# EFFECTS OF ANIMAL CLASS AND GENOTYPE ON THE NANOSTRUCTURE OF BEEF AND MEAT QUALITY

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**Abstract – The objective of the study was to determine the effects of animal class and genotype on the nanostructure of beef *M longissimuss thoracis et lumborum* (LTL) and beef quality. One-hundred and seventy (n = 170) cattle composed of 56 Bonsmara (BR), 65 Non-descript (ND) and 49 Nguni (NG) were slaughtered. The LTL muscle was removed at 24 hours *post-mortem*. Physico-chemical attributes of beef; ultimate pH ($pH_u$), lightness (L*), redness (a*) and yellowness (b*), Warner Bratzler Shear Force (WBSF) and histology of tissue structure as affected by animal-related were determined. The BR, ND and NG cows and heifers had visible skeletal fibres which were thin and long indicating improved tenderness of beef. The first important principal component's (PC's) as they appear from the analysis were $pH_u$, Tm, L*, a*, b* and WBSF. The first two PC`s of beef from heifers had the highest contribution of the total variance followed by bulls and cows. Therefore, animal classes; cows and heifers did not affect the nanostructures of beef, instead, the meat was tender due to longer and visible muscle fibers in heifers.**

**Key Words – Intercalated disc, muscle fiber and pre-slaughter stress.**

## I. INTRODUCTION

From farm to fork, different factors such as gender, age, nutrition, rearing conditions, weight at slaughter, genetic and environmental conditions usually interplay to determine the quality of meat including the amount of external and intramuscular fat, appearance and sensory properties [1]. Muscles are differentiated into smooth, cardiac and skeletal parts depending on their structure, contractile properties and control [2, 3]. The chemical composition and other biological properties of these muscles are significant for a better understanding of the major causes of variations in meat quality, particularly color, intramuscular fat and tenderness. Meat tenderness is influenced by the amount of myofibrillar and connective tissue of the muscle tissue [4]. Among the local genotypes, the Nguni cattle have favorable genes that contribute to better performance of this genotype in terms of meat quality [5, 6]. However, it becomes a challenge to improve tenderness through genetics if the nanostructure components such as sarcomere length, muscle fiber orientation and fiber texture are not known [7]. Studies have been conducted on the improvement for meat using genetic variation [8, 9] optical scattering and absorption coefficients of beef [4], sensorial consumer evaluation [10, 6], use of a microscope attached to the video image analysis (VIA) [6, 11] to measure sarcomere length where a longer sarcomere resulted to more tender beef as a good measured of tenderness. However, there is little information regarding the use of the scanning electron microscopy to evaluate the tenderness of beef hence the objective of the study was to determine the quality of beef as affected by animal class and genotype on the nanostructure of beef.

## II. MATERIALS AND METHODS

The study was conducted in Buffalo City Municipality at a commercial East London abattoir located in Eastern Cape Province of South Africa as shown in Figure 1. The permission to conduct the study was approved by the Research Ethics Committee of the University of Fort Hare, (UFH/UREC, MUC012 1SCHU01).

*Animal management and sampling*

One-hundred and seventy (n = 170) cattle composed of 56 Bonsmara, 65 Non-descript and 49 Nguni cattle that were bought to the abattoir from different environments were used in the study. The animals were identified at the lairages and classified into genotype, class (heifers, bulls and cows).

*Meat quality parameters*

The measurements of $pH_u$ and color coordinates (L*, a* and b*) were carried out at 48 hours after slaughter using the same sample. Representative samples (100 mm thick) of the LTL muscle between the 10th rib and the third lumbar vertebra were removed from beef carcasses.

*Determination of ultimate pH, color and Warner Braztler Shear Force*

A portable fiber-optic pH and Tm meter probe with a sharp metal sheath to prevent damage from raw meat (CRISON pH 25 Instruments S.A., Alella, Spain) was used to measure the ultimate pH and temperature of the carcasses 48 hours post mortem. The pH meter was calibrated before taking measurements using pH 4, pH 7 and pH 9 standard solutions (CRISON Instruments, SA, Spain). A Minolta color-guide 45/0 BYK-Gardener GmbH machine with a 20 mm diameter measurements area and illuminant D65-day light, 100 standard observer was used to measure the L* (Lightness), a* (Redness) and b* (Yellowness) color coordinates of beef.

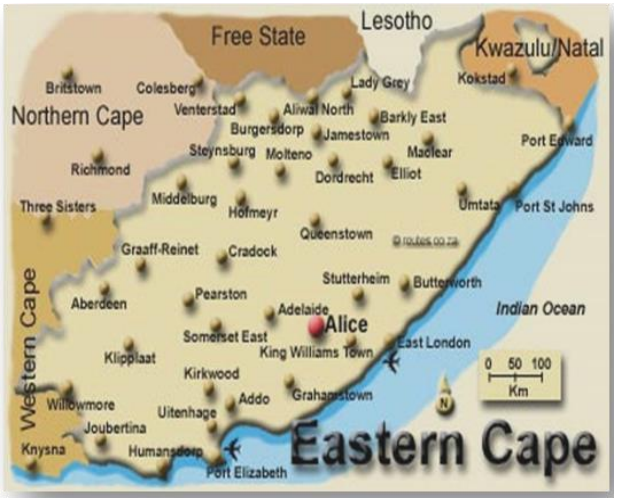


Figure 1 Map of the Eastern Cape Province indicating the study site, East London, South Africa.

The samples were further sheared perpendicular to the fiber direction using a Warner Bratzler (WB) shear device mounted on an Instron 3344 Universal Testing (cross head speed at 400 mm/min, one shear in the center of each core). Tenderness of beef was then determined using an Instron -WBSF machine. The mean maximum load recorded for the three cores represented the average of the peak force in Newton's (N) for each sample.

*Scanning Electron Microscopy Analysis*

During the period of dehydration, each sample was kept in ethanol for 20 minutes in an ascending order of 10% up to 100% respectively. In order to improve the electrical conductivity of the sample surface in the SEM, a thin film of gold palladium was used for sputter coating to enhance the analysis. Critical Point Drying (CPD) was performed using the Hitachi critical point dryer HCP-2 (Hitachi Koki Co Ltd, Tokyo Japan) to prevent the samples from alteration and to boost good structural preservation. (Au-Pb) using the Eiko IB.3 Ion Coater (EIKO Engineering Co TD, Japan). The samples were then observed under the JEOL JSM-6390LV scanning electron microscope (SEM) for the determination of the skeletal surface area of beef muscles.

*Statistical analysis*

The nanostructures of the skeletal surface area for beef samples (Nguni, Brahman and Non-descript) were sputtered with gold for visibility of the image using JEOL JM-5600 scanning electron microscope (SEM) at x 5,000 magnification. The relationship between $pH_u$, L*, a*, b* and WBSF among animals classes where genotype was used as a random variable, were determined using the Principal Component Analysis (PCA) [12].

## III. RESULTS AND DISCUSSION

*Nanostructure of beef muscles*

Figure 2 shows the length between intercalated discs of beef muscles. The ND cow length between the z-line was ranging between 967.47 nm to 1.33 µm whereas the width was between 441.81 and 684.69 nm. This is an indication of a significant difference between fiber orientations of cattle genotypes. Fiber orientation is linked to the tenderness of meat as it is greatly influenced by muscle structure [13]. Proteins such as nebulin and desmin also play part in the *post-mortem* tenderization of meat since the lie next to the z-line [14]. The sliding motion of many cross-bridges forces the thin filaments (actin) towards the center of a sarcomere, making the short fibers to affect the sarcomere length hence meat becomes tough [2].

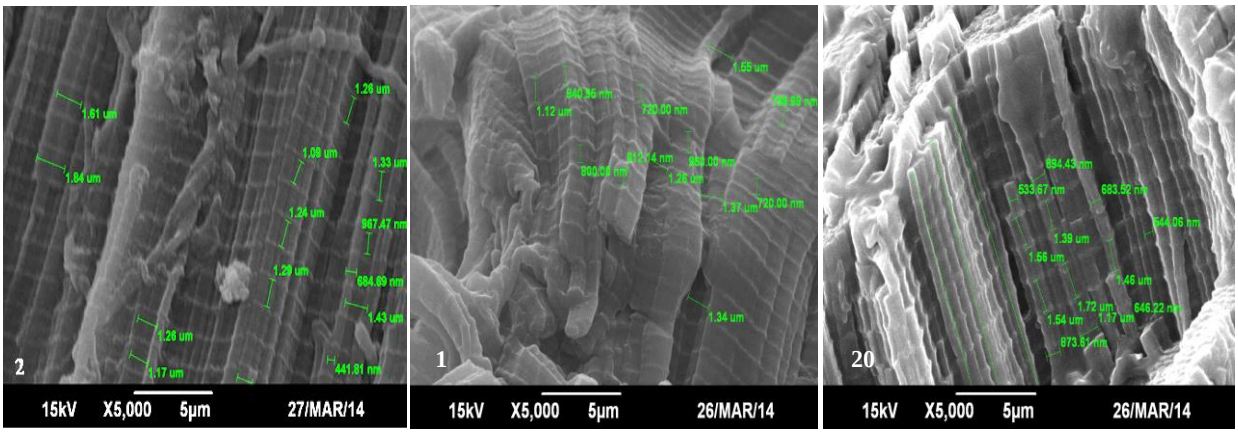


Figure 2 The length and width between the intercalated discs of the Nguni cow, Non-descript cow and Brahman cow, respectively.

Therefore, it is important to understand the function of sarcomere length which forms fibers in order to be able to improve the tenderness of meat [7].

*Beef quality parameters*

Figure 3 is a 3-D scatter plot of the first 3 eigenvalues of beef by genotype. The three genotypes (Bonsmara, Non-descript and Nguni) of cattle had almost similar PC's as observed in the scatter plot. The color of beef from BR was less than the normal values (< 34 %) while the color of ND and NG was within the expected values. It was reported that, meat becomes darker owing to higher consumption of the mitochondria resulting to poor color stability [15]. The results are also due to age differences between these genotypes because older animals tend to have a higher myoglobin content which lowers L* [16]. The amount of protein in the muscles is negatively affected with reduced *metmyoglobin* which affects the amount of water holding capacity (WHC) and color stability of the muscle [17, 18]. This implies that when considering the improvement of beef, one has to make sure that the factors that influence pH are minimized as possible. Ultimate pH ($pH_u$) is the major influence of meat quality and the extent of protein denaturation [19, 20].

## IV. CONCLUSION

It could be inferred from the study that, animal class and genotype affected the nanostructures of beef. Among the BR, ND and NG cattle, heifers had better meat quality than bulls and cows.

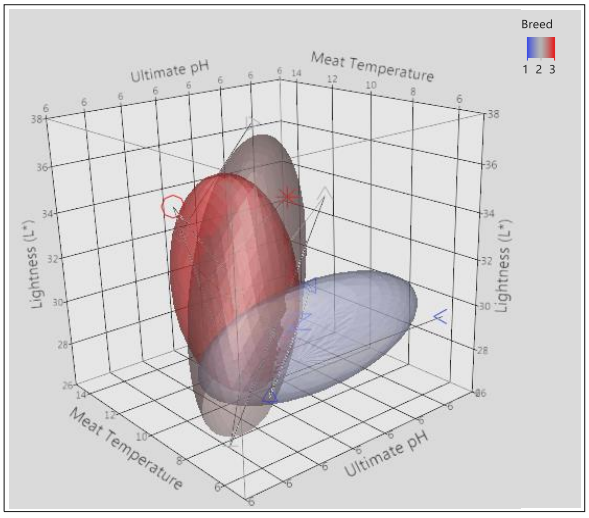


Figure 3 The overall 3-D scatter plot of the first three principal components of beef from all genotypes of cattle. 1 – Bonsmara, 2 – Non-Descript, 3 – Nguni.

The first two PC`s of beef from heifers had the highest contribution of the total variance followed by bulls and cows. Therefore, the nanostructures of beef were not affected by genotype with the Nguni cows having the best meat than Bonsmara. Considering the most important beef quality traits, heifers had better meat with $pH_u$, Tm and L* contributing the highest percentages in the total variance.

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