, 1983). It is thought that the increase in the H:L ratio is due to stresses imposed on the birds during handling, and that a relative increase in the inflammatory action of heterophils may also stimulate the release of the glucocorticoid hormone, cortisol. However, Gross & Siegel (1983) showed that the H:L ratio was a more reliable indicator of stress during transport, than the concentration of the glucocorticoid hormone (corticosterone) after transportation, regardless of the length of the journey. According to Leche *et al*. (2009), the glucocorticoid released during an ACTH challenge in Greater Rheas was corticosterone, and not cortisol, a finding supported by Mitchell *et al*. (1996), who transported ostriches and found a 75% increase in plasma corticosterone ($P < 0.05$) levels after transportation. These findings indicate that the glucocorticoid hormone most abundant in ratites is corticosterone. According to Maxwell (1993), stressed birds showed an increase in basophils and heterophils and a decrease in lymphocytes. These changes in haematological values of heterophils and lymphocytes during periods of stress, lead to an increase in the H:L ratio of birds (Gross & Siegel, 1983). The changes in H:L ratio can lead to birds being more susceptible to infections. Mushi *et al*. (1999) reported a 2:1 H:L ratio for adult ostriches when they did not encounter stress. According to Spinu *et al*. (1999), the H:L ratios of African Black and Red Neck adult ostriches were 2.72 ± 0.84 and 2.78 ± 0.53 respectively. Mitchell *et al*. (1996) reported an even higher H:L ratio for ostriches at baseline level, with a value of 8.5 ± 3.2. This variation points out the sensitivity of this parameter to indicate stress levels - even at baseline some populations may be stressed as a result of handling, noise, etc. encountered during the sampling procedures. The same changes would occur in cattle and or sheep.

Corticosterone is a well documented measure of a stress response and is a hydrophobic hormone that circulates in the plasma, with the majority of the hormone bound to a carrier protein called the corticosterone binding globulin (Rosner, 1990). Corticosterone hormones are released when an animal encounters a stressful situation and a high level of free corticosterone is maintained in the blood during a prolonged stress response (as cited by Leche *et al*., 2009 from Berg *et al*., 2002). The glucose is made available by the hyperglycaemic effect of corticosterone to aid the animal in a period when it requires sufficient energy for a flight-type stress response (Leche *et al*., 2009). Research has quantified the baseline values for corticosterone in different species from which deductions can easily be drawn as to the extent of the stress the animal experienced (Leche *et al.*, 2009; Mitchell *et al*., 1996).

Stress directly affects the post mortem glycolysis, as the bodily processes that are activated to combat the stressor increase the use of glucose within the muscle. If the animal was exposed to the stressor for a sufficient period of time during which glycogen/glucose reserves could not be replenished, it would result in an abnormally high (evolving as a continuum from pH>5.6) final pH (Grandin & Gallo 2007). Meat quality of a carcass is ultimately a function of meat/muscle pH, more specifically the rate of pH decline inter-related with the rate of temperature decline, as well as the ultimate pH (pH_u) which typically decreases tenderness (Schaefer, Jones, Tong & Young, 1990) and colour stability (Warriss, 2000) as well as the ability to bloom, and increases water-holding capacity (WHC) (Jeremiah *et al.,* 1992; Schaefer & Jeremiah 1992). High pH_u in beef is associated with an unattractive dark colour referred to as dark-cutting or dry, firm, dark (DFD) meat. Apart from its poor appearance, the high pH of DFD meat enhances the growth of bacteria (Lawrie 1998). This lowers shelf-live and renders it unsuitable for the vacuum-packed fresh meat market (Grandin & Gallo 2007).

DFD is a significant problem in beef, and Tarrant (1988) reported that some 1-5% of steers and heifers, 6-10% of cows and 11-15% of all young bulls produce DFD meat. The major cause of DFD in beef appears to be the mixing of unfamiliar animals prior to slaughter (in lairage) which promotes agonistic behaviour, particularly in young bulls (Warriss, 1990).

DFD has also been found to be a problem in venison and ostrich for different reasons. According to Wiklund & Malmfors (2004), the traditional reindeer selection technique of using a lasso is the most glycogen-depleting event yet studied in reindeer, resulting in a very high incidence of DFD. Game meat sold in Southern Africa is frequently perceived as being very dark in colour as well as being dry and it has been suggested that this may be the result of poor cropping techniques that place immense stress on the animals, so that DFD meat results. Hoffman (2000a) reported that wounded impala often show meat quality attributes similar to that classified as dark, firm and dry meat. Ostriches on the other hand have an instinctive flight response and, if unaccustomed to humans, are easily startled when they come into contact with them (Reiner *et al*., 1996), these birds are very excitable and experience a severe stress response, which results in a high final pH.

The effect of *ante mortem* stress on ostrich meat and carcass quality was assessed by our research team. They compared quality of meat, amount of bruising and psychological stress response in ostriches that were raised under various conditions and transported under different conditions to the abattoir. Two hundred ostriches were transported and slaughtered, from three different groups. The groups were divided on the basis of farming system they were raised in namely feedlot, semi-intensive and free range. There was no significant difference in stress score or serum corticosterone (ng/ml) between treatments. Since the rate of temperature decline varied between animals, all pH measurements were adjusted to 4°C. Significant differences were found in drip loss, cooking loss and shear force between treatments. Significant correlations were also found between drip loss (r = -0.456) and pH_u. A significant difference was found in the percentage carcass weight cut off (trimmed) from the feedlot (0.19 ± 0.032 %) and free range (0.07 ± 0.038 %) treatments due to bruising. The results of this study indicate that stocking density and road conditions could significantly impact on meat quality and bruising of ostriches during transport. These factors, mentioned above, could well have a greater effect on meat quality than factors such as the conditions birds were raised in.

Extensive work has also been done by the SU research team on the effect of different cropping methods in game animals. Knowledge on *ante-mortem* stress, and as a result, on meat quality in wild ungulates, is lacking and thus the purpose of this study was to investigate the effect of some of the commonly used cropping methods on the meat quality of red hartebeest, impala, gemsbok and kudu. *Ante-mortem* stress was measured using serum cortisol levels (nmol/L), a subjective stress score allocated to each animal as well as the rate and extent of pH decline in the *M. longissimus dorsi*. Special emphasis was also placed on the meat quality parameters drip loss, cooking loss, colour and Warner-Bratzler shear force (kg/1.27 cm diameter).

Day-cropped kudu had a lower mean pH_u (5.40 ± 0.030) than night-cropped kudu (5.48 ± 0.041) (Hoffman & Laubscher, 2009). No differences in pH_u were found for the red hartebeest although night-cropped gemsbok had a higher mean pH_u (5.54 ± 0.013) than day-cropped gemsbok (5.49 ± 0.014) (Hoffman & Laubscher, 2010). None of the constants of the exponential decay model used to predict pH decline over time differed for the red hartebeest although day-cropped gemsbok produced a lower constant than night-cropped gemsbok. Mean stress scores and cortisol levels were found to be higher in day-cropped animals for both the gemsbok and kudu while only cortisol levels were higher in die day-cropped red hartebeest. No treatment differences in drip loss or cooking loss were found for either the red hartebeest or gemsbok, while day-cropped kudu had a higher mean drip loss % (2.76 ± 0.261%) than night-cropped kudu (1.36 ± 0.361%). Night-cropped gemsbok and kudu produced higher mean shear force values (gemsbok = 4.19 ± 0.138; kudu = 4.06 ± 0.237 kg/1.27 cm diameter) than day-cropped animals (gemsbok = 3.57 ± 0.154; kudu = 3.45 ± 0.171 kg/1.27 cm diameter). Colour differences indicated that day-cropped gemsbok and kudu produced lighter meat than night-cropped animals. The results indicate no difference in the effects of day and night cropping in red hartebeest although day-cropped gemsbok and kudu experienced more *ante-mortem* stress than their night-cropped counterparts. The reason for the lack of stress effect on the pH of the meat warrants further investigation.

Research into the seasonal effects on the occurrence of DFD is also of value, as during autumn and spring the dramatic difference in day and night temperature might affect the pH due to animals shivering excessively at night after a hot day's transportation to the abattoir. The shivering is likely to increase glycolysis possibly resulting in DFD meat. Meta analyses of data from the abattoirs would be required to quantify this phenomenon

2.4 Hygiene / Contamination

The design of transport vehicles, lairage pens and slaughter lines is essential to minimise contamination and maximise hygiene. The floor design of lairage pens is important for a twofold reason, ease of cleaning for decontamination and hygiene and comfort for the animals to ensure minimal stress. Grandin (1990) described the design of suitable lairage pens for cattle, sheep and pigs in detail. In South Africa and Africa as a whole, other more novel species are slaughtered and in some instances one abattoir slaughters multiple types of animals, which might require different designs of pens for optimal comfort and practicality. There is the added possibility that bacterial cross contamination might occur between species which should also be investigated.

It has been found that in terms of hygiene a period off feed before transport and slaughter is believed to decrease risks of microbial contamination during evisceration caused by rumen rupture. However, Whythes & Shorthose (1984) and Wythes *et al*. (1984) showed that gutfill does not necessarily determine the ease of evisceration. These findings are supported by Ferguson *et al.* (2007) who determined the impact of reduced lairage time on meat quality. It has been determined that the degree of hygiene in the lairage pens and during transport are linked to contamination of the carcass during slaughtering. This is because the hides of animals collect pathogenic microbes (*i.e. E.coli* O157:H7) from the faeces and urine, which could be transferred to the meat if proper care is not taken during dressing (Arthur *et al*., 2007).

The prevalent organisms on ostrich carcasses and those found in a commercial abattoir were quantified by Hoffman *et al.* (2010). The prevalent microbial growth on carcasses before and after overnight cooling in an ostrich abattoir and de-boning plant was investigated. The effect of warm or cold trimming of the carcasses was examined together with possible causes of contamination along the processing line. An attempt was made to link the prevalent micro-organisms that were identified from carcasses to that from specific external contamination sources. Samples of carcasses and possible contaminants were collected in the plant, plated out and selected organisms were typed using a commercial rapid identification system. It was indicated that the cold trim (mainly of bruises) of carcasses were advantageous in terms of microbiological meat quality. Results indicated pooled water in the abattoir as the most hazardous vector for carcass contamination and that contamination from this source is mostly Gram-negative pathogens. *Pseudomonas* and *Shigella* were frequently isolated from surface and air samples and indicate that the control of total plant hygiene is a requirement for producing ostrich meat that is safe to consume and has an acceptable shelf-life.

This information proved vital to the processing plant as it not only changed policy (smaller bruises are now seen as being aesthetic and are removed in the deboning room – resulting in considerable savings to the ostrich industry) and more such studies need to be conducted to evaluate which microorganism make their way from farm through transportation and lairage to the slaughter line where contamination occurs (note these organisms are also frequently those responsible for bone taint). It is also necessary to establish if cross contamination between species slaughtered at the same abattoir occurs during lairage when these animals are frequently housed in pens adjacent to one another prior to slaughtering.

3. PRIMARY PROCESSING

3.1 Slaughtering, Evisceration, Dressing

Many abattoirs in South Africa often slaughter and dress animals of more than one species. Gill *et al*. (2000) found that in comparing the microbial load after the dressing of ostriches and that of other animals, that the dressing of each species should be regarded as an unique process. The specific method used for skinning and eviscerating the carcasses of a certain type of animal can contain the bacterial contamination on those carcasses, but the same procedure will most probably not be effective in preventing bacterial contamination in the dressing of a different species such as an ostrich carcass. Processors should know how to control the hygienic quality of the process to slaughter each type of animal handled in their abattoirs to minimize interspecies as well as extra species contamination (Gill *et al*., 2000). Research regarding cross contamination between species handled in the same facility is lacking and warrants further investigation as there are a number of abattoirs practicing lairage of two or more species in close proximity to each other.

To be able to effectively control slaughter practices and ensure meat of low initial microbial load, consideration has to be taken of which steps in the slaughter process are most hazardous in increasing the bacterial load and which steps can control or minimize the load effectively. Research by Karama (2001) suggested that most of the indicator organisms were already deposited during the flaying step and will thus be derived directly or indirectly from the hides. This was concluded from the data indicating that there was no significant change in the log cfu.cm^{-2} values for aerobic plate counts (APC) (4.32, 4.21 and 4.57), *Stahylococcus aureus* (2.89, 2.90 and 2.38) and *Enterobacteriaceae* (2.55, 2.78 and 2.73) from post-flaying to post-evisceration and post-chilling. This confirms the results of Harris *et al*. (1993). The high percentage of samples found to be positive for *E. coli* (53% of the 17 out of 90 positive isolates) and *Salmonella* (±45% of the ±25 out of 90 positive isolates, there was a slight variation between results on different types of media) on post-evisceration samples indicated that this is the process step most likely to add faecal contamination if it is not controlled. Further more, overnight chilling of carcasses between 0-4°C did not significantly reduce or increase microbial counts, except for psychrophilic micro-organisms (*Pseudomonas* spp. (post-flaying = 2.82, post-evisceration = 2.86 and post-chilling = 3.75)) which increased. Severini *et al*. (2003) investigated the influence of different skinning and dressing procedures on the microbial load of ostrich carcasses. He found that the skinning method assisted by mechanical air inflation did not negatively affect microbial quality and that currently the practice is not considered or forbidden under European Union (EU) legislation. Novel methods of skinning should be investigated in all species.

The EU previously only permitted the rinsing of red meat and poultry carcasses with potable water. In January 2004 new hygiene laws were promulgated (Anon., 2004), providing a legal basis to permit the use of substances other than potable water to remove surface contamination from products of animal origin. The EU Commission is also considering lifting an 11 year ban on imports of USA poultry rinsed in chemicals (phosphate, acidified chlorite, chlorine dioxide or peroxyacid) stating that these chemicals do not pose a risk to human health (Rne, 2008). The South African legislation

(Anon., 2007a) allows carcass wash with potable water, while the use of any anti-microbial agents is only permissible with the approval per individual case from the provincial executive officer. It would thus be worthwhile to investigate the different methods of washing of carcasses in pursuing a low post-evisceration microbial load. Severini *et al*. (2003) commented on final carcass wash (without addition of anti-microbial substances) after dressing and reported that it could have a positive effect in lowering carcass surface microbial load, but that more research on this practice is required. In the study performed by Gill *et al*. (2000) carcasses from all six species under investigation were washed with water at 50ºC from a spray nozzle. The final mean log cfu.cm^{-2} APC value of 2.15 on ostrich carcasses was lower than those reported above (Karama, 2001; Harris *et al*., 1993) and could indicate that the procedure is effective in lowering microbiological counts. Maunsell & Bolton (2004) discussed different methods of carcass decontamination including: vacuum cleaning; hot water washing while vacuum cleaning; spraying with low concentration lactic acid and hot water or steam pasteurization. They reported that these practices were common in USA abattoirs, but not in the EU; this report focuses on the meat industry as a whole and not specifically on ostriches. Huffman (2002) discussed current and future carcass decontamination techniques of livestock carcasses and listed post-harvest techniques including hot water rinsing, steam pasteurization, chemical rinses, lactoferrin and combined treatments (hurdle technology). Under chemical treatments, he specifically listed the organic acids, such as acetic, lactic and citric acids approved by the USDA in concentrations of 1.5 to 2.5%. In New Zealand, rinsing of ostrich carcasses are common practice and their processing standards (Ostrich and Emu Standards Council, 2002) prescribed both a pre-evisceration and a post-evisceration (final) carcass wash with either potable water or a sanitizer solution. The use of low concentration organic acids is gaining popularity in red meat abattoirs in New Zealand, Australia and the USA, but unfortunately no published research on the success of these substances in ostrich carcass rinsing (or other species in the African context) is available and this warrants further research.

Additionally, the microbial population that develops during storage will also be dependant on storage conditions and the intrinsic biochemical qualities of the meat (Gill, 2007). In a comparison of the meat from large game animals and birds, Gill (2007) concluded that the microbiological quality of farmed game meat is likely to be better than that of meat obtained from hunted animals. The most important reasons for the difference in meat microbiological quality will lie in the differences in slaughter practices. Firstly wild game is harvested in the fields and poor placement of shots can expose the meat to bacteria both externally (ground and air) or internally (from damaged intestines). Secondly the wild game is often eviscerated in the field where hygiene and carcass chilling facilities are not always readily available or up to required abattoir standards. Farmed game, on the contrary are slaughtered and eviscerated under standardized abattoir conditions and the meat quality thereof can thus be compared with that of domesticated animals (Gill, 2007). More research is needed to establish concrete methods of slaughtering in the field to ensure that contamination is minimized and a HACCP protocol can be established that is sufficient for export markets.

3.2 Stunning & Bleeding

Electronarcosis has been well established as a valuable stunning method for numerous livestock species. The optimisation of this process for various species is however still an on-going research objective, to ensure that animal welfare is prioritised and efficiency of the throughput at the abattoir is achieved. Animal welfare is becoming increasingly important and the need to establish an auditing regime in South Africa to ensure that adequate stunning is achieved is essential, which is clear from the recent review by Grandin (2010). Grandin noted in her review, that there are two methods to evaluate the effectiveness of stunning in pigs, sheep and cattle, firstly by correct placement of the electrodes and secondly by the vocalization immediately after the tongs are applied. Correct placement is essential to ensure instant insensibility by the electric current passing through the brain. Vocalization occurs if the tong is energized before full contact is made with the head. In order to pass an audit correct contact has to be made on 99% of the occasions. In the South African context certainty that these high standards are continually met in all the abattoirs is unknown and research into this is essential. Also little work has been done to establish what animal behavioural traits can be used to evaluate if ostriches have been stunned effectively and correctly.

Two methods of sticking are recognised in the literature, the gash cut or throat cut and the chest stick or thoracic stick. The method that is used most abundantly is the gash cut, which involves a cut with a very sharp knife from ear to ear, severing the main arteries in the neck. This method is easy to preform with minimal risk to the handler, but ballooning or occlusion of the arties occurs readily, which retards blood flow and the onset of death; a process that can be very stressful to the animal. The stick method is performed by a stab rostral to the sternum with the severance of the vessels near the heart inside the chest. In this manner death is achieved almost instantly and the chances of the animal regaining consciousness from stunning prior to death are minimised (Anil *et al*., 1995; Gregory *et al*., 2006). Thoracic stick is mainly used in the pork industry (Anil *et al*., 2000) as well as the ostrich industry, with some beef abattoirs also following this practice. There is much scope for more work in the implementation of the thoracic stick method to other species as this is widely recognised as a more humane method of ensuring death. In a South African context research still needs to be conducted on evaluation of the thoracic *vs*. throat cut in cattle and sheep (Hoffman has just completed a preliminary study on these two methods in ostriches). The major problem that has to be overcome in ostriches with the thoracic cut is the damage to the skin, as the skin is extremely valuable, a novel method needs to be designed to overcome this hurdle as the current method of throat cutting is not optimally effective.

3.3 Carcass chilling, electrical inputs and rigor mortis

The initial aim of electrical stimulation (ES) is to the increase the rate of post mortem glycolysis to accelerate the onset of rigor mortis and thus ensure that cold shortening or thaw rigor does not occur. The principle was first used on sheep (Chrystall & Hagyard, 1975) and cattle (Davey & Gilbert, 1975). It was later discovered that ES could accelerate post-mortem tenderisation (Savell *et al*., 1981) by enhancing the rate of proteolysis stimulated by the release of Ca^{2+} at a higher temperature (Hwang *et al*., 2003) and also by physically disrupting the structure of the muscle fibre (Takahasi *et al*., 1987).

ES has a profound impact on the quality characteristics of meat. In general, ES associated with a higher rigor temperature produces a paler colour, as noted by King *et al*. (2004) on cabrito (Boer goat cross kids) carcasses with high voltage ES increasing both the lightness (L*) and the yellowness (b*) of the *Longissimus thoracis,* due to increased protein denaturation and myofibrillar lattice shrinkage (Offer & Trinick, 1983). However, muscle colour is unaffected when treated with low voltage ES (King *et al*., 2004). Meat tends to be redder after high (Eikelenboom *et al*., 1985) and low voltage (Unrah *et al*., 1986; Sleper *et al*., 1983; Eikelenboom *et al*., 1985) ES in beef and Shaw *et al*. (2005) found that sheep carcasses which had undergone high and low voltage ES, compared to the non-stimulated carcass muscles, had redder and less dark muscles the next morning. This effect is due to damage to the enzyme systems responsible for oxygen consumption, reducing the oxygen consumption rate and thus the higher concentrations of MbO in the surface meat layer (Ledward, 1992). This observation is confirmed by Lawrie (1998) who also claims that the brighter red colour can also be attributed to the fast pH decline. This results in the proteins reaching their iso-electric point much sooner, thereby "opening up" the structure and easing the oxygenation of Mb. There is much debate in the literature as to the rate of deterioration of the colour of ES meat, and research by other teams are currently still underway to establish if it improves or deteriorates the colour stability.

ES, by accelerating pH decline, contributes to reduced water-binding capacity, but the extent is determined by the chilling rate. Low (Li *et al*., 2006) and high voltage (Eikelenboom *et al*., 1981; Strydom *et al*., 2005) ES increases the cooking loss of *Longissimus* steaks from the conventionally chilled carcasses, but King *et al*. (2004) found no differences, possibly due to rapid pre-rigor chilling. Li *et al*. (2006) state that ES decreases the water-holding capacity, probably due to denaturation of hydrophilic proteins.

There are three possible mechanisms which may alter the rate of tenderisation; reduced cold-induced shortening, the enhancement of the rate of proteolysis and alteration of protein structure (Hwang *et al*., 2003). The first theory is associated with the prevention of cold shortening. The second is based on the phenomenon that electrically stimulated carcasses release proteolytic enzymes sooner and that they work faster, compared to those in non-stimulated carcasses; this is due to the higher carcass temperature. The third theory is based on electron micrographs which show that muscles from electrically-stimulated carcasses reveal structural damages (Stiffler *et al*., 1999). The positive effect that ES has on the shear force values one to two days post mortem gradually disappears as aging progresses (Uytterhaegen *et al*., 1992; White *et al*., 2006; Toohey *et al*., 2008).

There are many conflicting results, but the general feeling is that ES does have a significant effect on proteolysis; however, the extent is regulated by the severity of the chilling regime. The application of either ES (Ducastaing *et al*., 1985; Uytterhaegen *et al*., 1992) or high temperature during the early post-mortem period (Whipple *et al*., 1990) has been shown to cause an increase in μ-calpain activity and the consequent improvement in tenderness. ES accelerates the rate of glycolysis and thus the onset of rigor, so that, as the muscle enters rigor at a high temperature, the meat commences to age rapidly at these high temperatures, and thus it would be consumer ready earlier.

Polidori *et al*. (1999) noted that the ageing of stimulated carcasses improves tenderness; they become even more tender than non-stimulated ageing carcasses. It is clear that both ES and ageing significantly improve the tenderness of meat. However, with an increase in aging time, there is a decrease in the difference of the shear force between stimulated and non-stimulated meat (Strydom *et al*., 2005).

Electrical immobilisation of a carcass has been devised particularly but not solely (could also be used as a low voltage ES system) for the immobilisation of freshly-slaughtered carcasses in an abattoir situation. Immobilisation is used in the animal processing industry as an aid to worker safety (Simmons *et al*., 2006). Head-only electrical stunning meets the requirement for instantaneous and sustained loss of consciousness that allows exsanguination to be the primary cause of death. However, the epilepsy triggered by a head-only stun cause severe convulsions that need to be managed both to limit risks to operators and to maintain high throughputs. The standard procedure used in New Zealand plants for both sheep and beef slaughter has been to follow the electrical stun with a period of electrical immobilisation during the bleeding procedure to suppress convulsive activity and thus allow the workers to safely undertake further workup on the carcass (Simmons *et al*., 2006).

The two most common forms of carcass immobilisation are by mechanical restraint, where limbs are physically pinned to prevent movement (the new ostrich stunning box works on this principle) and electrical restraint, which uses an applied electrical energy to override nerve function and control the muscles (Anon, 2008). Electrical immobilisation after stunning plays an important role in ensuring operator safety and maintaining high throughput levels. The conventional system, based on low frequency waveforms, often results in excessive pH decline during and following stimulation, particularly when immobilising large cattle that subsequently cool very slowly (Simmons *et al*., 2006).

Research has been conducted on electrical immobilisation and stimulation of beef carcasses and its effect on meat quality. Electrical immobilisation (EI) is used to control animal movement after electrical stunning, while electrical stimulation (ES) is used to induce rapid tenderisation. These two interventions are frequently used together. The objective of this investigation is to evaluate the combination of these two techniques on the meat quality of beef muscles. Forty Holstein steers were electrically stunned (head only, 2A, 50Hz, 2s) and slaughtered, after which low (14.3Hz, 90V peak, 10ms pulse duration; LFI) or high frequency (800Hz, 110V peak, 0.2ms pulse duration; HFI) EI (20 seconds) was applied within two minutes of killing. After carcass dressing, high voltage (1140V peak, 10ms pulse duration, 14.3Hz; HVS) or mid-voltage (300V peak, 14.3Hz, 1ms pulse duration; MVS) ES was applied. Meat-quality measurements were made from the *Longissimus dorsi* (LD) and *Semimembranosus* muscles after 1, 5 and 9 days of storage at 0°C. LFI HVS produced significantly greater drip during storage and shear force values (storage drip = 3.30±0.223%; shear force = 102.9±4.5N) when compared to the HFI HVS (storage drip = 2.45±0.261%; shear force = 5.2±4.0%) or HFI MVS (storage drip = 2.60±0.178%; shear force = 4.2±4.2N) in the LD. LFI HVS (a* = 20.79±0.31; chroma=22.92±0.33) and LFI MVS (a* = 20.24±0.27; chroma = 22.23±0.30) had a redder and more vividly bloomed colour than HFI HVS (a* = 19.71±0.33; chroma = 21.49±0.37) and HFI MVS (a* = 20.00±0.27; chroma = 21.98±0.31). MTT (*Tetrazolium Salt)* assay correlated linearly (r =-0.63 and -0.73) with a* values at 24 hours post-mortem after allowing 3 hours of bloom.

The effect of different electrical stimulation frequencies on muscle pH decline and beef tenderness was also evaluated for optimisation of the temperature and pH decline. Steers were electrically stunned (head only, 2 A, 50 Hz, 2 s) and slaughtered and then electrically immobilised (EI) for 20 seconds using high frequency (800 Hz, 110 V peak, 0.2 ms pulse duration; HFI) within 2 minutes of kill. After carcass dressing, electrical stimulation (ES) was applied, using medium voltage (300 V peak, 1 ms pulse duration; MVS) with either 5 Hz, 15 Hz or 50 Hz. Stimulation with 15 Hz (0.47±0.040) and 5 Hz (0.41±0.045) had a larger pH drop (ΔpH) during stimulation than 50 Hz (0.29±0.027). Shear force measurements and cooking loss percentage were obtained from the *Longissimus dorsi* after 24 hours of chilled storage at 0 ^{o}C. There were no difference between the stimulation treatments for shear force (15 Hz=121.3±3.3 N; 5Hz=123.8±7.6 N; 50 Hz=114.8±7.94 N), while cooking loss was higher in 15 Hz (28.8±0.47%) than 50 Hz (25.9±0.71%), which correlated linearly (r =0.43; p=0.01) with ΔpH. By modulating the pulse frequency, the rate of pH decline can be manipulated so as to optimise the pH-temperature interaction in accordance with the specific product produced by the plant without making wholesale changes to the system.

Presently the Stellenbosch Meat Science Research Team is busy evaluating the effect of ES on game animals in Africa. The idea behind this is that most of the harvesting of game occurs in the winter nights when the ambient temperature with a wind chill factor is regularly below 0 ^{o}C; situations ideal for cold shortening.

3.4 Carcass classification

The classification system that is currently used in South Africa as well as some Southern African countries have become archaic in certain areas and revision of these practices has been highlighted by certain key players in the industry. The modern society trend is that the meat industry must market a product that the consumer prefers and not what the producers happens to produce. The current system was designed and implemented in the 1980's, major advances in technology, and consumer preference has occurred since.

The primary function of classification is to facilitate trade by describing the commercially important attributes of the carcass, allowing proper communication from producer straight through to consumer. This is where the modern consumer differs significantly from the consumer in the 1980's – the distance between the producer and the consumer has dramatically increased and the consumer is no longer aware what the classification means. In addition, the modern consumer seldom purchases from a butcher but rather pre-packed meat from a retailer. This hinders the communication of consumer preference to producer, which delays or conveys the incorrect information about consumer preference to the producer and intermediary.

The current system separates carcasses into groups sharing relative uniform characteristics in terms of age, conformation, fatness, sex and bruising. The grading system is said to include or correlate well with the consumer's perception of quality. The major drawback to the current system in terms of the producers lies in the complexity. The grading system results in 60 plus classification groups that all have a price coupled to them.

In terms of technology, traditionally the classification is done prior to the carcass entering the chilling chamber by manual labour, which has been criticised at times for being subjective and inconsistent as well as tedious. The advances in technology have been such that mechanised in-line systems have been developed that are able to perform this repetitive task uniformly, constantly and consistently (Allen, 2001). The basis of the mechanised system, rests on Video Image Analysis (VIA) and regression analysis software to emulate the human classification system. Through intricate programming the system assesses the carcass characteristics to give information about the fat content and conformation of the carcass, which are then converted into the grading of the carcass (Boggaard *et al*., 1996; Sonnichsen *et al*., 1998). This system is also able to predict saleable content of the carcass, which is a tremendous advantage to producer, manufacturer and consumer. Butler remarked in his presentation at the AMS International Meat Secretatiat Regional Conference, Sao Paulo, Brazil, April 2007, that instrument grading enhances grading accuracy and consistency by reducing variation, improves producer and packer confidence, product consistency and consumer satisfaction.

A preliminary trial for the installation and verification of a VIA system was already undertaken with the Namibian Meat Association and was overseen by Hoffman. In the final analysis, a decision was taken not to implement this system. The following are some of the reasons for this decision: the VIA system is primarily designed to predict carcass, and more specifically, cut yield (ie, muscle, fat and bone) and not conformation and fat cover. The other issue was the price – if the Namibian Meat Association was to implement this system, they would have to implement it into all their abattoirs or else the farmers might be unhappy with two different carcass grading systems. Other problems were more physical around the implementation of the VIA which would be solved (albeit at a cost) with some modifications to the carcass flow in the abattoir.

Within South Africa, it may be of value to re-evaluate the functionality of the present carcass classification system. Most of the animals slaughtered come directly from a feedlot and are produced according to specifications set by the market – in this case, supermarkets. The consumer trusts that the supermarket will deliver the expected quality meat, if this does not happen, then the consumer may choose another source. Therefore, there is a prior agreement between the supplier and the supermarket on the carcass characteristics that may also include other factors such as weight, muscle pH, etc. and if these are not met, the client will not accept the carcass. Thus, the question posed is whether the present classification system is of any value?

Another aspect that requires further research is the classification of the suitability of weaners for feedlot performance. If the feedlot are able to accurately and objectively classify the potential performance of a weaner in the feedlot, they would be able to, amongst others, determine the optimum feed composition and rate as well as time spent in the feedlot, etc. This would all make the whole production system more streamlined and profitable.

3.5 Cutting

Muscle profiling has been a buzzword in the scientific community for some time. Rhee *et al.* (2004) conducted an in-depth study of within muscle variation for several traits in eleven beef muscles. Their objective was to determine the variation within and relationships among these muscles. The results gave significant insight into understanding the source of variation in tenderness. The drive to market individual muscles rather than the traditional cuts lies in the variation that they characterised. It is possible to minimise variation and increase the revenue generated from a carcass if individual muscles could be marketed instead of traditional cuts that mostly comprise of different muscles where variation tends to be high and potential high income generating muscles are lost. Von Seggern *et al*. (2005) have done similar work on the profiling of muscles in the chuck and round, yielding valuable information on the alternative use of these traditional cuts if sold or used as individual muscles. Ovine muscles have been characterized in several papers (Cross *et al*., 1972, Jeremiah *et al*., 1971, Smith & Carpenter, 1970, Smith *et al*., 1970a,b). Muscles from poultry and pork have also been profiled and early works include publications on veal (Paul & McLean, 1946). The results from these studies indicate that the market is ready for a change in the manner in which carcasses are fabricated and that specificity in terms of muscles and muscle characteristics can be used to the advantage of the producer, production plant and consumer. However, South Africa will not be able to use the data quoted as the muscles from South African beef will have different characteristics due to the routine use of growth stimulants that will change the characteristics, especially tenderness. The local industry thus need to profile the local produced muscles.

The ostrich industry has used muscle profiling successfully and have positioned them in the market in a unique manner through a scientific approach to carcass fabrication. Research is necessary to establish value muscle with high consumer acceptance in terms of quality that are currently lost due to traditional cuts. Muscle profiling has not been done on the traditional game species found in Africa and needs careful attention, as the consumer would probably not bulk at the purchase of deboned game meat.

3.6 Waste management

Waste management was high on the list of priorities to be researched at the Red Meat Abattoir Association Congress (RMAA, 2010). Waste management in Sub-Saharan Africa is essential, as water shortages, landfill scarcities and highly stressed sewerage systems are tangible problems. Changing legislation is also forcing abattoirs to re-think the manner in which they have dealt with blood offal in the past. Blood accounts for approximately 4% of an animal's weight and constitutes a major pollutant in terms of COD (15% total load) if discharged directly into the sewer as part of the cold wash-down, which constitutes about 27% of the wastewater volume (Water and waste-water management in the red meat industry, Natsurv 7, WRC Project No. 145 TT 41/89, 1989, SRK). Blood solids, can be converted into blood meal, however, at small abattoirs blood represents a severe problem for disposal. On average cattle and horses yield 13-15l blood, calves 2-7l, sheep 1.3-2l and pigs 2-4l. This amounts to a substantial volume for which the abattoirs normally pay municipal levies if blood is disposed through them. Currently the following methods of blood disposal are commonly used; municipal drainage, oxidation dams, buried, run off or spraying onto fields, by-products and pig feeds. Some of these practices are very costly and under new legislation frowned upon or now termed illegal (MSA, NEMA and NWA).

Research has documented that the use of foetal blood effluent for pharmaceutical purposes or processing of other blood effluent into blood meal are two of the most promising disposal methods. The review from the Red Meat Abattoir Association on Waste Management – Red Meat Abattoirs (2010) mentions more novel methods currently under investigation. The Eco-Energy Concept from the Green Circle (EU, North Ireland) presented by Oliver Hart at the RMAA (2010) brings many research possibilities to the table that can be employed in small scale abattoirs that would prove cost effective and green in the long run. Makinde & Sonaiya (2010) also reported on simple technologies where vegetable carriers were used to produce sun dried animal feeds with comparable animal feeds in Nigeria, which could prove very helpful in the African context. An interesting review by Mandal *et al*. (1999) investigated the use of blood from abattoir in the human food for the preparation of protein isolates and globin protein isolates, which have excellent nutritive value which would make it suitable for incorporation into meat and bakery product. At the University of Stellenbosch, the Monogastric Nutrition Research group are using flies and their larvae to convert blood protein into a protein source suitable for animal nutrition. The results of this research is very promising.

There is also immense scope to work with engineering departments to use international and African research and implement better and more effective blood processing facilities for abattoirs that comply with the ever more stringent green laws.

3.7 Deboning

Hot-deboning was developed in response to commercial desires for reduction in both energy usage and refrigeration space requirements (Pollok *et al*., 1997). Hot-deboning could negative affected eating quality due to the risk of cold-shortening (Taylor *et al*., 1981). Fortunately, this can be avoided by delayed chilling, but it is suggested by Taylor *et al*. (1981) that the maximum saving in time and cost are achieved when hot-deboning is preceded by electrical stimulation.

In general, temperature decline in hot-deboned muscles is faster and more uniform than in muscles left on the carcass (Van Laack & Smulders, 1992), which is beneficial for controlling microbial spoilage (Lawrie, 1998). However, since chilling and freezing commences rapidly in hot-deboned meat cuts, the tendency of cold-shortening and super contraction of muscle fibres may be enhanced. To avoid cold-shortening, it has been recommended to debone at muscle temperatures between 5ºC and 15ºC and then holding the vacuum-packed meat cuts at this temperature for at least 10 h *post-mortem* (Lawrie, 1998). Alternatively, electrical stimulation of the carcass immediately after slaughter could also be used to decrease risk.

Contradictory results have been recorded in literature regarding water binding capacity (WBC) of hot-deboned meat. Taylor *et al*. (1981) confirmed hot-deboning of beef muscles minimized drip loss due to more rapid cooling. However, electrical stimulation marginally increased drip loss compared to non-electrical stimulated meat when electrical stimulation was applied. Weakly *et al*. (1986) and Wiley *et al*. (1989) documented that drip loss increased after hot-deboning of pork muscles and subsequent chilling, while the results obtained by Van Laack & Smulders (1992) showed that hot-deboning hardly affected drip loss in pork. The contradicting results could be ascribed to different methods used in the individual studies to measure WHC, and because chilling conditions did not result in appreciable differences in pH and temperature decline. It is therefore important to provide thorough information on the pH and temperature profiles during chilling, in order to determine which factor influences WHC.

Cross (1979) reported that, when electrically stimulated, hot-deboning resulted in less purge in vacuum packed beef cuts that had been stored for 7, 14 and 20 d compared to cold-deboned cuts. Griffin *et al.* (1992) also indicated that electrically stimulated, hot-deboned beef muscles (*M. longissimus thoracis et lumborum* and *M. semimembranosus*) showed lower visible purge in vacuum packages than non-stimulated, cold-deboned muscles. Griffin *et al*. (1992) suggested that if electrical stimulation was used in combination with hot-deboning, bovine muscles could be stored for 7 to 21 d in vacuum packages without any detrimental effects on subsequent retail display appearance.

Raw meat colour in hot-deboned meat was more even coloured across large bovine muscles because of rapid cooling (Taylor *et al*., 1981). Cross (1979) found that muscles removed at 1 h *post-mortem* were significantly darker than those removed at 48 h *post-mortem* after storage for 20 d. In contrast, Griffin *et al*. (1992) did not find any difference in colour after storage between electrically stimulated, hot-deboned and non-stimulated, cold-deboned beef muscles. These differences open the research field into determining why.

The effect of hot-deboning (1 h *post-mortem*) on the shelf-life and the physical meat quality characteristics of vacuum packed ostrich (*Struthio camelus var. domesticus*) meat cuts from the *M. gastrocnemius, pars interna* and the *M. iliofibularis* during *post-mortem* refrigerated aging were evaluated at Stellenbosch University. The course of temperature (ºC) decline, change in pH, as well as the effect of temperature (ºC) on the course of *rigor mortis* were also investigated for the first 22 to 24 h *post-mortem* in the *M. gastrocnemius, pars interna* and the *M. iliofibularis*

Sensory evaluation indicated that hot-deboned *M. gastrocnemius, pars interna* was significantly tougher ($P < 0.001$) and less juicy ($P = 0.004$) than the cold-deboned (24 h *post-mortem*) muscles at 48 h *post-mortem*. Hot-deboned *M. gastrocnemius, pars interna* (2.05 ± 0.18 μm) also had shorter sarcomere lengths ($P = 0.0001$) at 24 h *post-mortem* than the cold-deboned muscles (2.52 ± 0.14 μm). However, with *post-mortem* refrigerated aging beyond 5 d at 4ºC, and for 14 d at -3º to 0ºC, respectively, the difference in toughness between the hot-deboned and the cold-deboned *M. gastrocnemius, pars interna* was insignificant. In contrast to the *M. gastrocnemius, pars interna*, hot-deboning had no significant effect ($P > 0.05$) on the tenderness of the *M. iliofibularis*.

Hot-deboning had no significant effect ($P = 0.2030$) on the pH when hot and cold-deboned *M. gastrocnemius, pars interna* were aged at 4ºC. In contrast, when aged at -3º to 0ºC, muscle pH was significantly ($P = 0.0062$) higher for the cold-deboned *M. gastrocnemius, pars interna* and *M. iliofibularis* (5.93 ± 0.12) than for hot-deboned *M. gastrocnemius, pars interna* and *M. iliofibularis* (5.91 ± 0.11).

Hot-deboning had a significant negative effect ($P < 0.0001$) on the water holding capacity of both the *M. gastrocnemius, pars interna* and the *M. iliofibularis*, causing the hot-deboned muscles to have more purge (%) during *post-mortem* aging than the cold-deboned muscles.

The effect of hot-deboning on the raw meat colour was mainly observed in the L*-values, where the cold-deboned *M. gastrocnemius, pars interna* were significantly ($P < 0.0042$) darker in colour (30.04 ± 2.29) than the hot-deboned muscles (30.71 ± 1.88) when aged at 4ºC. In contrast, when muscles were aged at -3º to 0ºC, hot-deboning resulted in the *M. gastrocnemius, pars interna* (30.48 ± 1.98) to be significantly ($P < 0.05$) darker in colour than the cold-deboned muscles (31.44 ± 1.80), while hot-deboning had no significant effect (P > 0.05) on the L*-values of the *M. iliofibularis*.

Hot-deboning had no significant effect on the shelf-life of meat cuts from both the *M. gastrocnemius, pars interna* and the *M. iliofibularis*, resulting in no increase in bacterial contamination prior to vacuum-packaging, nor in an increase in microbial counts during *post-mortem* storage for 42 d at -3º to 0ºC.

Both the intact *M. gastrocnemius, pars interna* and the intact *M. iliofibularis*, when stored < 4ºC, showed a rapid fall in muscle pH early *post-mortem*, reaching a mean minimum pH of 6.07 ± 0.41 at approximately 3.50 ± 0.84 h *post-mortem* and a mean minimum pH of 5.81 ± 0.07 at approximately 2.50 ± 0.58 h *post-mortem*, respectively. Furthermore, it was found that the muscle samples from the *M. gastrocnemius, pars interna*, maintained at 37ºC, reached fully developed *rigor mortis* (maximum isometric tension) at the point of minimum muscle pH (5.76 ± 0.13).

With the rapid fall in pH (reaching a minimum pH at 2-4 h *post-mortem*), as well as the early onset (1 to 4 h) of *rigor mortis,* it was concluded that hot-deboning of ostrich muscles at 3 to 4 h *post-mortem* would be without detrimental effects on the eating quality in terms of meat tenderness.

These results indicate that it would be feasible in terms of quality to implement hot deboning of ostrich meat. Further studies should be conducted to establish how fast post seaming-out the muscle could be frozen and what the impact of the rapid freezing would be on the quality of the product. It would also be beneficial to investigate the microbiological shelf life of hot and cold deboned ostrich meat, as this species is characterised by abnormally high final pH, which influences shelf life significantly.

4. SECONDARY PROCESSING

4.1 Retail packing & Shelf Life

Research by several groups has reported on the APC and levels of other indicator organisms on carcasses (Harris *et al*., 1993; Gill *et al*., 2000; Karama, 2001). A comparison of the APC values is a useful tool to evaluate microbiological quality and thus the level of hygiene attained in an abattoir. Furthermore, it can be indicative of the expected shelf-life of the meat.

Results of a study by Karama (2001) showed higher log mean values than for other studies under review on the indicator organisms (also commented on by Gill, 2007). Bobbit (2002) reported a shelf life of four weeks for vacuum-packed ostrich meat with an initial APC of <3 log cfu.g^{-1}. From the above data it can be concluded that ostrich carcasses slaughtered and dressed under proper process control is expected to carry a microbial load of between ±3.0 and 4.5 log cfu.cm^{-2}. South Africa contributes up to 70% of the ostrich meat produced internationally (Hoffman, 2005). The largest volume (more than 90%) of the ostrich meat produced in South Africa is exported (SAOBC, 2007) to the European Union (EU) and thus the expected initial microbial load on carcasses falls well with-in the limits specified by the EU regulation (Anon., 2007b) for red meats of APC 3.5-5.0 log cfu.cm^{-2}.

The handling and packaging of ostrich (and other meat types) meat cuts after de-boning will influence the microbiological population in the meat as well as the numbers in which the organisms are present. From this, it might be advantageous to study the effect of different carcass washing agents to decrease the microbial load on the carcasses prior to further processing. The use of ultra violet rays (UV) and ozone (O_3) in chillers for overnight chilling of ostrich carcasses were investigated to reduce the aerobic viable counts and *Enterobacteriaceae* counts by more than 90% and could be an effective method to enhance the shelf-life of ostrich meat (McKinnon *et al*., 2005). However, the practical application and cost effectiveness of these techniques still require evaluation and confirmation. Ostrich meat is most often vacuum packed and sold at refrigerated temperatures (Alonso-Calleja *et al*., 2003; Hoffman, 2008); both practices are intended to suppress the growth of aerobic bacteria and subsequently to prevent spoilage due primarily to *Pseudomonas* spp. the meat against spoilage and thus increase its keeping quality (Capita *et al*., 2006).

Alonso-Calleja *et al*. (2003) investigated microbial levels of retail refrigerated vacuum packed ostrich steaks in Spain as well as the influence of final pH on the bacterial levels of the meat. The data indicated levels of APC >7 $\log_{10}$ cfu.g^{-1}, which is the threshold for spoilage in fresh meat. This was deemed high compared to studies by Otremba *et al*. (1999) and Capita *et al*. (2006) and was ascribed to the fact that these studies were done on the carcasses and not on retail cuts, emphasising the importance of investigating the cold chain management for the export meat from South Africa.

Alonso-Calleja *et al*. (2003) reported a positive correlation between high pH values and high microbial levels, with the lowest microbial loads found on meat with a pH ≤ 5.8. The influence of pH on microbial load of refrigerated vacuum-packed ostrich meat suggests a positive benefit of ensuring a low final pH in ostrich products to improve the quality of these products. The pH observed (6.00 ± 0.39) was similar to that reported in other ostrich studies (Sales & Mellet, 1996; Paleari *et al*., 1997). The positive correlation between high pH values and high levels of microorganism growth was also reported by Gill & Gill (2005) who found that the storage life of vacuum packed, chilled meat depends on the extent of contamination with spoilage organisms at the time of packaging as well as the meat pH. They also found that bacteria with high spoilage potential can grow rapidly on muscle tissue at pH > 5.8 and thus can cause early spoilage of the vacuum packaged meat. Novel methods of tracking microbial spoilage by major pathogens have been developed by the Department of Microbiology at the University of Stellenbosch. Some preliminary studies have been done on minced beef packaged under modified atmosphere tracking the growth of these microbes. This work is currently still under investigation, but promises great application in the study of pathogen growth under various packaging regimes and on meat that has traditionally been recognised as fast spoiling, *i.e.* dark cutting meat (DFD) and ostrich meat.

A study was also undertaken to establish if there was a difference in the shelf life between fresh ostrich steaks and previously frozen ostrich steaks. The study evaluated the microbial shelf life as well as the physical parameters that affect shelf life. It was found that the previously frozen and fresh meat did not differ with regards to APC counts and had a shelf life of five days under overwrap packaging, 7-8 days under nitrogen MAP and >10 days under oxygen MAP. The literature indicates that the initial microbial load of the ostrich carcass is relatively high, which might hinder the application of novel packaging methods such as MAP. Investigation into the reduction of this load could prove significant for the application of new packaging regimes for ostrich meat as well as DFD meat.

Research on the sources of microbial contamination in ostrich abattoirs (Hoffman *et al*., 2010a,b) indicated that a major pool of contamination was from bacteria found in the water pools on the floor of the abattoir. The SOP in this specific abattoir required regular washing of the floor which was conducted with a high pressure hose. This caused vaporisation of the water molecules into a fine mist that also contained some of the pathogens. Another source of contamination was the air inlets. Both these sources could also be found in most major abattoirs. What is required is for this to be evaluated together with the high water usage - it seems as if most water used in an abattoir is to keep the working areas (in the primary dressing zone) “clean”.

The research team to establish prolonged colour stability and improved shelf life is currently conducting a study into the effect of carbon monoxide (CO) packaging of Bluefin Tuna. The EU does not accept the use of CO but the US does allow the application under certain conditions. It is hoped that the investigation into safe and appropriate use of the gas is to be used by the industry to persuade the EU to change the legislation regarding its use. The use of CO for packaging in mince is approved in the USA – research into the use thereof under South African conditions is required to see whether this intervention is suitable for local conditions.

4.2 Offal processing & value adding

Traditionally in South Africa, offal has been a delicacy among all sectors of the population, and with the increase in tourism, it has become a niche product in certain top restaurants. The so-called fifth quarter of a carcass has traditionally been seen as being of limited value. However, managers and owners of abattoirs are realising that the value of the offal is on the increase, as it is no longer only sold to the lower income market, this a trend not only visible in South Africa but globally. Irrespective of who the end consumer is, there is a need in the industry for more information on the nutritional value of the major offal found in livestock. Currently, limited scientific literature is available on the nutritional values for offal, except for nutrition food tables available on the internet that do not take the origins of the samples into account. Research findings reported in the public domain often only include selected chemical analyses of a few organs, for example proximate composition, cholesterol and fatty acids of brain, heart, liver and tongue of sheep (Mustafa, 1988; Abdullah, 1998; Williams, 2007).

The question also arises as to which extrinsic factors affect the chemical composition (and thus nutritional value). Park *et al.* (1991) reported slight differences between goat breeds for the moisture, total fat and cholesterol content of the liver, kidney and heart of two goat breeds. Park & Washington (1993) later reported significant differences in the fatty acid composition of organ meat between two goat breeds and between organs, within breed. Mustafa (1988) also found differences in proximate composition between beef and mutton organs as well as finding that cooking method affected proximate composition values.

Two studies were conducted by the Stellenbosch University's Meat Science team to ascertain the nutritional value of offal. The first was in cattle finished off in feedlots *versus* free-range steers, and the second on Dorper and Merino type lambs, slaughtered at an A2/A3 carcass classification level and reared in a free-range (natural pasture) system since both breeds are particularly popular in the South African agricultural industry

The results are currently being processed for publication, but include specific reference to proximate composition that differed between organs and breeds with Merino heart, spleen, and testicles having a higher moisture contents than their Dorper counterparts. Dorper brain, heart, spleen and testicles had higher protein contents than those of Merino. Merino organs also tended to have a higher fat content. Amino acid and fatty acid profiles differed between organs and breed. Very few differences were noted in total SFA and MUFA between organs and breed. Merino heart had significantly higher total PUFA than Dorper heart. All the organs showed favourable P: S ratios, with the exception of the tongue, heart and stomach. Dorper and Merino brain, lungs and testicles had favourable n-6/n-3 ratios. Cholesterol content differed between both organs and breeds. Calcium and magnesium were found in the lowest concentrations while sodium and iron were found in the highest concentrations. Liver was found to be a good source of iron and zinc and Dorper organs generally had higher levels of iron.

The nutritional value of the feedlot *vs* the free-range cattle showed that the origin had a significant effect on the proximate composition of the organs, most notably on the fat content with feedlot organs having a continuously higher fat content. Proximate composition also differed between organs. Cholesterol level was also found to differ between organs and was consistently higher in organs from feedlot animals. However, feedlot organs also tended to have higher PUFA: SFA ratios than free-range organs, which is a positive attribute concerning its relative cholesterol risk factor. Free-range organs contained more n-3 fatty acids in relation to n-6 fatty acid when compared to feedlot organs. Amino acid profiles and mineral concentrations differed between organs as well as between origins. Sodium levels were found to be higher in the organs than any other mineral, with the exception of iron, which was found in very high levels in the spleen.

The information from these studies is intended to be used by the team to develop novel value added products from offal that could be marketed to a wider range of consumers.

4.3 Cold chain management

Infrastructure and information management is a critical component in national and international trade of meat and meat products. There is a need for development in the distribution and storage of chilled and frozen foods (Beasley, 1998). This process and information management as well as the equipment involved are referred to as the 'cold chain'. In practice, significant deviations occur from specified conditions therefore temperature monitoring and recording has become a prerequisite for cold chain control to ensure that the product quality remains optimal at the consumer's end (Wells & Singh, 1989). Identification of the critical parameters affecting food quality and safety and quantification through a systematic modelling approach allows the monitoring of the quality and safety status of food products throughout the cold chain (Giannakourou *et* al., 2001). Progress in chain management is more transparency, information and traceability driven than arising from the development of new technologies (Billiard, 2003).

Temperature abuse dramatically reduces the shelf life of meat products, the storage temperature having a significant influence on microbial counts. Capita *et al*. (2006) performed a study to compare the microbial levels of ostrich steaks packaged under vacuum or under aerobic atmosphere and then stored for 9 days at different temperatures. They showed that both the specific temperature and oxygen exclusion proved to be critical factors on most bacterial groups.

The monitoring of the cold chain is still very primitive in certain areas of the meat sector within South Africa and serious attention and research has to be undertaken to evaluate the current systems and improve upon these to facilitate traceability as well as improvement of shelf life.

Also the cost analysis of traditional abattoir practices with large chilling rooms *versus* hot deboning plants needs to be evaluated, especially in SA context where electricity prices are said to continually increase and are know to be one of the main expenses. The use of ES, hot deboning and process engineering could lead to significant reductions in cost for abattoirs, which could ultimately be carried to the consumer.

Work is currently underway investigating the primary freezing and thawing practices in the ostrich industry. This work is laying the foundation for further studies in the field of cold chain management and monitoring, as well as effective use of resources time and space. At present, the Research Team have developed a prediction model that can predict the freezing rate of whole muscles taking into account their surface area to volume ratio as well as their chemical composition: moisture, protein and fat have different thermal properties and thus cool down at different rates. An interesting result from this research is that it is the freezing rate alone and not this rate combined with the thawing rate that leads to increases drip loss and deterioration in meat quality. During these experiments it was also noted that the meat industry as a whole require urgent training in the correct usage of chilling and freezing facilities – for example a number of blast freezer rooms were found to be incorrectly stacked with meat pallets resulting in non-optimal cooling rates and thus energy wastage.

4.4 Eating quality

A trained and a consumer panel are frequently used in conjunction to assess the eating quality of meat. Trained panels are used to establish the characteristics (sensory attributes) of the meat during an analytical process. The attributes include aroma, juiciness, tenderness and flavour. The consumer panel tests how consumers will react to a product, specific attribute of a product or a product idea. The consumer panel is then used in conjunction with the trained panel to establish the drivers of liking, using multivariate analysis statistics. The sensory profile as well as the degree of liking and drivers of liking in the traditional and exotic game species of Africa has not been documented extensively. As the game meat industry is expanding and modern consumer are becoming more adventurous and the availability of these species is becoming prevalent through restaurants a need has arisen to qualify the eating quality of these product. Value-added products produced from these products also need to be quantified and determined whether the consumer approves of the product. Some preliminary work has been done in this regard. Firstly on product development and sensory assessment of ostrich products (eg. bacon and ham like products), also on Salami made from traditional Namibian game species, rabbit meat, hot-deboned ostrich meat, blesbok and springbok through enhancement with inorganic salts, free-range *vs* feedlot lamb meat quality and many other studies.

Currently sensory profiling of traditional bred broilers *vs* free-range broilers is being investigated as well as benchmarking work on Egyptian Geese. The first study is aimed at finding concrete characteristics that separate traditional broilers and free-range meat. The second investigation aims at defining the sensory profile and determines the degree of liking from the consumers to establish if a viable market exists to commercially market Egyptian Geese.

The team aims to focus on new product development of value added products from novel game species and offal from traditional farmed species.

5. CONCLUSION

The objective of this review was to place the current status of knowledge of factors influencing the fresh meat production into an African perspective. At the same time, some of the past and on-going research being conducted at Stellenbosch University was also highlighted. A number of potential areas for research was also mentioned and briefly discussed.

A factor that was noted during the compilation of this review and from personal experience from working in the southern Africa meat industry is that although there is a huge amount of research available in the scientific community (from research conducted in South Africa but also from research conducted Internationally), the trade per se is not aware of this. An innovative method must be found to bring the industry and the scientific researcher together so that this flow of knowledge can be implemented. Another aspect that I and the other Meat Scientists find frustrating is that the Meat

Industry are under the impression that local research is not of an International standard and they would thus rather, at great cost, make use of international consultants.

Within South Africa there are a few core Meat Science research centres that not only collaborate amongst themselves but also with colleagues in the other related disciplines such as animal nutrition, animal breeding and food science. These centres are found at (this list is ranked in a random order and does not reflect importance); Stellenbosch University, University of Pretoria, University of the Free State and then the new team from the University of Fort Hare. Then of course, there is the strong group at the ARC.

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