SLAUGHTER TRAITS AND MEAT QUALITY CHARACTERISTICS OF FIVE STRAINS OF TANZANIA SHORTHORN ZEBU

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN TROPICAL ANIMAL PRODUCTION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

A study was carried out to assess the suitability of five strains of Tanzania Shorthorn Zebu (TSZ) for production of quality meat. It involved assessing requirements for quality beef by the niche market followed by assessing the potential of five strains of TSZ to produce quality beef. A survey was carried out in Dar es Salaam (January and February 2019) to assess beef quality attributes required by the niche market. A total of 135 respondents (beef processors, retailers and consumers) were included. The potential of TSZ strains namely Iringa Red (IR), Gogo (GG), Mbulu (MB), Maasai (MS) and Singida White (SW) to produce quality beef was also assessed. A total of 50 animals aged 3-4 years were sampled from slaughter slabs in five districts. Slaughter traits, physicochemical properties and the response to post-mortem ageing were studied. Freshness, slight intramuscular fat (IMF), medium subcutaneous fat (SCF) and medium tenderness were the quality attributes preferred by retailers and consumers while the maturity of the animal, hygiene, safety and freshness were preferred by processors. The results showed overall means for heart girth (HG), estimated slaughter weight (ESW), empty body weight (EBW), hot carcass weight (HCW) and dressing percentage (DP) were 138.1cm, 201.4 kg, 171.4 kg, 101.4 kg and 50.6%, respectively. IR strain had the highest carcass measurement values while MB had the lowest. Non-significant effects of strain on muscle % and fat % of 6^{th} rib dissection were observed. Overall moisture content (MC) of *Longismuss thoracis* (LT) muscle was 72.53%, dry matter (DM) was 27.47%, ash was 4.56%, crude protein (CP) was 22.83% and ether extract (EE) was 4.77% while mean ultimate pH was 5.64. The colour change was significant for strains and ageing time. The drip loss and cooking loss were influenced by ageing, their values decreased with ageing time. Tenderness was lower for SW and higher for IR with the average of 62.35 N and it was decreased with ageing time.

Keywords: Ageing, beef quality, consumers' requirements, slaughter traits, zebu

DECLARATION

I, **JANETH MATHIAS BARUANI**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ATP	Adenosine Triphosphate
BIA	Bioelectrical Impendence Analysis
BQ	Beef Quality
Ca^{2+}	Calcium
CBGA	Canadian Beef Grading Agency
CF	Crude Fat
CIELAB	Commission International De L'Ecairage
Cl	Cooking Loss
CL	Carcass Length
CP	Crude Protein
CU	Control Unit
CV	Coefficient of Variation
DAGRIS	Domestic Animal Genetic Resources Information System
DFD	Dark Firm and Dry
DL	Drip Loss
DM	Dry Matter
DP	Dressing Percentage
EBW	Empty Body Weight
EE	Ether Extract
ESW	Estimated Slaughter Weight
FAO	Food and Agriculture Organisation of the United Nations
FGIT	Full Gastro-Intestine Tract
GDP	Gross Domestic Product
GG	Gogo
H_2SO_4	Sulphuric Acid
H_3BO_3	Boric Acid
HCl	Hydrochloric Acid
HCW	Hot Carcass Weight
HG	Heart Girth
HLC	Hind Leg Circumference
HLL	Hind Leg Length
IEP	Isoelectric Point
IFD	Internal Fat Depot
IMF	Intramuscular Fat
IR	Iringa Red
JMGA	Japanese Meat Grading Association
Lab	L* lightness, a* Redness, b* Yellowness
LL	*Longissimus lumborum*
LSD	Least Significant Difference
LT	*Longissimus thoracis*
M	Muscle
MB	Mbulu
MS	Maasai
N	Newton

NARCO	National Ranching Company
NBS	National Bureau of Statistics
NCC	Non Carcass Components
pH	Hydrogen Ion Concentration
pHu	Ultimate Hydrogen Ion Concentration
pm	Post-mortem
PSE	Pale Soft Exudative
RMY	Red Meat Yield
SAS	Statistical Analysis System
SCF	Subcutaneous Fat
SD	Standard Deviation
SEM	Standard Error of the Mean
SPSS	Statistical Package for Social Science
SUA	Sokoine University of Agriculture
SW	Singida White
SWt	Slaughter Weight
t	Tonne
TFY	Trimmable Fat Yield
TSZ	Tanzania Shorthorn Zebu
UK	United Kingdom
URT	United Republic of Tanzania
USDA	United States Department of Agriculture
W	Weight
WBSF	Warner-Bratzler Shear Force
WHC	Water Holding Capacity

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Livestock plays a crucial and significant role in supporting rural livelihoods in smallholder mixed crop-livestock and pastoral systems in developing countries (Kerley *et al.,* 2018; Muzzo and Provenza, 2018). About 80% of rural households in Sub-Saharan Africa are keeping livestock (Herrero *et al.,* 2014). The importance of cattle breeds is arising in most African countries due to an increasing demand for meat at local and international levels. However, the trend of increasing demand is currently not corresponding with the production (Herrero *et al.,* 2014).

Nandonde *et al.* (2017), in 2016/17, Tanzania produced about 493 000 metric tonnes (MT) of red meat, mostly beef (83%) with the remaining amount coming from sheep and goats. Nandonde *et al.* (2017), further reported that most production (97%) came from pastoral and agro-pastoral communities and red meat marketing was predominantly done for domestic consumption, with little exports. Furthermore, the Bank of Tanzania in 2018 reported that production of meat rose in tandem to 648 810 tonnes in 2016 from 579 757 tonnes in 2015 following an increase in demand particularly in mining and tourism industries as well as an expansion of export markets mainly in Mozambique, Vietnam, Oman, Qatar and the United Arab Emirates. Also, based on the Tanzania Livestock Master Plan of 2017, livestock consumption is expected to grow by 71% (to 867 302 tonnes) in 2022.

Currently, Tanzania has a total of 30.6 million heads of cattle, among which 95% are Tanzania Shorthorn Zebu (TSZ) which represent the second-largest cattle population in Africa (NBS, 2018). Cattle fulfil several functions in the Tanzanian economy, some of which are food (beef), cash income, drought power and organic fertilizer. The livestock sub-sector contributes about 5.9% to Gross Domestic Product (GDP) (Engida *et al.,* 2015).

Red meat production in Tanzania is based on traditional systems under agro-pastoral and pastoral production systems that use very little modern technology (Kerley *et al.,* 2018; Kanuya *et al.*, 2006). The main source of red meat comes from indigenous cattle (Tanzania Shorthorn Zebu), sheep (undifferentiated African long-fat-tailed types and the Red Masai) and goats (Small East African). The identified TSZ cattle strains (which account for the major part of red meat) so far are 12 namely; Mkalama, Gogo, Singida white, Chagga, Pare, Fipa, Iringa red, Mbulu, Maasai, Tarime, Sukuma and Zanzibar

(Msalya *et al.,* 2017). TSZ breed belongs to indigenous African humped cattle (*Bos indicus*) and according to Strydom *et al.* (2000) their meat quality characteristics include low carcass weight (producing leaner meat) and low tenderness as a result of higher muscle calpastatin activity. Calpastatin inhibits calpain enzymes to break down muscle protein during post-mortem proteolysis and low level of marbling since they are mostly fed with relatively low energy diet and/or they are not slaughtered at extremely fat levels.

1.2 Problem Statement and Justification

Less consideration on beef production has resulted in the lack of information on the potential of Tanzania Shorthorn Zebu for producing quality beef. Their slaughter traits and meat quality traits are not well studied to determine their potential for producing quality beef. Nevertheless, previous studies have attempted to assess the effect of feedlot performance on carcass characteristics of TSZ based on various feed resources; local feed resources (Mushi, 2020), concentrate diet and hay as well as agro-processing by-products (Asimwe *et al.,* 2015, 2016). Also, studies have been conducted on growth performance and the economy of producing quality beef (Mwilawa *et al.,* 2010) and evaluation of slaughter and carcass characteristics from indigenous beef in abattoirs of Tanzania (Shirima *et al.,* 2016). Furthermore, phenotypic and genotypic characterization, their potential in milk production and their disease resistance features have also been studied (Msanga *et al.,* 2012; Laisser *et al.,* 2015; Msalya *et al.,* 2017). However, these studies have been limited in number and used either the same strain or locality, for instance, some authors used the same locality (Kongwa), and this might probably lead to the use of the same strain of TSZ. Comparative studies to assess the carcass characteristics of indigenous cattle strains (TSZ) fed under their local environment in Tanzania are lacking. Slaughter traits and meat quality characteristics can be influenced by breed or strain of an animal due to variation in muscle structure and meat physiology (Soini and De Haas, 2010). For that matter to develop and orient baseline information on slaughter traits and meat quality characteristics, as well as the need to understand the status of the indigenous cattle population is essential. Moreover, the values, motivations, expectations and requirements of livestock keepers and consumers need to be addressed.

Currently, the demand and consumption of meat from animals including ruminants and non-ruminants and its derivatives are on the increase due to various reasons (Guerrero *et al.,* 2013) such as an increase in the human population, the rising of middle-class income people, the growth of tourism industry and marketing information. These factors have increased the consumption of meat and meat products, (Soini and De Haas, 2010). Simultaneously, most consumers pay attention to the quality of the products they eat, meat inclusive (Guerrero *et al.,* 2013). **Although,** TSZ **contribute about 94% of the total production of red** meat **and** meat **products (UNIDO, 2012), beef production in Tanzania is constrained by low productivity and poor quality beef as a result of slow growth rate. Slow growth leads to a longer time (greater than five years) for the animals to reach the desired market weight. Too old market weight affects the local and international market for TSZ beef due to poor carcass conditions (both quantity and quality)**. Some key players in the niche market argue that beef from TSZ cannot meet specialized market requirements. For instance, a T-bone steak should weigh at least 250g and must be tender (Personal communication with Dr. Daniel Mushi, Department of Animal Science and Production at Sokoine University of Agriculture, 2018). This perception is used as the reason for importing beef for the niche market such that about 700 tonnes were imported in 2015 (Trevor, 2015). Consumer preference for beef specific quality attributes was found to include medium adipose fat, chilled carcass, medium to high tenderness and hygiene (Nandonde *et al.,* 2013). Generally, the development of the beef industry in Tanzania needs more innovative ways to address the issue of quality in order to meet market demand. Along that line in July 2015, the Ministry of Livestock and Fisheries Development launched the Tanzania Livestock Modernization Initiative. The initiative aims, among other things to identify suitable strains of TSZ and promote them as high quality and recognizable brands in the domestic, regional and international market. Knowledge on the intrinsic differences among TSZ strains will therefore help to know the potential of these strains and how they can be improved to produce quality beef economically.

1.3 Objectives

1.3.1 General objective

To assess the suitability of different strains of Tanzania Shorthorn Zebu for quality beef production.

1.3.2 Specific objectives

i. To assess the current requirements of quality beef for niche market
ii. To evaluate the slaughter traits of five strains of Tanzania Shorthorn Zebu
iii. To evaluate the physico-chemical properties of beef from five strains of Tanzania Shorthorn Zebu
iv. To evaluate the response of beef from five strains of Tanzania Shorthorn Zebu to post-mortem ageing.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Beef Quality Attributes and Consumer Preferences

Meat quality is normally defined by the compositional quality (lean to fat ratio) and the palatability factors such as visual appearance, smell, firmness, juiciness and tenderness, flavour (FAO, 2014), appearance quality (freshness and wholesomeness), and reliance quality trait (safety) (Joo *et al.*, 2013). It can also be defined as a measure of traits that are sought and valued by the consumers (Mullen, 2002). Additional aspects of quality are nutritional composition and other technological aspects (pH and water holding capacity). The nutritional quality of meat is objective yet "eating" quality, as perceived by the consumer, is highly subjective. Since consumers' demand for high-quality meat is increasing in many developing countries, the need to produce beef that is tasty, safe and healthy for the consumers is important. To produce high-quality beef and its products that meet consumer preference and satisfaction, it is necessary to understand the meat quality traits and factors controlling them.

According to Brunsø *et al.* (2002), consumers' preference is the subjective taste of an individual consumer measured by his/her satisfaction with the item purchased. Hence, from the consumers' preference point of view, meat quality has four major dimensions which are; appearance, palatability, health and convenience (Udomkun *et al.*, 2018). These dimensions are highly influenced by several factors notably sensory properties, psychological properties and marketing. Moreover, Polkinghorne *et al.* (2008) noted that, consumers' eating quality preferences are affected by pre-slaughter issues like; breed, age, growth rate, growth promoters, marbling and/or fatness and gender. Other factors include post-slaughter issues like pH, temperature, ageing, hanging (tender-stretch vs. Achilles hang) and cooking methods of meat. Besides, some consumers are becoming aware on the production process, issues like organic production, the use of growth promoters (non-genetically modified) and animal welfare are more important (Ridley *et al.*, 2015; Gao, 2007). Fig. 1 summarizes the extrinsic beef quality characteristics (subjective and objective) as described by consumers. The extrinsic quality attributes of meat have been described to include product-focused attributes and process-focused attributes.

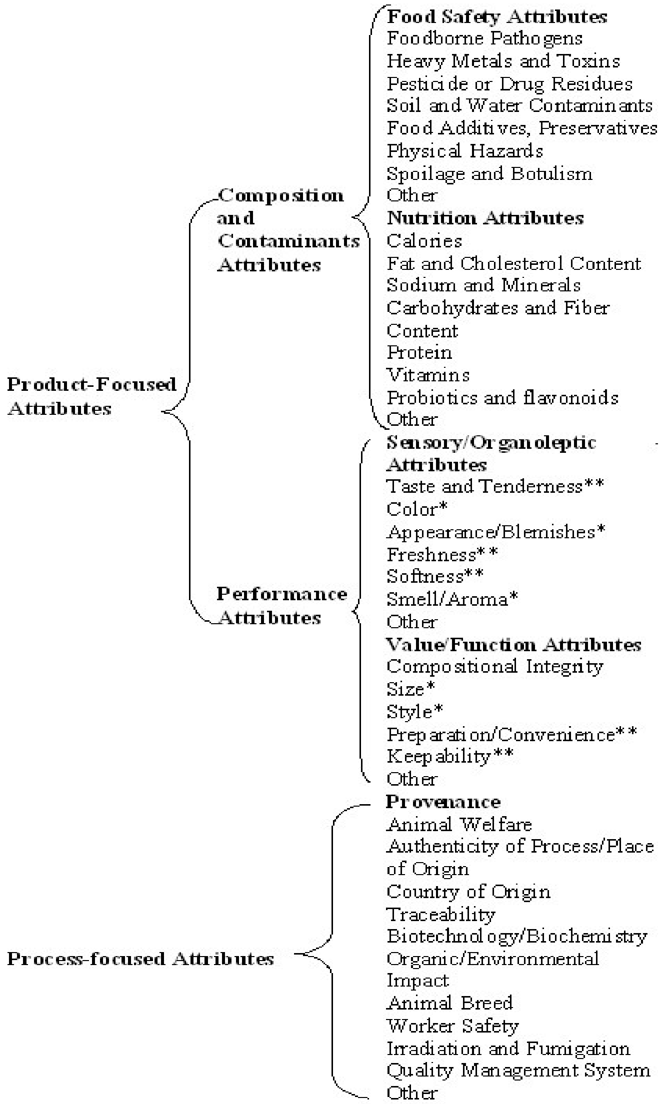


Figure 1: Extrinsic quality attributes (Adopted from Gao, 2007)

According to Owusu-Sekyere (2014), extreme important beef quality attributes preferred by consumers in their purchasing decision were; leanness, certification, shopping environment and packaging. Moreover, tenderness, freshness and price were of moderate importance and origin of the animal was considered not important.

2.2 Tanzania Shorthorn Zebu (Indigenous strains)

Like many African cattle, TSZ breed is grouped into *Bos indicus* (humped cattle). TSZ breed is well known for their versatility and survival in extremely harsh environmental conditions and is capable of withstanding high temperature and prolonged dry season, high tolerance to diseases and they are resistant to trypanosomiasis (Okeyo *et al.,* 2015). However, as a result of their low genetic potential and poor management, these animals have slow growth rates and low mature weights (Msalya *et al.,* 2017).

In Tanzania, 50-70% of indigenous cattle are kept under the agro-pastoral system in arid and semi-arid areas (Nandonde *et al.,* 2017). They produce most of the red meat contributing to 68% of total meat production (URT, 2017) and approximately 75-80% of milk produced (Kanuya *et al.,* 2006). Nevertheless, their meat quality is characterized by low tenderness and lean. Its leanness can give rise to cold shortening (cross-bonding between actin and myosin fibres) if the carcass is rapidly chilled at low-temperature post mortem, which might lead to the toughness of meat (Strydom *et al.,* 2000; Fuller *et al.,* 2004). However, indigenous cattle can produce quality beef under proper pre and post-slaughter conditions (Strydom *et al.,* 2000).

In Tanzania there are twelve strains of TSZ, with distinctive features in terms of coat colour, horns (shape and size), body size, hump position and size of naval flap. According to Msanga *et al.* (2001, 2012), Iringa Red and Singida White are very unique in their coat colour, while Maasai and Gogo strains have a multi-coloured coat. Msanga *et al.* (2001) gave distinctive features of various strains of TSZ as follows;-

The Gogo Zebu

The origin of this strain is Dodoma region, central Tanzania. The coat colour of this strain is variable, however, the common being black, brown, grey, black/white spotted or pied. The body colour varied from iron to steel grey. It has compact and small body frame, large thoracis hump that is erect but tends to be sloppy in mature males, it has small-sized dewlap and naval flap and small erect ears. The face profile is flat with short straight horns facing upwards with wide spacing between them.

The Iringa Red

The Iringa red strain of zebu is found in Iringa region, mainly Iringa and Kilolo districts. The coat colour varies from red, darkish-red, brown or multi-colour, where more than one colour is found in one animal. The multicolours are red and white or brown and white and the coat pattern is mainly spotted with few pied. Face profile is flat with brown ear tips and muzzle, horns are short, medium, straight shaped and widely spaced with an upward orientation. The animals have medium body frames with a thoracic well placed erect hump, the dewlap is medium-sized, the naval flap is small and the tail switch is brown.

The Maasai Zebu

Its origin is Maasai land in Arusha region. The animals are multi-coloured but the common ones are black, brown and black/white spotted. The animals are of medium body frame with a thoracic medium-sized erect hump, dewlap is medium-sized and the naval flap is large. Face profile is flat with medium-sized horns, not very widely spaced, straight with an upward orientation.

The Mbulu Zebu

The strain is found in Mbulu and Hanang' districts of Manyara region. The coat colour is mainly black, though a few black and white spotted animals can be seen. Horns are short, with lateral orientation and widely spaced. The strain has a small body frame with a medium-sized erect thoracic hump and their tails are long and narrow at the base.

Singida White

The strain is found in Singida and Iramba districts of Singida region. The colour is white all over the body. For the mature males, the neck is grey and/or tends to be black. But also, it has silver-grey to white colour while the brush of the tail, skin, hooves and muzzle are black. Face profile is flat; it also has medium-sized straight horns, with an upward orientation. The animals are of medium body frame with a floppy thoracic hump, medium-sized dewlap and the small-sized naval flap.

2.3 Killing out Characteristics or Slaughter Traits

It involves slaughter weight (SW), carcass weight (CW), dressing percentage (DP) and empty body weight (EBW). Slaughter weight is the weight of the animal (live weight) at slaughter. According to Fuller *et al.* (2004) live weight includes the weight of gut contents, which varies with diet and feeding pattern. Carcass weight refers to the weight of the eviscerated animal when other parts such as feet, head, and skin are also removed. Carcass weight (hot carcass weight) can be used to allow estimation of cold carcass weight and dressing percentage. Dressing percentage (DP) is the carcass weight expressed as a proportion of the animal's live weight. Typically, dressing percentages vary between 41 and 56% depending on fat score and age of the animal for ruminant species such as cattle, sheep and goats (McKiernan *et al.*, 2007). The dressing percentage of pigs is higher (around 75%) due to the relatively lower weight of the viscera, but also the skin, head and feet are regarded as part of carcasses. Slaughter characteristics also include empty body weight (EBW) which is defined as the total weight minus gut content (Fuller *et al.*, 2004). Empty body weight can also be defined as the sum of hot carcass weight, blood, all set of external organs, all set of internal organs, discard fat and empty GIT (Cattelam *et al.*, 2018).

2.3.1 Slaughter weight

Slaughter weight is the key factor in determining carcass composition. Slaughter weight is affected by age, genetics, sex and nutrition, which in turn affects carcass composition (Teye and Sunkwa, 2010). At a given age, slaughter weights differ between breeds due to differences in growth rate. Larger frame-sized breed types attain heavier final weights and have heavier carcasses than the smaller frame-sized breed types (Du Plessis and Hoffman, 2007). Apart from genetic factor, steers, compared with bulls, are characterized by a slower growth rate and lower feed efficiency, but their meat has higher intramuscular fat content, has lower carcass weight, tender and has the higher water-holding capacity (Martí, 2012). Heifers deposit fewer muscles and more fat than do steers resulting in carcasses that are less desirable both economically and nutritionally (Teye and Sunkwa, 2010). Slaughter weight can be determined by, targeted market weight and/or age/maturity. Based on weight and age/maturity of the animal, slaughtering is recommended to be done at a lighter weight, during which the animal is at a younger age (12-24 month of age) (Mohammed, 2004). Animals at a young age produce cuts which are small, tender and most desirable. Moreover, slaughter weight can be decided based on the amount of fat deposited. The mature animal is likely to have quality meat, because of the desirable amount of fat which is associated with flavour (Nogalski *et al.*, 2014). Traditionally, TSZ strains are slaughtered around the age of 3-4 years, during which the weight may range from 207 to 294 kg (Kashoma *et al.*, 2011). Slaughter weight can affect carcass composition, as an animal slaughtered at a heavier weight its carcass composition (muscle and fat) increases.

2.3.2 Carcass weight

Carcass weight (CW) is the weight (kg) of the body of an animal after dressing. Carcass weight recorded within 45 minutes of slaughter for pigs and within one hour of slaughter for cattle and sheep is termed hot carcass weight (HCW). On the other hand, carcass weight following the chilling process is termed as cold carcass weight (CCW). Carcass weight can be estimated and/or predicted by using body measurements i.e. external body measurements like heart girth, abdominal circumference and hump measurements (height, depth and circumference). According to Abdelhadi *et al.* (2011), various carcass measurements like hind leg length and hind leg circumference can be used to predict carcass weight. That study found a significant correlation between carcass weight and various carcass measurements.

2.3.3 Dressing percentage

Dressing percentage **(**DP**)** is obtained by dividing the hot carcass weight by the live weight and it is expressed in percentage. It is a very important parameter in determining the profitability of the slaughtered animal. Dressing percentage is affected by many factors. The study by Koonawootrittriron *et al.* (2011), found that breed, gender, age, seasonal variation and diet are the factors which affect DP. A review by Muir and Thomson (2008) found that due to breed differences, the dressing percentage of heavier and fatter animals is higher compared to that of lighter animals. For instance, dairy cattle yield 3% less in dressing percentage (49.9% vs. 53.2%) than beef cattle, because beef cattle tend to have a heavier weight and high-fat content than dairy cattle (Muir and Thomson, 2008). Some authors observed different DP on different breeds of beef cattle as shown in Table 1. Based on gender, male cattle had larger carcass weights and dressing percentages than heifers.

Moreover, at a similar fat level heifers are usually 1.5 to 2.0% lower in DP than steers. However, Biagini and Lazzaroni (2005) found that the DP of male cattle was lower for intact bulls than for the castrated males (62.9% vs. 67.8%). Based on age, the ratio of the gut to other body parts is greater in young animals, thus young animals will exhibit a lower dressing percentage than mature animals, therefore, the live and carcass weights increase with increasing age (Priyanto *et al.*, 2019). Diet has also been reported to significantly affect the DP (Du Plessis and Hoffman, 2007). Intensively fed animals had higher dressing percentage as compared to extensively fed animals. This was attributed to the amount of gut fill and the degree of fatness at slaughter. Intensively fed animals have less gut fill and higher carcass fat. The study by Priyanto *et al.* (2019) suggested that an increase in body fat score resulted in increased slaughter and carcass weight and thus high DP.

Table 1: Slaughter characteristics of selected beef cattle breeds

Breed	**Live weight (kg)**	**Carcass weight (kg)**	**Dressing percentage (%)**	**Source**
Tanzania Shorthorn Zebu (Gogo)	209	108	51	Mwilawa *et al.* (2010)
Tanzanian Boran	258	132	51	Mwilawa *et al.* (2010)
Ethiopian Boran	268	200	52	DAGRIS (2006)
Ghana shorthorn	204	-	48	DAGRIS (2006)
Improved Boran	368	237	55.7	DAGRIS (2006)
Angus	-	314	56.3	Muir and Thomson (2008)
Simmental	-	331	56.6	Muir and Thomson (2008)
Limousin	-	330	57.2	Muir and Thomson (2008)

2.3.4 Non-carcass components

Non-carcass components are the organs that are not part of the carcass but, they contribute a large proportion to the live weight of the animal (Mohamed, 2004). With exception of pigs, they constitute all set of external and internal components namely; head, feet, skin/hide, tail, red offal (heart, liver, trachea, lungs, kidneys and spleen) and green offal (oesophagus, rumen, intestine and mesenteric and omental fats). Non-carcass components are affected by age, gender and type of diet. Based on age and weight, the increase in carcass weight may be accompanied by smaller non-carcass components (Fuller *et al.,* 2004). Since body weight increases with age, the proportion of internal components is greater during early stages of life and decreases as age progresses (Cattelam *et al.,* 2018). This study also observed the effect of gender in which steers were confirmed to have higher weights of internal organs due to their higher development rate in early stages of life and as a result of an increasing number of cells of the tissues and the vital organs are also increasing in size.

The effect of diet on non-carcass has been reported. Fitzsimons *et al.* (2014) reported the decrease in the weight of the gastro-intestine tract (GIT) by 8% in animals that had a reduced dry matter intake (DMI). Moreover, improved nutrition has a significant effect on the non-carcass components. Ahmed *et al.* (2015) found that the weight of non-carcass components (pancreas, GIT and liver) increased with an increasing level of treated sugarcane bagasse in the diet. The overall mean for feet, hide, head and tail were reported by Sestari *et al.* (2012) for Nallore cattle to be 10 kg, 40.36 kg, 11.96 kg and 1.16 kg, respectively.

2.3.5 Carcass composition

Carcass composition comprises of muscle, fat and bone. These tissues can be affected by genetic factors, physiological age, sex type, nutrition and growth hormone (Irshad *et al.,* 2012). Based on the carcass weight, Afolayan *et al.* (2002) reported an average of 70% muscle, 19% fat and 11% bone on various cattle genotypes.

Body composition and body shape change dramatically and continually during growth. At the beginning of the growing period, muscle tissue is laid down faster than fat, but later the development of fat tissue exceeds the rate of muscle growth. Stage of maturity is an important factor in the genotype-dependent variation in carcass composition (Irshard *et al.,* 2012). Depending on maturity types, early-maturing beef breeds, such as the Aberdeen Angus, Hereford, Belmont Red and Murrey Gray have a lower mature body size and weight, which is reached earlier, compared with later-maturing breeds like Charolais, Limousine and Simmental (Ritchie, 2009). Practically, that means early-maturing breeds will be physiologically "older" at the same age compared to late-maturing breeds, thus late-maturing beef breeds have, in general, higher growth potential and deposit fat later than early-maturing beef breeds (Prendiville *et al.,* 2013).

According to Fuller *et al.* (2004), growth promoters like testosterone, oestrogens, β-agonists and many other hormones, have a direct or indirect effect on carcass composition. Generally, they are important in increasing the efficiency of growth by increasing nitrogen incorporation into muscles, thus increasing muscle protein, decreasing fat production and in older animals, they cause epiphyseal plate fusion in bones thus can reduce skeletal size.

To explain various internal and external factors affecting carcass composition, there is a need to understand growth and development pattern of these three tissues. Hossner (2005) described growth at the cellular level as an increase in cell size and cell number or as the change in function at the organ level. At the cellular level, there is cell replication to increase overall mass by increasing cell numbers (hyperplasia). Also, the cell can grow to increase size or volume (hypertrophy). True growth consists of an increase in mass, length and height of the animal; during which muscle and bone cells increase and fat tissue is deposited (Hossner, 2005). Bodyweight, height at withers and body lengths are parameters that can be used to examine the pattern of growth (Hifzan *et al.,* 2015). True growth pattern can be measured by slaughtering and dissecting animals of different ages and weights. The growth curve of meat animals is described as a sigmoid curve. It has an initial exponential growth phase when growth is very rapid, slow growth phase and plateau during which growth is very slow and essentially ceases. At this stage the animal has reached maturity (Hossner, 2005). At maturity, the fattening phase is very important since the animal will continue to accumulate fat; changing body composition and the flavour of the meat will be attained. In summary, the bone is considered as an early developing tissue, giving room for muscle to attach (intermediate developing) and fat as the late-developing tissue.

2.3.5.1 Methods of estimating carcass composition

Estimating carcass composition is very important in the beef industry because it is used to evaluate the amount of edible meat as well as the value of beef (Angela, 2015). Various methods include physical methods, equations and grading system can be used to estimate carcass composition. Physical methods involve dissection of the rib cuts; for instance, the use of 6th rib joint (Serra *et al.,* 2004; Mwilawa *et al.,* 2010) and 10th-11th-12th rib joints (do Prado *et al.,* 2015).

Serra *et al.* (2004) used 6th rib joint and found 68.2% muscle, 12.7% fat and 16.3% bone. Mwilawa *et al*. (2010) found the dissection of the 6th rib of TSZ (Gogo) to have 67% muscle, 14% fat and 19% bone. The use of 6th rib is believed to be more accurate method in estimating carcass composition as compared to the use of 10th rib (Serra *et al.,* 2004, Olivan *et al.,* 2001) because of the high correlation of 6th rib dissection and half carcass dissection compared to the tenth rib. Generally, the dissection of rib joint specifically 10th rib tends to overestimate the amount of fat than half carcass dissection (Olivan *et al*., 2001). Other advanced methods include video analysis, ultrasound, X-ray, computer-assisted tomography and total body electrical conductivity. Angela (2015) used three grading systems, which were United State Department of Agriculture (USDA), Canadian Beef Grading Agency (CBGA) and Japanese Meat Grading Association (JMGA) as well as Bioelectrical Impedance Analysis (BIA) to predict red meat yield (RMY) and trimmable fat yield (TFY). In her study fabrication results from an experiment was used to evaluate the mentioned systems. Results indicated that the BIA method was highly correlated with the fabrication yields (r=0.72). Thus BIA is a most accurate and non-invasive predictor of beef carcass composition. Among the grading systems, USDA (r=0.71) was the best compared to the other two systems, CBGA (r=0.61) and JMGA (r=0.36) to RMY% (Angela, 2015).

2.4 Carcass Measurements

De Boer *et al.* (1974) described carcass measurements into hot carcass weight and other standard measurements taken on the left half of the carcass. Such measurements include carcass length, hind limb length, hind limb width and internal chest depth. Moreover, according to Serra *et al.* (2004), carcass compactness can be derived from carcass weight divided by carcass length and hind limb compactness from hind limb width divided by hind limb length are also considered as carcass measurements. Knowledge concerning carcass measurements is widely used in evaluating carcasses in terms of edible meat and economic value. It involves standard cutting procedures whereby the carcass is divided into two halves, followed by ribbing between 12th and 13th rib, then separating the fore-quarter by cutting between 5th and 6th rib and breaking of the hindquarter by cutting anterior of the pubis on the aitchbone. Ribbing is important in measuring the ribeye (REA), subcutaneous fat (SCF) and intramuscular fat (IMF). These measurements are useful in assessing carcass conformation and fat scores (quality grade). For instance, the REA is used to measure muscling and fatness (Polkinghorne *et al.*, 2010). Degree of IMF is used to determine the quality grade. The yield grade is evaluated by considering the amount of boneless and high value trimmed retail cuts (the round, loin, rib and chuck) (Hale *et al.,* 2013). According to FAO (1991), the forequarter can be separated into the chuck, fore-shank, brisket, rib and plate while the hindquarter into the flank, round and loin. To obtain retail cuts various beef cutting styles can be implemented for example, in United Nation Economic Commission for Europe (UNECE, 2013) standard for retail meat cuts, including topside, silverside, eye round, rump, sirloin, short loin, T-bone, tenderloin, strip loin, thick and thin flank from the hindquarter. Also, primal rib, prime rib, short rib, ribeye (cube roll) and blade prepared from forequarter.

2.5 Meat Quality

Meat quality is defined as a measure of traits that are sought and valued by the consumers (Mullen, 2002). This may include appearance quality (freshness and wholesomeness), eating properties (tenderness, juiciness and flavour) and reliance quality trait i.e. safety (Joo *et al.,* 2013). Additional aspects of quality are nutritional composition and other technical aspects such as pH and water holding capacity (WHC). As consumers' demand for high-quality meat is increasing in many developing countries the need to produce beef that is tasty, safe and healthy for the consumers is important. To produce high-quality beef, it is necessary to understand the meat quality traits and factors controlling them.

2.5.1 Meat colour

Meat colour is most important because it is used by consumers as an indication of freshness. It determines a consumer's response and decision at the point of retail (Węglarz, 2010). Meat colour can be evaluated by the use of instruments such as Hunter Lab or CIELAB colour space system (CIE L*a*b*). It expresses colour as three values: L* for the lightness (from black (0) to white (100)), a* relative redness (from green (−) to red (+)) and b* for relative yellowness (from blue (−) to yellow (+)) (Commission International De L' Eclairage, 1976) or by visual assessment. Meat colour is affected by various exogenous and endogenous factors (Neethling *et al.,* 2017). Exogenous factors include; seasonal variations, heat stress, feeding management, ante mortem stress (pre-slaughter handling practises) and post-slaughter handling. Endogenous factors include; ultimate pH, water holding capacity, age, species, sex and muscle fibre types. However, there are many other factors which may contribute to discolouration of meat during processing, storage and display (Suman and Joseph, 2013). The complexity of the interactions between these factors makes understanding and control of meat colour very challenging.

Based on age, as the animal grow the amount of pigment (myoglobin) increase. Myoglobin is the principal protein responsible for meat colour. It exists in four major forms of chemical states, namely deoxy-myoglobin, oxy-myoglobin, carboxy-myoglobin, and met-myoglobin (Suman and Joseph, 2013). Therefore, the colour of meat from young and old animals often differs in redness. The study by De Lima *et al*. (2016) found that with increased weight and age at slaughter there was an increased amount of pigment red content (a*) and reduced lightness (L*). Furthermore, sex of the animal affects meat colour. As a result of the high content of intramuscular fat, castrates have higher lightness

(L*) and redness (b*) values compared to intact bulls (Dejan *et al.,* 2018). This has led to a higher likelihood of dry firm and dark (DFD) meat in bulls than castrates. The DFD meat in bulls is associated with high-level activities which cause depletion of glycogen reserve and thus resulting in high ultimate pH (pHu).

2.5.2 Ultimate pH and water holding capacity

Muscle pH is the key factor concerning meat quality. During the conversion of muscle to meat, lactic acid is produced and muscle pH is reduced from 7 to 5.5. Lactic acid causes the reduction in reactive groups on muscle proteins which are responsible for water binding. As a result of less reactivity, the net charge of proteins is zero (pH is at its isoelectric point). The isoelectric point is described as the point of minimum charges of muscle protein which occur at pH of 5.0-5.2 (Robyn, 2017). At this point, muscles lose more fluid and hence possess low water holding capacity (Robyn, 2017).

Meat pH can also affect water holding capacity (WHC), the meat of high pHu with high WHC will result in darker cutting, hence, DFD meat. In contrast, the meat of low pH with denatured protein will result in the pale colour of the meat, the condition is referred to as pale, soft and exudative (PSE). These meat conditions are thought to affect almost all livestock species. However, it only depends on how animals are handled pre-slaughter (Adzitey and Nurul, 2011). These two parameters (DFD and PSE) are very problematic in the beef and pork industry. They affect processing as well as consumer acceptability. Water holding capacity (WHC) is defined as the ability of fresh meat to retain its naturally occurring water (Pearce *et al.,* 2011). It is an important property of fresh meat which is used to determine the visual acceptability; thus influencing consumer willingness to purchase the product. It is used to determine water loss during transportation, storage, processing and cooking (Robyn, 2017).

Water is very important in shaping muscle structure; as it is associated with myofibrils. WHC of meat is influenced by several intrinsic and extrinsic factors. Among the most important intrinsic factors are genotype and feeding of animals which affect muscle characteristics directly. For the extrinsic factors, treatment of animals before slaughter is likely to cause stress, which ultimately decreases muscular glycogen reserves, a process which may lead to high pHu and high water content of meat (Cheng and Sun, 2008). WHC of meat affects both yield and quality of the meat. Poor water holding capacity as a result of shrinkage of myofibrils, membrane permeability and protein denaturation may affect carcass yield (loss in carcass weight) and causes dryness of meat (toughness). Moreover, water holding capacity has an impact on shrinkage and swelling of myofibrils and thus affecting meat tenderness during post mortem ageing (Robyn, 2017).

2.5.3 Tenderness

Tenderness is an important parameter to consider from eating quality point of view and from consumer preference point of view. Maltin *et al.* (2003) observed some factors that have been shown to affect beef tenderness like early post-mortem changes, muscle fibre types, pH, drip loss, buffering capacity, post-mortem proteolysis (during beef ageing), connective tissue, selective breeding and genotype as well as growth rate and nutrition as the major determinants of meat quality in terms of tenderness. Meat tenderness can be measured by using meat tenderness measurement devices (tenderometer and/or Warner Blatzer shear force), also, through consumer studies (sensory tenderness scores). According to the criteria established by Simmons *et al.* (2006) beef cattle carcass muscles may be classified by their shear force (N) as extremely tough, shear force value above 107.87 N, acceptable, shear force value between 107.87 N to 78.45 N and tender, shear force value less than 68.64.

In the early post-mortem, muscles are highly sensitive to ATP and Ca^{2+} which are both involved in the contraction-relaxation process. As ATP drops and calcium level increases post-mortem (pm), the irreversible cross-bonding is formed between actin and myosin head. At this point, rigor mortis occurs in the tissue. Formation of rigor bonds is associated with an increase in toughness (Maltin *et al.,* 2003). After rigor mortis, muscle cells continue to undergo molecular changes that result in proteolysis of myofibrillar proteins. Among the major endogenous proteolytic system is calpain system (Bhat *et al.,* 2018). Calpains are enzymes that break down proteins, thus associated with meat tenderization during post-mortem proteolysis. The calpain system has three members which include Ca^{2+}-dependent proteases, a typical calpain (μ- and m-calpain) and calpastatin (Goll *et al.,* 2003). Calpastatin has been classified as the one that inhibits the activity of calpain proteases. The calpain system can be affected by calcium level (Ca^{2+}) as well as pH level (Du Toit and James, 2013). The typical calpain is a Ca^{2+} requiring proteases, therefore, both μ- and m-calpain are active at the physiological level of $Ca^{2+,}$ it requires, micromolar Ca^{2+} (for μ-calpain) and millimolar Ca^{2+} (for m-calpain) (Goll *et al.*, 2003).

The post-mortem beef tenderization in most cases is mainly due to μ- calpain (CAPN 1) gene which lasts for 4 days post-mortem (Essays, 2018). However, the activation of m-calpain, provide a beneficial effect on tenderness after μ- calpain has stopped. Colle *et al.* (2018) found a significant influence of m-calpain on Warner Blatzer shear force of *M. longissimus lumborum* (LL) and on day four sensory tenderness scores after early post-mortem calcium injection. This means calcium chloride injection provides enough calcium to activate m-calpain activity.

2.5.3.1 Beef ageing

Ageing of meat is defined as a process which aims to increase palatability (juiciness, tenderness and flavour) of meat naturally at refrigeration temperatures for several days during which post-mortem proteolysis of myofibrillar proteins occurs in the muscles (Perry, 2012). It has been reported that to improve the consistency of meat quality concerning tenderness, beef should be aged for at least 14 days (Šárka *et al.*, 2011). In the beef industry, ageing is normally done under controlled temperature, relative humidity and airflow.

The ageing process has been grouped into three categories namely; dry ageing, dry-ageing in a package and wet ageing (Hatice and Ümit, 2018). Traditionally, dry ageing was performed i.e. hanging beef carcasses or unpackaged prime cuts in a cool room at 1-3°C and 70-85% relative humidity for 1-5 weeks. This conventional method was claimed to be expensive due to the requirement of large rooms, high risk of contamination and high trim loss which affects yield and thus it has economical implication (Hatice and Ümit, 2018). Nowadays, new methods are available like dry ageing in packages and wet ageing.

Dry ageing

Generally, dry ageing carcasses are kept in a controlled environment (temperature, humidity and airflow) for several days usually 14 - 35 days unpacked. Dashdorj *et al*. (2016) explained these two techniques of dry ageing; one is a conventional-type which involves hanging of carcasses in a refrigerated room without a protective barrier and the other one involves packaging carcasses in a high moisture-permeable bag. In contrast with the traditional dry-ageing method, dry-ageing in package/bags is positively associated with increased safety, quality, yield and shelf life (De Geer, 2009). Apart from having many disadvantages, dry-aged beef is more palatable than wet-aged beef, since, the ageing method does affect the level of beef flavour. Dry ageing can enhance beef flavour, due to concentration of various beef compounds since water is lost from the meat over time making dry-aged beef to contain different volatile flavour compounds than wet-aged beef (Smith *et al.*, 2008). Furthermore, there are incidences in the literature where consumers preferred dry-aged beef over wet-aged beef; however, there are also cases where consumers detected no difference between ageing methods or preferred wet-aged beef over dry-aged beef.

Wet ageing

In wet-ageing, the meat is aged in a sealed barrier package (vacuum-packaged bag) at refrigerated temperatures. It represents the primary method of beef ageing today. The popularity of wet ageing is due to its ability to prevent shrinkage and trim loss, thus, ensuring an economic advantage over dry ageing. Also, a wet-aged product is easier to store and transport than the dry-aged product (Dikeman *et al.*, 2013). Therefore, wet ageing should be the preferred method of ageing for most of the beef industry. Sitz *et al.* (2006) found the choice for wet-aged samples were numerically higher than that for dry-aged beef. This may indicate that consumers are not accustomed to palatability characteristics that are thought to be associated with dry-aged beef, or there is truly no difference in palatability characteristics between dry- and wet-aged products.

2.5.4 Chemical/nutritional composition

Meat is highly nutritious and palatable. It is an important source of high-value animal protein and essential nutrients that are required for good health throughout life (Pereira *et al.,* 2013). Based on meat quality point of view, the nutritional value is among the important factors influencing consumer preference for poultry, red meat and processed meat products. The major determinant of the nutritional value of meat includes protein quality, intramuscular fat (IMF) content and composition, trace elements and vitamins (Scollan *et al.,* 2017). Chemically meat is composed of major and minor constituents. The major ones are water, protein, lipids and carbohydrates. A review by Raj *et al.* (2013) found that the composition of meat, after rigor mortis, can be approximated to 75% moisture, 19% protein, 3.5% soluble and insoluble substances and 2.5% fat. Moreover, the review showed that protein-rich diets were low in carbohydrates. The minor constituents are vitamins A and B-complex vitamins, iron, zinc, selenium, phosphorous, potassium, magnesium and sodium (Wyness, 2015). It also contains enzymes, pigments and flavour compounds and provides metabolic bioactive compounds. The adequate proportions of these constituents give meat its particular structure, texture, flavour, colour and nutritive value. For instance, the carbohydrates ‘glycogen" though it is found in low content in meat, but has an indirect impact on colour, texture, tenderness and water holding capacity of meat. During early-stage post-mortem, glucose metabolism results into the production of lactic acid which lowers the pH and in turn affects the quality of meat (Ahmad *et al.,* 2018).

According to Williams (2007), beef is meat derived from dressed carcasses of a bovine animal. Its protein content consists of all essential amino acids. Beef is also a significant source of dietary choline, a precursor of neurotransmitters and membrane phospholipids.

It was reported to be rich in minerals (iron and zinc) and it provides riboflavin, niacin, vitamin B6 and pantothenic acid (Williams, 2007).

Chemical composition of beef is influenced by many factors such as age, and type of diet, feeding regime, growth enhancer and carcass condition at slaughter and meat cuts. Moholisa *et al.* (2018) found that among all factors, carcass chemical composition was highly influenced by the type of diet. This study reported a significant difference in the chemical composition of three types of muscles namely *M. longissimus lumborum*, *M. biceps femoris* and *M. semitendinosus*. The composition of *M. longissimus lumborum* cut at 1^{st} to 5^{th} lumbar vertebrae had 25% dry matter, 0.97% ash, 21.1% crude protein, 3.12% ether extract and 74.8% moisture for grain-fed steers. For grass-fed steers composition was 23.6% dry matter, 1.16% ash, 21.1% crude protein, 1.36% ether extract and 76.4% moisture. Based on fatty acid profiles, a grass-fed group had more content of desirable fatty acids preferred by consumers (omega 3-polyunsaturated fatty acids) and conjugated linoleic acid (Moholisa *et al.*, 2018).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study I. Assessment of the Current Requirements of Quality Beef for the Niche Market

3.1.1 Location of the study

The study was conducted in Ilala and Kinondoni districts of Dar es Salaam region, Tanzania. The region was selected because it is the largest commercial city, with a high population of middle-income people, a lot of tourist hotels, attractive beaches and several meat processing plants. According to the 2012 national census data, Dar es Salaam had human population of 4.36 million (URT, 2013), with a projected population of 5.47 million in 2016 (NBS, 2016). Dar es Salaam region has four administrative units namely Kinondoni, Temeke, Kigamboni and Ubungo municipalities. The study was specifically carried out in Kinondoni municipality (Msasani, Mikocheni, Hannanasif and Bunju wards) and in Ilala municipality (Kisutu, Mchafukoge and Kivukoni wards).

3.1.2 Research design and data collection

A cross-sectional survey design was used. The primary data were gathered by the aid of structured questionnaires. The questionnaires for different categories of beef stakeholders were developed and administered to beef consumers, beef retailers (supermarkets and hotels) and processing plants. In summary, the questionnaires assessed various intrinsic and extrinsic aspects of beef quality attributes such as eating quality, hygiene and safety quality, appearance and considered important quality attributes by various stakeholders in beef value chain. This activity took place from January to February, 2019. Three types of questionnaires (Appendices 1, 2 and 3) were administered to the operators of beef processing plants, beef retailers and consumers, respectively. For beef processors (Appendix 1) the following were assessed: knowledge of processors on quality beef (QB), their preferences for beef quality attribute, the source of quality beef reasons for sourcing beef from certain places, form and type of beef products they process, who were their customers and their willingness to pay for quality beef. To beef purchasing officers in tourist hotels and supermarket managers in the supermarkets (Appendix 2) the following were assessed: knowledge of beef retailers on quality beef, retailer's preferences on quality beef, level of importance for various attributes of quality beef to retailers, reason for purchasing beef from various places, types of products they process and most preferred form and curing methods, if any. To consumers (Appendix 3) the following information were required; the demographic characteristics of respondents, the knowledge of consumers on quality beef, consumers' preferences on single most important quality beef attribute and consumers level of importance attached to various quality beef attributes.

The secondary information concerning importation of beef, exportation of beef, consumption of beef, demand of beef and other beef marketing information were reviewed and cited in the text from National Bureau of Statistic (NBS) and the Ministry of Livestock and Fisheries Development (MLFD).

3.1.3 Sampling size and procedure

A total of 100 beef consumers, 30 beef retailers (20 supermarkets and 10 tourist hotels) and five operators of processing plants from Kinondoni and Ilala districts were selected and interviewed. These districts were selected due to the presence of many supermarkets, tourist hotels and high-income people, but also due to the availability of meat processing plants. On the consumers' side, the targeted respondents were obtained at Namanga butcher market located in Kinondoni district.

3.1.4 Data analysis

Data from the questionnaires were coded and analysed using the Statistical Package for Social Science (SPSS) program version 16.1 for qualitative data. Descriptive statistics were used to calculate averages, percentages and cross-tabulation tables were made. Multiple response analysis was also done for questions with more than one answer.

3.1.5 Limitations of the study

In most of the supermarkets and tourist hotels, apart from interviewing the hotel and supermarket managers to fill in the questionnaire (Appendix 2), I was not allowed to interview the consumers. The main reason was that they did not want their customers to be disturbed. For this case, to obtain consumers' information, the interview had to be carried out at Namanga, the biggest butcher market believed to sell quality beef in Kinondoni, where various types of consumers including people from other nationalities prefer to buy beef.

3.2 Study II: Slaughter Traits of Five Strains of Tanzania Shorthorn Zebu

3.2.1 Location of the study

The study was carried out in five districts namely Singida municipality in Singida region, Bahi in Dodoma, Kilolo in Iringa, Monduli in Arusha and Hanan'g in Manyara. These areas were selected due to the high concentration of targeted TSZ strains, which were Singida White, Gogo, Iringa Red, Maasai and Mbulu, respectively. The data were collected in slaughter houses/slabs from March to July 2019. The regions were grouped into three agro-ecological zones namely Northern zone (Arusha and Manyara), Central zone (Dodoma and Singida) and Southern zone (Iringa). The northern part of the country has bimodal rainfall, which falls during the October–December (short rains) and March-May (long rains) seasons. The Central and Southern zones of Tanzania are experiencing a unimodal rainfall regime which exhibits a single wet season from November to April.

During data collection (March-July 2019) the rainfall pattern was as described below:-

i. In Singida region the rains fell from November to January. Data were collected from 12th March to 4th April, during which the green pastures were plenty. For this case the animals had gone through the rain season, their body condition score was good.

ii. In Manyara the rainfall started in December to January, data were collected from 6th to 22nd April. The green pastures were available and animals had gone through the short rain season and their body condition score were good.

iii. In Arusha, rains started in November and the long rain started from the end of April to June, data were collected from 6th to 26th of May, during which new pastures (lash) were available. The animals had gone through a short period of feed scarcity, their body condition score were average.

iv. In Dodoma region the rains started in December to March and data were collected from 10th to 29th of June. Standing hay was plenty.

v. In Iringa region the rains started in November to April. Data were collected from 4th to 24th of July. There was plenty of standing hay, and the animals' body conditions were good.

3.2.2 Procedure for sampling and animal identification

During ante mortem inspection experimental animals were identified according to the sampling framework. The cattle used in the study were pure TSZ originating from the five selected regions reared on natural pasture without supplementary feeding. The information was inquired from native people to make sure the animals were indigenous to that area. Some of the common and detailed features were confirmed by literature (Msanga *et al.,* 2001). A total of 50 animals (25 entire bulls and 25 castrates), by which 10 animals (5 entire bulls and 5 castrates) from each strain in every region were sampled.

Purposive sampling was used to select animals of respective strains with approximately 3-4 years of age. The age of the animal was confirmed by dentition. An animal with 4 permanent incisors (4pi) was estimated to be 2.5 years old, with 6pi estimated to be 3 years old and the one with 8pi (corner teeth replaced) to be 4 years old.

3.2.3 Estimation of slaughter weight

A weigh band was used to measure heart girth (in cm) by placing a measuring tape directly behind the front legs and base of the hump. The equation adopted from the study by Kashoma *et al.* (2011), $Y = 4.55\ X - 409 \pm 17.9$ where, Y = live weight (kg), X = heart girth (cm) was used to validate estimated slaughter weight obtained using weigh band.

3.2.4 Slaughter procedure

Animals were starved overnight before slaughter to minimize the effect of feed intake on gut fill. They were slaughtered at the slaughter slabs available. Most of these slaughter slabs were able to slaughter an average of six animals per day except for the Singida municipal slaughter slab which had the capacity of 30-40 animals per day. In order to abide to the Halal procedure the animals were slaughtered without stunning. Skinning and evisceration was done on the floor and the hide was used to prevent the carcasses from getting into contact with floor. Using a knife, the head was removed at the antlanto-occipital joint. The fore feet were removed at the carpal-metacarpal joint and hind feet were removed at the tarsal-metatarsal joint. The dressed carcass was divided into two halves and hanged on iron bars.

3.2.5 Measurements of carcass and non- carcass components

Non-carcass components were weighed by using a hanging weighing scale with the capacity of 200 kg. These included external organs (head, feet, skin and tail) and internal organs (small intestines, pluck, full and empty digestive tract). The weight of internal fat depots (IFD) was taken using a portable electronic (10 kg/10g weigh-hang).

Empty body weight (EBW) was derived from the difference between slaughter weight and gut fill. Gut fill was derived from the difference between the weight of full and empty digestive tract within 45 to 60 minutes of slaughter. After splitting the carcass into equal halves and quarters, hot carcass weight (HCW) was measured using a portable hanging scale in kg. Dressing percentage was derived from expressing the hot carcass weight as a percentage of slaughter weight. Carcasses were quartered between the 12^{th} and 13^{th} rib to allow pH measurement on the LT muscle and the ribeye area from the right side of the dressed carcass was sketched in this joint on translucent paper. pH measurement was recorded approximately 1 hour post-mortem using pH meter (Knick Portamess 910), also, ribeye area between 12^{th} and 13^{th} rib was sketched on the translucent paper using a permanent marker. By using a Zero Setting Compensating Planimeter the area in cm^2 was estimated. The trace arm length was set at 115.9, the known area of 50 cm^2 (5:10) scale was traced and the reading was used to calculate the actual area of the sketched ribeye.

On the left side carcass, linear carcass measurements namely hind leg length, hind leg circumference and carcass length were measured in cm using a tailoring tape. The descriptions of the measurements taken were as follows.

i. Hind leg length (HLL) was measured in cm between the front edge of the pubis bone and midpoint of bones of the tarsal joint.

ii. Hind leg circumference (HLC) was measured by the use of measuring tape around the widest part of the hind leg above the curve of aitch bone.

iii. Carcass length (CL) was measured from the pubis bone to the front of the 1st rib.

3.2.6 Carcass composition

Carcass components namely muscle, fat, bone and dissection loss (including fascia) were dissected from the 6th rib sample joint (Serra *et al.,* 2004) of the left side of each animal. A total of 50 samples of 6th rib joint were purchased, weighed and dissected. By using a sensitive weighing balance (10 kg/10g portable electronic weigh-hang) the 6th rib joint was weighed (g) then dissected into muscle, fat (subcutaneous fat-SCF and intramuscular fat-IMF), bone and dissection loss. The weight of each component was then expressed as percentage of the weight of the whole 6th rib joint. To prepare the sixth rib sample joint from the left side of the carcass, the carcass was first quartered, the fore limb removed and separating by cutting the posterior edge of fifth and the anterior edge seventh rib bone with a knife and by cutting end of rib bone.

3.3 Study III: Physicochemical Properties and Response of Beef from five Strains of Tanzania Shorthorn Zebu to post-mortem Ageing

The *Longissimus thoracis* (LT) muscle from right side of each animal was excised from the prime rib (i.e. from 5th to 12th rib) after 1.5 to 2 hours of slaughter. The LT muscle samples were weighed and packed in Polyvinyl bags and refrigerated at 4° C for 24 hours during which the second pH reading was recorded and thereafter the samples were deep frozen until when they were transported to the laboratory at Sokoine University of Agriculture for physico-chemical analyses (pH, colour, drip loss - DL, cooking loss - Cl, tenderness and chemical composition). During analysis, the samples were removed from deep freezer, thawed under refrigeration at 1ºC - 4ºC overnight and each sample cut into seven pieces for DL and Cl for day zero, day 7 and day 14 and proximate analysis. The labelling were DL day zero, Cl day zero, DL day 7, Cl day 7 also, DL day 14, Cl day 14 and for proximate analysis. The samples labelled day zero were used for immediate analysis of pH, colour, drip loss, water holding capacity and tenderness. The samples labelled day 7 and 14 were used for assessing the response of pH, colour, DL, Cl and WBSF of meat from five strains to post mortem ageing. Finally the proximate analysis was done once for all samples.

3.3.1 Carcass pH and colour

The first pH reading of carcasses was taken post-mortem (i.e. before rigor) within 45 to 60 minutes on REA of the right side carcass between the 12th and 13rd rib cut, the second reading was taken 24 hours post-mortem on the LT muscle excised from 5th to 12th rib and after rigor, the third reading was taken on the same LT muscle excised from 5th to 12th rib at thaw. The pH was measured by inserting a calibrated electrode (Metler Toledo) of a portable pH-meter (Nick Portames 910, Germany) in the *M. longissimus thoracis* in the locations as described above. The carcass colour was measured at thaw (zero day), at 7 and 14 days of ageing on the fresh-cut meat surface of LT muscle. Muscle colour was measured on meat surface using Minolta chromameter CR-400 (Konica Minolta Inc. made in Japan) based on CIE L* a*b* system, where L* – metrical lightness; a* – redness; b* – yellowness.

3.3.2 Cooking loss (Cl) and Warner-Bratzler shear force (WBSF)

The samples were thawed at 1ºC - 4ºC overnight and prepared for cooking loss (Cl) and Warner-Bratzler shear force (WBSF) determination. The LT muscle excised between 5th

and 12th rib of the right side half carcass was cut into a piece of approximately 50-160 grams depending on the size of the muscle, labelled and placed in a plastic bag. For immediate determination of Cl and WBSF at 0 day, the sample labelled for day zero was weighed and placed in a thin-walled plastic bag then sealed using electronic sealing machine ready for cooking. For the determination of the response of five strains to post-mortem ageing the samples were stored in the refrigerator at 1ºC - 4ºC for 7 and 14 days ageing time. After each ageing time, the samples were weighed (W1), labelled, placed in thin-walled plastic bags and then sealed using a sealing machine. The samples were cooked in a thermostatically controlled water-bath at 70°C for 1 hour, after which the samples were removed from the water bath and cooled in running cold water for 2 hours. The samples were then removed from plastic bags, dried with a paper towel and weighed again (W2), the cooking loss was calculated as per the equation below.

$$Cl\ (\%) = \frac{(\text{Weight of raw meat (W1)} - \text{Weight of cooked meat (W2)}}{\text{Weight of raw meat (W1)}} \times 100$$

The samples cooked for cooking loss/water holding capacity assessment were cut into 1 cm x 1 cm x 1 cm cubes parallel to the direction of the muscle fibres. Warner-Bratzler shearing device (Zwick/Roell, Z2.5 and Germany) instrument was used to determine the maximum force (N) required shearing 1cm^3 meat blocks perpendicular to the grains. The device was set with 1 kN load cell with a crosshead speed of 150 mm/min to determine tenderness.

3.3.3 Drip loss determination

A *M. longissimus thoracis* sub-sample measuring approximately 21 to 71 g was weighed (W1), tied in a plastic thread and hanged in an inflated plastic bag. After a storage period of 24 hours at 1°C - 4°C, the samples were weighed again (W2) and the drip loss (DL) was calculated as weight loss expressed as a percentage of the original weight of the sample.

$$DL(\%) = \frac{\text{(Original sample weight (W1)} - \text{Weight after 24 hours (W2)}}{\text{Original sample weight (W1)}} \times 1000$$

3.3.4 Determination of chemical composition of carcass

Forty-eight samples (one sample each for Mbulu and Singida white went missing) of *M. longissimus thoracis* labelled for proximate analysis were frozen and then minced in a manual mincing machine until a homogeneous mixture was obtained. Determination of dry matter (DM), ash and crude protein (CP) and ether extract (EE) contents was done according to proximate analysis scheme (AOAC, 2005).

3.4 Statistical Analysis

Data from slaughter traits namely, estimated slaughter weight, empty body weight, dressing percentage, carcass and non-carcass weights, carcass measurements, as well as those from meat quality characteristics including pH, colour, drip loss, cooking loss and tenderness were analysed using General Linear Models procedure of SAS (2003). The fixed variables for slaughter traits were strain and sex type whereas for meat quality characteristics were strain, sex type, ageing time and their interaction. Effects of these fixed variables on the dependent variables were tested using PDIFF option of SAS. The level of significance used for various traits was ($P \leq 0.05$). The statistical model was:-

3.4.1 Model I for slaughter traits and meat quality characteristics

$$Yijk = \mu + Si + Tj + STij + eijk$$

Yijk- Observation on slaughter traits and meat quality characteristics

μ- General mean to all observations in the experiment

Si- Effect of i^{th} strain (1=Gogo, 2=Iringa red, 3=Mbulu, 4=, Maasai, 5=Singida white)

Tj- Effect of j^{th} sex type (1=Entire bull, 2= Castrate)

STij- Effect of interaction between i^{th} strain (1=Gogo, 2=Iringa red, 3=Mbulu, 4= Maasai, 5=Singida white) and j^{th} sex type (1=Entire bull, 2= Castrate)

eijk –is the random error effect specific to each observation.

3.4.2 Model II for response of strain and sex type to post-mortem ageing

The statistical model was:-

Yijkl = μ+ Si + Tj + Ak +STij + SAik +TAjk + eijk

Yijk- Observation on meat quality characteristics

μ- General mean to all observations in the experiment

Si- Effect of i^{th} strain (1=Gogo, 2=Iringa red, 3=Mbulu, 4= Maasai, 5=Singida white)

Tj- Effect of j^{th} sex type (1=Entire bull, 2= Castrate)

Ak –Effect of k^{th} ageing time (1=0, 2=7 and 3=14 days)

STij – Effect of interaction between i^{th} strain (1=Gogo, 2=Iringa red, 3=Mbulu, 4= Maasai, 5=Singida white) and j^{th} sex type (1=Entire bull, 2=Castrate)

SAik- Effect of interaction between i^{th} strain (Gogo, 2=Iringa red, 3=Mbulu, 4= Maasai, 5=Singida white) and k^{th} ageing time (1=0, 2=7 and 3= 14 days).

TAjk - Effect of interaction between j^{th} sex type (1=Entire bull, 2=Castrate) and k^{th} ageing time ((1=0, 2=7 and 3= 14 days).

eijk –is the random error effect specific to each observation.

CHAPTER FOUR

4.0 RESULTS

4.1 Assessment of the Current Requirements of Quality Beef for the Niche Market

4.1.1 Demographic characteristics of respondents

Table 2 describes the characteristics of the respondents based on age, education qualification, occupation and marital status, number of people in the household and children with less than 18 years in the household.

Table 2: Characteristics of consumer respondents

Category of household consumers	Household consumers percentage (n =100)
Sex	
Females	49
Males	51
Age (%)	
15-30	42
31-45	43
46-60	14
61 and above	1
Education qualification (%)	
Primary	21
Secondary	33
University/collage	45
Other (Specify)	1
Occupation (%)	
Employed	24
Business /Self employed	64
Other (Students)	10
Other (Retired)	2
Marital status (%)	
Single	43
Married	54
Divorced	3
Number of people in household (%)	

1-3	61
4-6	27
7-9	8
10 and above	4
Age less than 18 (%)	
None	63
1	8
2	18
3	7
4 and above	4

4.1.2 Knowledge of consumers and beef retailers on quality beef

The knowledge on quality beef by consumers and beef retailers is shown in Table 3 and Table 4, respectively. For both groups, hygiene and safety were mentioned to be the first quality attribute followed by freshness based on colour appearance.

Table 3: Consumers' knowledge of beef quality attributes (n=100)

Beef quality attributes	Percentage*
Hygiene and safety	36
Freshness based on colour appearance	29
Less fat	12
Palatability (tenderness, juiciness and flavour)	12
Don't know	8
Age /maturity of animal	7
Moderate fat	2
Proper handling practices	1
More fat	1
Texture	1
White fat	1

*Responses are not mutually exclusive

Table 4: Knowledge of beef retailers (supermarkets and hotels) on beef quality attributes (n=30)

Beef quality attributes	Frequency	Percentage
Hygiene and safety	11	37
Freshness based on the colour appearance	10	33
Palatability (tenderness, juiciness and flavour)	5	17
Age/Maturity of the animal	4	13
Proper slaughter procedure	2	7
Don't know	1	3
Prime cuts	1	3
Proper production practices	1	3

4.1.3 Knowledge of meat processers on beef quality attributes

Based on beef processors' knowledge on beef quality, three out of five processing plants reported the age/maturity of the animal should be considered as the first quality attribute followed by hygiene and safety.

4.1.4 Consumers' preference

Consumers' preference for the single most important beef quality attribute is shown in Table 5. Hygiene and safety was the major quality attribute preferred by the consumers. About 53% of respondents preferred this attribute which implies that the consumers wanted to eat beef which is safe and free from diseases and contaminants.

Table 5: Consumers' preferences on a single most important beef quality attribute (n= 100)

Most preferred attribute	Percentage
Hygiene and safety	53.0
Appearance	23.0
Palatability	20.0
Type of muscle/cut/part	4.0
Total	100.0

4.1.5 Retailers' preference

Supermarket retailers' preferences on quality beef are shown in Table 6. Retailers preferred fresh beef which was slightly marbled and with low subcutaneous fat. The preference was reported by 66.7%, 50% and 76.7% of the mentioned attributes, respectively. On the other hand, 50% of hotel retailers preferred beef which was of medium tenderness.

Table 6: Retailers' preferences on quality beef

Quality attributes	Frequency	Percentage
Supermarkets	**(n= 20)**	
Appearance/colour		
Freshness	20	66.7
Chilled	7	23.3
Frozen	3	10.5
Level of Marbling		
High marbling	3	10.0
Slightly marbled	15	50.0
Low marbled	12	40.0
Level of Subcutaneous fat		
High Subcutaneous fat	0	0
Medium Subcutaneous fat	7	23.3
Low Subcutaneous fat	23	76.7
Hotels	**(n=10)**	
Level of tenderness		
High tenderness	3	30.0
Medium	5	50.0
Low tenderness	2	20.0

4.1.6 Importance attached to various beef quality attributes by consumers

The level of importance attached to various beef quality attributes by consumers is shown in Table 7. Consumers felt that when purchasing or requiring beef for consumption the most important factors to consider were, place for buying (92.0%), price (92%) and colour of the meat (91%). However, they gave less consideration to the brand (75%) and the amount of subcutaneous fat (54%).

Table 7: Consumers' level of importance for various beef quality attributes (n=100)

Quality attributes	Low importance (%)	Average importance (%)	High importance (%)
Colour	5.0	4.0	91.0
Amount of intramuscular fat	39.0	22.0	39.0
Amount of subcutaneous fat	54.0	21.0	25.0
The cut (ribeye, T-bone)	44.0	19.0	37.0

Packaging	30.0	29.0	41.0
Brand	75.0	2.0	23.0
Price	4.0	4.0	92.0
Processed	46.0	18.0	36.0
Place where you can buy	1.0	7.0	92.0

4.1.7 Importance attached to various beef quality attributes by retailers

The level of importance retailers' attached to various beef quality attributes is shown in Table 8. Retailers attached high importance to certification (96.7%), price (96.7%), the type of cut (93.3%), colour of beef (86.7%) and the way of packaging (80%) in order to satisfy their customers. On the other hand, the amount of subcutaneous fat (SCF) and brand were considered to be of low importance.

Table 8: Levels of importance of various quality characteristics by retailers (n=30)

Quality attributes	Low importance (%)	Average importance (%)	High importance (%)
Colour	7.0	6.6	86.7
Amount of intramuscular fat	40.0	30.0	30.0
Amount of subcutaneous fat	66.6	26.7	6.7
The cut (ribeye, T-bone)	6.7	0.0	93.3
Packaging	10.0	10.0	80.0
Brand	56.7	20.0	23.3
Price	3.3	0	96.7
Treatment with other ingredients	50.0	10.0	40.0
Certification	3.3	0.0	96.7

4.1.8 Influence of consumers' level of education on the preference for different beef quality attributes

Level of education affected preference for different beef quality characteristics as shown in Table 9. When buying beef, slightly red colour, slightly marbled and medium subcutaneous fat beef receives high consideration from university respondents as compared to other categories. The percentages were 25%, 34% and 26%, respectively.

A similar pattern was observed in other education levels. When consuming beef 38% of university respondents preferred slightly tender, 29% slightly juicy and 42% liked intense beef flavour.

Table 9: Effect of level of education of consumers on the preference for different beef quality characteristics/attributes (n=100)

	Primary	Secondary	College/ University	Other	Total (%)
WHEN BUYING					
Colour preference					
Bright red	8	10	18	0	37
Slightly red	11	20	25	0	56
Dark red	2	4	1	0	7
Marbling preference					
None	1	10	6	0	17
Slightly	19	22	34	1	76
Intense	1	2	4	0	7
Subcutaneous fat preference					
Low	4	14	18	1	37
Medium	17	19	26	0	62
High	0	1	0	0	1
WHEN CONSUMING					
Tenderness					
Tough	2	1	0	0	3
Slightly tender	16	26	38	1	81
Extremely tender	3	7	6	0	16
Juiciness					
Dry	7	11	9	1	28
Slightly juicy	13	22	29	0	64
Juicy	1	1	6	0	8
Beef flavour					
None	0	1	1	0	2
Slightly	0	1	1	0	2
Intense	21	32	42	1	96

4.1.9 Reasons for purchasing beef in local places

Retailers provided different reasons as to why they sourced quality beef locally (Table 10). Easy availability (65.7%) followed by quality (22.9%) and value for money (11.4%) were the topmost reasons.

Table 10: Reasons given by retailers for purchasing beef from various local places (n=35)

Reasons	**Frequency**	**Percentage**
Easy availability	23	65.7
Quality	8	22.8
Value for money	4	11.4
Freshness	2	5.7
Own farm	1	2.8

4.1.10 Types of beef products processed

Most processors and retailers (94.3%) processed various beef cuts such as T-bone, beef fillet, sirloin steak, ribeye steak, rump steak, flank steak, beef brisket (Table 11), followed by minced meat (57.14%) and sausage (57.14%).

Table 11: Types of products processed by different meat processing plants, tourist hotels and supermarkets (n=35)

Beef products	**Frequency**	Percentage
Beef cuts	33	94.3
Minced meat	20	57.1
Sausage	20	57.1

4.1.11 Form of beef being processed

All five processing plants processed chilled beef, while four out of five processed fresh beef (Table 12). Moreover, chilled form of beef was reported by three processing plants to be the most preferred beef followed by fresh beef. Curing was not common in most processing plants because only one processing plant was curing (salting, marinating) beef for preservation and flavour.

Table 12: Form of beef processed, most preferred form and curing process done by processing plants (n=5)

Variable	Frequency	Percentage
Form of beef		
Chilled	5	100
Fresh	4	80
Cooked	1	20
Most preferred		
Chilled	3	60
Fresh	2	40
Other (Frozen)	1	20
Beef curing		
No	4	80
Yes	1	20

4.1.12 Customers of beef processing plants

Processing plants identified different customers to whom they supply quality beef. Three plants said their customers were hotels and ordinary people (Table 13). The restaurants occupied the second position and were supplied beef by two plants while the rest included government institutions, catering services and fast-foods. All of the processing plants declared that their customers were willing to pay for the quality beef products.

Table 13: Main customers of processing plants and their willingness to pay for quality beef (n=5)

Variable	Frequency	Percentage
Main customers		
Hotels	3	60
Individual customers/Ordinary people	3	60
Restaurants	2	40
Supermarkets	2	40
Government institutions (hospitals, colleges etc.	1	20
Provider of catering services	1	20
Fast-food	1	20
Willingness to pay		
Yes	5	100
No	0	0

4.1.13 Sources of quality beef

The sources of quality beef, reason for importing, quantity of quality beef sold per month and constraints in getting quality beef are presented in Table 14. All five beef processing plants and 30 beef retailers sourced quality beef and beef products locally. However, in addition to local sources two processing plants were also importing beef (bright choice and butcher shop). The reason for importing was assurance for better quality beef. In addition, two out of the five plants had the capacity to supply about 1 tonne (t) of quality beef per month and only one plant was currently capable of supplying 100 tonne (this was the current amount supplied by NARCO) per month. It was also observed that four out of five processing plants had difficulties in getting quality beef. The reasons were small storage facilities for processors (for instance, Ges Butcher Limited claimed to have a small cold room), irregular supply and market fluctuation as well as lack of government support on a proper production.

Table 14: Sources of quality beef, reason for importing, quantity of quality beef sold per month and constrains in getting quality beef as explained by processing plants

Variable	Frequency	Percentage
Source of quality beef by processing plant	**(n =5)**	
Local- Iringa, Tanga, NARCO (Kongwa, Ruvu, Kalambo, Missenyi and West Kilimanjaro),	5	100
Import -Botswana, South Africa, Kenya (Farmers choice)	2	40
Source of quality beef for beef retailer	**(n=35)**	
Local –from processing plants and butcher markets	35	100
Reason for importing	**(n=2)**	
Quality	2	100
Quantity of quality beef sold per month (MT)	**(n=5)**	
100	1	20
2	1	20
1.5	1	20
1	2	40

Meeting demand of supplying QB	**(n=5)**	
No	3	60
Yes	2	40
Constrains in getting quality beef	**(n=5)**	
Yes	4	80
No	1	20
Reasons of not meeting the demand	**(n=3)**	
Poor storage facilities	1	33.3
Irregular supply and market fluctuation	1	33.3
Lack of government support on proper production	1	33.3

4.2 Slaughter Traits

The overall means for heart girth, estimated slaughter weight, empty body weight, hot carcass weight and dressing percentage were 138.1 cm, 201.4 kg, 171.4 kg, 101.4 kg and 50.6%, respectively (Table 15). The strain of animal had a significant effect ($P < 0.05$) on all slaughter traits. Iringa Red (IR) was the heaviest but comparable with Maasai (MS) and Gogo (GG) strains in live weight. Mbulu (MB) strain was the lightest followed by the Singida White (SW) strain. Again, IR had the highest empty body weight (EBW) while Mbulu strain had the least EBW. IR had the highest hot carcass weight ($P < 0.05$), but statistically similar to that of GG strain while the other four strains had almost similar HCW. Moreover, the mean dressing percentage of Maasai strain was lower ($P < 0.05$) than those of the other four strains. Sex type did not affect ($P > 0.05$) any of the slaughter characteristics.

Table 15: Least squares means for heart girth, estimated slaughter weight, empty body weight, hot carcass weight and dressing percentage for different strains of Tanzania Shorthorn Zebu

		Slaughter traits				
Factor	**n**	**HG (cm)**	**ESW (kg)**	**EBW (kg)**	**HCW (kg)**	**DP (%)**
Overall means		138.1	201.4	171.4	101.4	50.6
Strains						
Gogo	10	139.5^{ab}	207.8^{ab}	166.6^{bc}	105.4^{ab}	50.7^{a}
Iringa Red	10	144.4^{a}	230.1^{a}	196.4^{a}	117.1^{a}	50.8^{a}

Mbulu	10	132.2^{c}	174.6^{b}	149.7^{c}	92.2^{b}	52.9^{a}
Maasai	10	139.1^{abc}	206.0^{ab}	185.0^{b}	96.4^{b}	47.1^{b}
Singida White	10	135.2^{bc}	188.3^{b}	159.5^{bc}	95.9^{b}	51.3^{a}
SE		2.54	11.56	10.81	5.74	0.94
P-Value		0.02	0.02	0.03	0.03	0.002
Sex						
Entire bulls	25	139.0	205.7	175.2	103.7	50.7
Castrates	25	137.1	197.0	167.7	99.1	50.5
SE		1.60	7.31	6.80	3.63	0.59
P-Value		0.40	0.40	0.44	0.38	0.80
Strains*Sex						
P-Value		0.47	0.47	0.51	0.40	0.07
CV		5.8	18.16	19.85	17.91	5.86

Means with different letter superscripts in a column are significantly different (*P* < 0.05), TSZ=Tanzania shorthorn zebu, HG = Heart girth, ESW = Estimated slaughter weight, EBW = Empty body weight, HCW=Hot carcass weight, DP=Dressing percentage, CV = Coefficient of variation.

4.2.1 Non-carcass components

Results in Table 16 show significant (*P* < 0.05) effects of the strain on external offals (feet and head) and internal offals (full and empty gastro-intestine tract and pluck). Maasai strain had the highest percentage of feet with a very low percentage of full and empty gastro-intestine tract than the rest of the strains. Moreover, except for skin and internal fat depots (*P* < 0.05), sex had a non-significant effect (*P* > 0.05) on most non-carcass components.

Table 16: Least squares means for non-carcass components as % of empty body weight for different strains of Tanzania Shorthorn Zebu

Factor	n	Feet	Head	Tail	Skin	FGIT	EGIT	IFD	SI	Pluck
Overall means Strains	**50**	2.7	7.5	0.5	8.3	22.7	5.3	0.4	6.3	5.1
Gogo	10	2.6^{b}	8.1^{a}	0.47	8.9	29.6^{a}	5.6^{b}	0.37^{ab}	6.0	6.7^{a}
Iringa Red	10	2.8^{b}	8.4^{a}	0.52	9.2	25.4^{b}	5.7^{a}	0.56^{a}	7.1	4.9^{b}
Mbulu	10	2.3^{b}	6.8^{b}	0.46	7.2	20.3^{b}	5.7^{a}	0.34^{ab}	5.6	4.2^{b}
Maasai	10	3.1^{a}	6.7^{b}	0.52	8.5	15.4^{c}	3.1^{c}	0.32^{b}	6.4	4.8^{b}
Singida White	10	2.6^{b}	7.6^{a}	0.42	7.8	23.1^{b}	6.3^{a}	0.28^{b}	6.6	4.6^{b}
SE		0.13	0.32	0.03	0.45	1.28	0.36	0.05	0.46	0.27
P-Value		0.04	0.002	0.48	0.02	<0.0001	<0.0001	0.003	0.19	<0.0001
Sex										
Entire bulls	25	2.6	7.8	0.48	8.9^{a}	22.9	5.2	0.32^{b}	6.6	4.9
Castrates	25	2.7	7.3	0.48	7.8^{b}	22.5	5.4	0.43^{a}	6.1	5.3
SE		0.08	0.20	0.02	0.29	0.71	0.23	0.03	0.29	0.17
P-Value		0.38	0.12	0.87	0.01	0.67	0.54	0.01	0.19	0.16

Strain*Sex									
P-Value	0.32	0.47	0.75	0.03	0.72	0.42	0.62	0.78	0.5
CV	15.4	14.1	21.2	17.2	17.9	21.5	41.8	22.7	17.0

Means with different letter superscripts in a column are significantly different (*P* < 0.05)
SI=Small intestine, FGIT=Full gastro-intestinal tract, EGIT=Empty gastro-intestinal tract, IFD=Internal fat depot, CV = Coefficient of variation

4.2.2 Carcass measurements

Influence of strain on carcass measurements is presented in Table 17. Strains significantly differed in length of the hind leg (*P* < 0.05), hind leg circumference (*P* < 0.01) and carcass length (*P* < 0.01). Iringa Red had the longest hind leg length (HLL - 63.3 cm) of all while Mbulu had the shortest (58.3 cm). On the other hand, Iringa Red, Gogo and Maasai had the widest hind leg circumferences (HLC) of 78.3 cm, 78.1 cm and 77.4 cm, respectively. Moreover, the carcass length (CL) of Iringa Red was longer than the rest and that of Gogo was the shortest of all. Again sex had no significant (*P* > 0.05) influence on carcass measurements.

Table 17: Least squares means for hind leg length, hind leg circumference and carcass length as influenced by strain and sex

		Carcass measurements			
Factors	**n**	**HLL**	**HLC**	**CL**	**Ribeye area (cm^2)**
Overall means	50	61.24	75.96	102.92	47.96
Strains					
Gogo	10	62.0^{a}	78.1^{ab}	97.2^{b}	46.8
Iringa Red	10	63.3^{a}	78.3^{a}	111.1^{a}	45.4
Mbulu	10	58.3^{b}	71.9^{c}	103.4^{b}	45.5
Maasai	10	61.0^{a}	77.4^{ab}	99.2^{b}	51.0
Singida White	10	61.6^{a}	74.1^{bc}	103.7^{b}	51.1
SE		1.14	1.44	2.60	1.87
P-Value		0.04	0.01	0.01	0.067
Sex					
Entire bulls	25	60.6	75.4	102.0	47.19
Castrates	25	61.9	76.6	103.8	49.47
SE		0.70	0.90	1.64	1.18
P-Value		0.19	0.39	0.45	0.18
Strain*Sex					
P-Value		0.82	0.26	0.44	0.4
CV		5.72	5.97	7.97	12.31

Means with different letter superscripts in a column are significantly different at *P* < 0.05

HLL=Hind leg length, HLC=Hind leg circumference, CL-Carcass length

4.2.3 Carcass composition

Overall means for carcass composition of TSZ strains selected were 63.52% muscle, 8.15% fat, 20.68% bone and 7.65% dissection loss (Table 18). The results showed that except for the bone ($P < 0.0001$), strain had no significant effect on the proportions of dissectible carcass tissues. Gogo, Iringa red, Maasai and Singida white had slightly higher proportions of bone with the average of 21.21% as compared to Mbulu strain which had the lowest proportion (18.57%). The proportion of muscle and fat were significantly ($P < 0.001$) influenced by sex. Entire males had about 2% units higher proportion of muscle than castrates. On the other hand, the amount of fat was about 2% units higher in castrates than in entire bulls.

Table 18: Least squares means for muscle, fat and bone tissues (%) as influenced by strain and sex

		Carcass composition (%)			
Factor	**n**	**Muscle**	**Fat**	**Bone**	**Dissection loss**
Overall means	**50**	63.52	8.15	20.68	7.65
Strains					
Gogo	10	62.92	8.11	21.72[a]	7.27[b]
Iringa Red	10	63.70	7.43	21.95[a]	6.92[b]
Mbulu	10	64.14	8.14	18.57[b]	9.16[a]
Maasai	10	63.23	8.15	20.54[a]	8.08[a]
Singida White	10	63.62	8.91	20.64[a]	6.84[b]
SE		0.53	0.54	0.47	0.51
P-Value		0.55	0.46	<0.0001	0.012
Sex					
Entire bulls	25	64.39[a]	7.32[b]	20.75	7.54
Castrates	25	62.65[b]	8.98[a]	20.61	7.65
SE		0.34	0.34	0.29	0.32
P-Value		0.0007	0.002	0.74	0.62
Strain*Sex					
P-Value		0.29	0.97	0.3	0.23
CV		2.65	21.10	7.13	20.98

Means with different letter superscripts in a column are significantly different ($P < 0.05$)

4.3 Physicochemical Properties of Beef and their Response to Post-Mortem Ageing for 7 or 14 Days

4.3.1 Chemical composition

Proximate composition of meat from the strains of TSZ is shown in Table 19. The overall means for dry matter (DM), ash, crude protein (CP) and ether extract (EE) were 27.47%, 4.56%, 22.83% and 4.77%, respectively. Strains differed significantly ($P < 0.01$) in dry matter and crude protein content. Highest DM values were obtained in Singida White whereas Mbulu and Maasai cattle had higher CP values than the rest. Sex had significant effect on the dry matter and ether extract ($P < 0.01$). Castrates had higher dry matter and fat content compared to entire bulls.

Table 19: Least squares means for dry matter, crude protein and ether extract for five strains of Tanzania Shorthorn Zebu

Factors	n	Moisture (%)	DM (%)	Ash (%)	CP (%)	EE (%)
Overall means	48	72.53	27.47	4.56	22.83	4.77
Gogo	10	73.16[a]	26.84[b]	4.48	21.58[b]	4.29
Iringa Red	10	73.95[a]	26.05[b]	4.6	22.88[b]	4.54
Mbulu	9	73.88[a]	26.12[b]	4.68	24.61[a]	4.73
Maasai	10	72.67[a]	27.33[b]	4.28	23.27[ab]	4.18
Singida White	9	69.19[b]	30.81[a]	4.76	22.02[b]	6.19
SE		0.7	0.7	0.21	0.57	0.54
P-Value		0.0002	0.0002	0.55	0.0082	0.1
Sex						
Entire bulls	25	73.83[a]	26.17[b]	4.41	22.99	4.10[b]
Castrates	23	71.30[b]	28.70[a]	4.71	22.75	5.47[a]
SE		0.46	0.46	0.21	0.37	0.35
P-Value		0.0033	0.0033	0.14	0.66	0.008
Strain*Sex						
P-Value		0.001	0.001	0.03	0.56	0.0003
CV		3.07	8.1	14.57	7.86	39.17

Means with different letter superscripts in a column are significantly different at $P < 0.05$
DM= Dry matter, CP= Crude protein, EE= Ether extract, CV= Coefficient of variation

The interaction between strain and sex was significant (P < 0.05) for moisture and dry matter, (P < 0.05) for ash content and (P < 0.05) for ether extract. Whereas sex types for other strains were similar in DM and EE, the DM content for castrated SW strain was higher than that of the entire bulls (35.13% vs. 26.5%) which also reflect the lower moisture content for castrated SW strain. Moreover, the EE for SW castrates was higher by 4.5 percent unit than that of SW entire bull.

4.3.2 Muscle pH and colour

The pH and colour change for five strains of Tanzania shorthorn zebu are presented in Table 20. The pH at 24 hours and at thaw was significantly (P < 0.001) influenced by strain. At 24 hours Singida white strain had the highest pH (5.9) while Gogo had the lowest pH of all (5.59). At thaw Maasai strain had the highest value of pH (5.76) whereas Iringa red had the least (5.51). Meat from the five strains differed (P <0.05) in relative redness (a*) and yellowness (b*). More red meat was observed in Gogo strain (15.93) than in the rest. Again the yellow colour of meat was higher in Gogo strain and lower for Iringa red. Sex affected (P < 0.01) pH at thaw but not meat colour; entire bulls showed high value as compared to castrated animals. Period of ageing affected all parameters for colour with aged meat being lighter (higher L*) and less red (lower a*) than the one not aged. The interaction between strain × ageing time existed for redness and yellowness. Redness decreased by 2.67 units in IR from day zero to 7 and slight increase was observed in day 14. The same situation appears in SW strain, the values were 17.8 (day zero), 13.08 (day 7) to 11.94 (day 14), slightly different trend of redness were observed in other strains (GG, IR, MB and MS) whereby, the values decreased to day 7 then slightly increased in day 14. Sharp increase of yellowness was observed in IR (4.99 to 11.49) as ageing progressed from day zero to day 7, in GG strain (6.23 to 11.69) and then decreased slightly to 11.49 in day 14.

Table 20: Least squares means for pH and colour variables for five strains of Tanzania Shorthorn Zebu as influenced by strain and ageing time

Variables	n	pH at Slaughter	pH at 24 hours	pH at thaw	L*	a*	b*
Overall means	48	6.34	5.74	5.64	40.02	14.60	9.10
Gogo	10	6.25	5.59^{c}	5.60^{bc}	42.01	15.93^{a}	9.80^{a}
Iringa Red	10	6.56	5.64^{bc}	5.51^{c}	39.16	14.42^{b}	8.31^{bc}
Mbulu	9	6.23	5.83^{a}	5.67^{b}	38.73	13.89^{b}	9.61^{ab}
Maasai	10	6.34	5.76^{ab}	5.76^{a}	39.32	14.46^{b}	8.32^{bc}
Singida White	9	6.33	5.90^{a}	5.67^{b}	40.86	14.27^{b}	9.57^{ac}
SE		0.08	0.05	0.03	0.90	0.50	0.42
P-Value		0.08	0.001	<0.0001	0.06	0.04	0.02
Sex							
Entire bulls	25	6.37	5.77	5.69^{a}	39.20	14.20	8.98
Castrates	23	6.31	5.72	5.60^{b}	40.83	14.99	9.27
SE		0.05	0.03	0.02	0.57	0.31	0.27
P-Value		0.42	0.33	0.003	0.05	0.07	0.46
Ageing period		-	-				
0 day		-	-	5.65	36.15^{b}	16.17^{a}	7.33^{c}
7days		-	-	5.66	42.38^{a}	13.56^{b}	10.61^{a}
14days		-	-	5.62	42.51^{a}	14.06^{b}	9.3^{b}
SE		-	-	0.03	0.7	0.38	0.34
P-Value		-	-	0.5	<0.0001	<0.0001	<0.0001
Strain*Ageing		-	-				
P-Value		-	-	0.5	0.22	0.04	0.0007
CV		4.21	2.92	3.14	12.14	17.79	25.5

Means with different letter superscripts in a column are significantly different (*P* < 0.05), L*=lightness, a*=redness, b*=yellowness, CV= Coefficient of variation
-Means pH at slaughter and at 24 hours were not taken during ageing period

4.3.3 Drip loss (DL), cooking loss (Cl) and Warner-Bratzler shear force (WBSF)

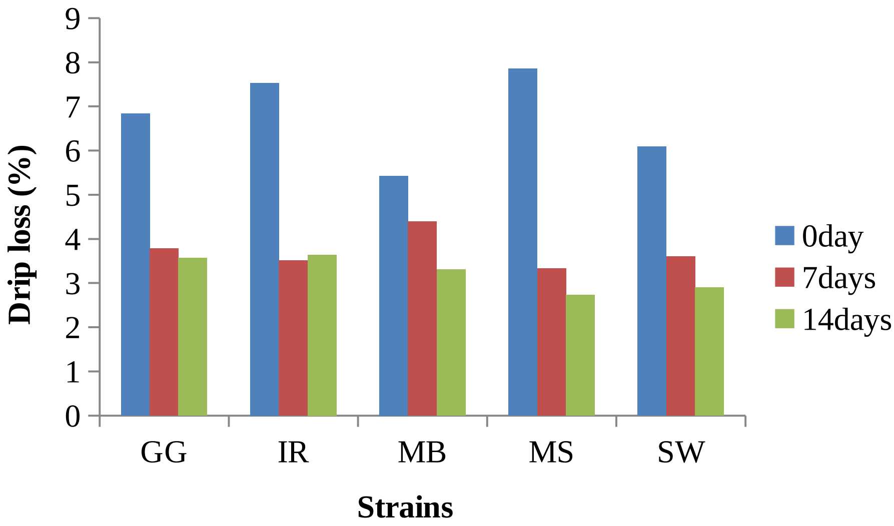
The effect of strain, sex and ageing time on drip loss, cooking loss and tenderness are shown in Table 21. Except for tenderness (WBSF), which was significantly (*P* < 0.001) affected by strain, the rest were not. Singida white and Gogo had lower shear force values among all strains while Iringa red had the highest. Sex had significant effect (*P* < 0.001) on shear force values. Castrates had lower WBSF values compared to entire bulls. On the other hand, as ageing increased, the DL, Cl and WBSF values decreased (*P* < 0.001). The interaction between strain × ageing time existed for DL and WBSF. Mbulu strain lost little water from day zero, 7 to 14 (i.e. by about one unit from 5.43 to 4.39 and then to 3.31 while other strain lost slightly higher amount of water (Fig. 2). Shear force value decreased markedly (110.1-56.1 N) in IR compared to Mbulu strain (82.4-63.9 N) as ageing time increased from day zero to day 14 (Fig. 3).

Factors	n	Drip Loss (%)	Cooking Loss (%)	WBSF (N)
Strains		4.57	21.96	62.35
Gogo	10	4.73 ± 0.25	22.05 ± 0.65	56.52 ± 1.30[d]
Iringa Red	10	4.89 ± 0.25	21.15 ± 0.65	79.95 ± 1.55[a]
Mbulu	9	4.38 ± 0.26	21.74 ± 0.69	70.50 ± 1.48[b]
Maasai	10	4.64 ± 0.25	21.81 ± 0.65	60.09 ± 1.23[c]
Singida White	9	4.19 ± 0.26	23.07 ± 0.69	55.79 ± 1.51[d]
P-Value		0.32	0.37	<0.0001
Sex				
Entire bulls	25	4.43 ± 0.16	22.48 ± 0.42	69.13 ± 0.94[a]
Castrates	23	4.7 ± 0.16	21.45 ± 0.42	60.11 ± 0.85[b]
P-Value		0.25	0.09	<0.0001
Aging				
0 day	48	6.75 ± 0.20[a]	24.32± 0.52[a]	81.08 ± 0.12[a]
7 days	48	3.72 ± 0.20[b]	20.95 ± 0.52[b]	59.16 ± 1.04[b]
14 days	48	3.23 ± 0.20[b]	20.62b ± 0.52[b]	53.16 ± 1.13[c]
P-Value		<0.0001	<0.0001	<0.0001

Strain*ageing			
P-value	0.007	0.47	<0.0001
CV	29.95	16.27	32.55

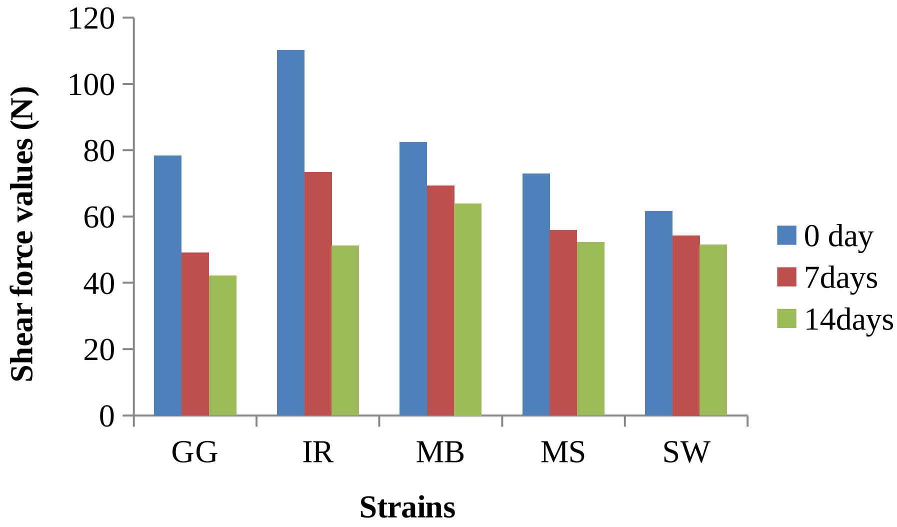
Table 21: Least squares means (± SE %) for drip loss, cooking loss and shear force values for five strain of Tanzania Shorthorn Zebu as influenced by strains, sex and ageing time (n=48)

Means with different letter superscripts in a column are significantly different at $P < 0.05$, WBSF= Warner-Bratzler shear force, CV= Coefficient of variation



GG= Gogo, IR= Iringa Red, MB = Mbulu, MS= Maasai, SW= Singida White

Figure 2: Response of different strains of Tanzania Shorthorn Zebu on drip loss after ageing



GG= Gogo, IR= Iringa Red, MB = Mbulu, MS= Maasai, SW= Singida White

Figure 3: Response of different strains of Tanzania Shorthorn Zebu on WBSF after ageing

CHAPTER FIVE

5.0 DISCUSSION

5.1 Current Requirements of Quality Beef for the Niche Market

5.1.1 Demographic characteristics of respondents

Demographic characteristics can have a major impact on the various aspects of quality beef (Felderhoff *et al.*, 2020). Males and females were equally involved in the study. The ages of sampled respondents ranged between 15-60 years with the majority (57%) being 31-60 years. This is an active working group and found to be with families made up of dependants to whom they have to take care of, thus they can provide information needed in this study.

Moreover, education plays a major role in economic growth. The distribution of respondents by education qualification (Table 2) shows that the majority of respondents were educated. They had secondary (33%) and university/college (45%) education levels. This situation gives a clear picture that respondents are likely to provide the required information which represents the requirements for the niche market.

Most of the sampled respondents were married (54%) and majority of the families (61%) had a range of 1-3 people. It is believed that household size decreases with increasing level of family economy and for this case, the requirements for quality beef is expected to increase. Similar findings concerning the effect of demography on consumers' motivation for preference of fresh beef were reported in the study by Reicks *et al.* (2011). The authors reported age (20-30), gender (50.1% males vs. 49.9% female) and household size (1-2). The education level in their study was slightly higher of which 88% had high school or college/training education compared to 78% in the current study. These authors also described the demographic characteristics which affect consumers' purchasing decision to be the geographical region, gender, age, income, education, number of adults in the household and frequency of beef consumption. However, according to their results, consumer occupation and number of children in the household did not affect consumer purchasing motives for fresh beef.

5.1.2 Knowledge of beef processors, retailers and consumers on quality beef

The concept of QB among beef processors, retailers and consumers varies from one group to another. In the present study, the majority of beef retailers (37%) and consumers (36%) considered hygiene and safety as the quality attribute to define quality beef. This was probably due to awareness on the need for hygienic beef which is healthier and uncontaminated. These findings are contrary to that of Vougat *et al.* (2016) who reported 57.92% of households in Cameroon chose meat colour to be the first criterion for defining meat quality. In the present study colour of the meat (freshness and/or appearance) was also considered but as the second quality attribute to define quality beef. Moreover, three out of five beef processing plants in the present study considered age or maturity of the animal as the best quality attribute to define quality beef followed by hygiene and safety. This shows that apart from knowing the importance of maturity in the quality of beef they also consider their customers need to hygiene and safety.

5.1.3 Beef retailers' and consumers' preferences

This study shows that consumers make beef purchasing decisions based on beef quality attributes which they consider them important. Similarly the interviewed consumers (53%) prefer hygiene and safety followed by appearance. As well as, clean meat that had been certified to be safe to eat by the meat inspector. However, Mapunda (2007) found that consumers in Tanzania prefer freshness of beef as the single most important quality indicator. Moreover, beef retailers (supermarkets) preferred fresh beef, with slight amount of IMF (marbling) and low amount of SCF. This indicates that beef retailers are more aware of the advantages of IMF on the palatability of beef. Also it might be due to increasing awareness on the health risks posed by high-fat beef. According to Webb (2014), the degree of IMF, feeding system (grain vs. pasture), ageing and breed (*Boss indicus* vs. *Bos taurus*) are the major factors affecting beef flavour. Similar results were observed by Nandonde *et al.* (2013) who found medium adipose fat to be the most preferred attribute of beef. Furthermore, the preference of beef retailers (hotels) for medium to high tender beef is in agreement with Nandonde *et al.* (2013).

5.1.4 Preference of beef quality attributes by consumers and retailers

The identified attributes of beef products were rated in order of importance from low to high. From these findings, it was observed that consumers rated price, the place where to buy and colour of beef were of high importance when purchasing beef. These two attributes (price and colour) were also important for retailers. This is contrary to the results by Owusu-Sekyere (2014) who observed leanness, certification, shopping environment and packaging as extremely important attributes of beef preferred and considered in purchasing decision. The author also mentioned tenderness, price and freshness as important attributes and that appearance/colour is of lower importance when purchasing beef products. Furthermore, consumers considered safety of the meat and the place where they want to buy meat as of high importance. On the other hand, consumers consider brand to be important this was also reflected on retailers' side who considered it to be of less importance. Generally, the implication made from the results in the current study includes the perception of consumers on colour as the indication of freshness, in line with cleanness, (hygiene and safety) of beef.

5.1.5 Influence of consumers' level of education on the preference for different beef quality attributes

The observed preferences such as red colour, marbling and medium subcutaneous fat in beef by college/university respondents could be attributed to their awareness on the effects of these parameters on healthfulness (dietary and health-related issues) compared with people of less education. Moreover, people with higher education are generally expected to have higher income and can afford to pay more for improved beef products (Udomkun *et al.*, 2018).

The overall findings show that when buying beef consumers prefer slightly red coloured beef, slightly marbled beef and with medium SCF. In addition, the consumption of beef was based on meat tenderness, juiciness and flavourness. These findings are in agreement with Robbins *et al.* (2003) who found consumers require steak which is somewhat marbled and with moderate bright red colour when purchasing beef.

5.1.6 Sources of quality beef

All five beef processing plants and beef retailers were sourcing beef and beef products locally and in addition to local sources two out of five were also importing beef. This indicates a deficit in quality beef and the presence of opportunities in improving local cattle in order to supply quality beef. The findings on sources of quality beef observed similar to the findings reported by Kamugisha *et al.* (2017) who found that most consumers, beef retailers and processors are sourcing beef locally in Dar es Salaam, Arusha and Manyara. Furthermore, by that time about 91.67% of imported quality beef were mainly from Kenya (Kamugisha *et al.*, 2017).

5.1.7 Reasons for purchasing beef in local places

The processing plants and beef retailers indicated that easy availability was the main reason that influenced their decision to source beef locally. However, the reason for importing beef was because of better quality of beef. According to Chamhuri and Batt (2013) the selection of purchasing source depends on the quality, good environment and competitive price.

5.1.8 Value addition to beef products

In this study most of the processing plants and retailers' practice beef cutting to various standard cuts, mincing and chopping. Also they make sausage and very little curing. According to Heinz and Hautzinger (2007), meat processing involves a wide range of physical and chemical treatment methods, normally combining a variety of methods. It includes cutting/chopping (size reduction), mixing, salting/curing, utilization of spices/non-meat additives, stuffing/filling into casings or other containers, fermentation and drying, heat treatment and smoking. Findings from the current study imply that there is still more opportunity of producing broad varieties of beef products.

5.1.9 Main customers of processing plants and their willingness to pay for quality beef

All customers in the present study were willing to pay for QB. This reflects the existing opportunities for marketing quality beef since the diversity of customers exists. According to Baryeh (2015) and Owusu-Sekyere (2014) consumers are willing to pay for the quality beef products based on the factors such as price, the system of production and certification that the meat is safe and of high quality. Based on production system (grain vs. pasture-fed), consumers are willing to pay a significant premium for the beef that they prefer. According to Umberger *et al.* (2002), 62% of the participants in Chicago and San Fransisco preferred corn-fed beef flavour and they were willing to pay an average of $1.61 per 0.5 kg more. On the other hand, 23% of the participants preferred the grass-fed beef flavour and were also willing to pay an average of $1.36 per 0.5 kg more for their preference. In Tanzania most of the beef is grass fed and only few undergo fattening. Generally, consumers/retailers in Tanzania pay little or/no attention to the mode of production unlike in developed countries.

5.2 Slaughter Traits of Five Strains of Tanzania Shorthorn Zebu

5.2.1 Slaughter traits

The observed values for ESW, EBW, HCW and DP % are within the range of those reported by Asimwe *et al.* (2015) and Shirima *et al.* (2016). These authors have documented the range 204-245 kg LW, 163-263 kg EBW, 91.6-123 kg HCW and 49-53% DP for TSZ strains. The variation observed could be attributed to differences in the age of the animals, strains evaluated and feeding system.

Similarly, the observed higher values in HG, ESW and EBW in IR strain than the rest of the other groups was probably due to their higher market weight as compared to other TSZ strains. Moreover, it can also be explained by the fact that inherently IR strain has slightly larger body frame than other strains thus they favourably obtain higher muscle mass resulting into significantly higher weights than others. This implies that there is a need for selection program to select and improve the animals with medium to larger body size for the production of high yield cuts. Furthermore, the slightly lower DP for TSZ strains than other local crossbred cattle might probably caused by their larger alimentary tract size and fill as well as distribution of body fat. The observed lack of significant effect of sex on all slaughter traits is in agreement with Lage *et al.* (2012) who found no effect of gender on EBW and DP among steers and heifers of crossbred zebu in Brazil.

5.2.2 Non-carcass components

The observed heavier head from Singida White, Gogo and Mbulu strains versus Maasai strain that had heavier feet than the rest was due to differences observed on the slaughter traits (ESW, HCW and EBW). For instance, animals with the larger size of the digestive tract had relatively higher body weight and are believed to have higher weights of vital organs (Sestari *et al.*, 2012). This is true for the Gogo strain which had higher ESW and thus highest % of pluck and FGIT. Similar results were observed by Shirima *et al.* (2016) who compared the differences in Ankole and TSZ breeds. The non-carcass parts of beef cattle are sources of food and industrial raw materials but their main relevance to beef producers is their influence on the killing-out proportion which determines carcass weight and hence carcass value (Keane, 2011).

The highest proportion of skin and IFD for bulls and castrates, respectively, might be attributed to differences in earliness of maturity, with castrates maturing earlier and depositing fat earlier than entire bulls (Martí, 2012). This author also suggested that pre-pubertal castration in particular has positive effect on growth efficiency. Castration hastens onset of fattening phase in animal growth pattern as it is the fact that castrated animals preferentially derived the energy into fat depots. Moreover, large proportion of fat in castrates lowers the proportion of skin in an animal’s live weight. In the present study castrated animals had higher IFD compared to bulls.

5.2.3 Carcass measurements

Iringa Red had highest values for HHL, HLC and CL whereas Mbulu had the least value for these measurements. This trend of linear measurements correspond to that of body weight indicating that Iringa Red had largest body frame whereas Mbulu had the least. The observed differences in carcass measurements is similar to results reported by Piedrafita *et al.* (2003) for seven Spanish local beef breeds (Asturiana de la- Montana (AM), Asturiana de los Valles (AV), Avilena-Negra Iberica (A-NI), Bruna dels Pirineus (BP) ,Morucha (Mo), Pirenaica (Pi), Gasconne (Ga) and Salers (Sal) where HLL ranged between 75.0- 89.8 cm and CL between 121.4-139.3 cm. The lowest values observed in the TSZ strains are probably due to their low body and carcass weight. The higher IR in HLL, HC and CL indicating its good carcass conformation and thus if improved can be able to increase its carcass yield.

The determination of the ribeye area (REA) is correlated with muscling present in the cattle carcass (Setrari *et al.,* 2012). The overall value obtained 47.93cm^2 was within the range of 38.9 to 65.0 cm^2 reported by Piedrafita *et al.* (2003) when studying carcass quality of seven Spanish local beef breeds. In the current study, there was no significant effect of sex, however, castrated animals showed slightly higher REA (49.47 vs. 47.19cm^2) than entire bulls. Lage *et al.* (2012) determined the effect of gender on carcass traits of beef cattle and reported greater values of REA than in the present study, which were 62.62 cm^2 for steers and 58.82 cm^2 for heifers. This variation is associated with carcass weight (Drake, 2004).

5.2.4 Carcass composition

Non-significant effects of strain on muscle % and fat % of 6th rib joint were observed in the present study. The observed values 63.52% for muscle and 8.15% for fat were within the range observed by Piedrafita *et al.* (2003), who found a range of 60.5-76.0% muscle and 7.6-18.7% fat of 6th rib dissection of seven Spanish beef breeds. They are also in agreement with Paulino *et al.* (2005) who found a range of 4.87 to 7.22% fat content based on the dissection of 9-11th rib joints when estimating the carcass physical composition of Zebu cattle. The authors suggested that estimating fat content using 9-11th rib section may lead to overestimation of fat in Zebu due to its high deposition of SCF than IMF.

Bulls presented a higher proportions of muscle % (64.39 vs. 62.65) while castrates presented a higher proportion of fat % (8.98 vs. 7.32). These results are in agreement with do Prado *et al.* (2015) who observed higher muscle % for bulls (67.33 vs. 62.91) and higher fat % for steers (22.52 vs. 22.00) when determining carcass composition by using 10^{th}-12^{th} rib section of bulls and steers. They are also similar to Lage *et al*. (2012) who estimated physical carcass composition of steers and heifers using 9^{th}-11^{th} rib dissection. The difference in muscle between sex groups observed in the present study can be due to the influence of androgens which allow the proliferation of satellite cells causing recruitment of new nuclei into existing muscle fibres in entire bulls than in castrated animals (Martí, 2012). The effect of sex on fat may also be related to higher fat deposition in castrated animals, following the fact that castrated animals do not synthesize steroid hormones, leading to the reduction in muscle growth and thus nutrients absorbed are diverted to fat deposition (Lage *et al.,* 2012). In addition, with regards to earliness of maturity castrates tend to mature and deposit fat earlier than entire bulls (Martí, 2012).

5.3 Physicochemical Properties and Response to Ageing

5.3.1 Chemical composition

The observed moisture content of 72.53% was within the range of 71.1-76.6 reported by other studies (Serra *et al.,* 2008; Bessong *et al.,* 2015). Prado *et al.* (2009) found 74.0% of moisture in LD muscle of Brazilian beef cattle. Variations in moisture percentages occur when there is a variation in lipid percentages in the LD muscle (Prado *et al.,* 2009). This was also confirmed in this study in which the Singida White strain with numerically higher ether extract % had the lowest moisture %. Dry matter content is inversely related to its moisture content, by which the strain with high DM % had lowest MC %. Dry matter is an indicator of the amount of nutrients, having high dry matter, SW strain, had highest numerical values for ash and fat content.

In the current study, the average CP in the LT muscle was 22.83% and is in agreement with Karakök *et al.* (2010) who reported the average CP % in *Longissimus* muscle varying between 20.5 and 23.1%. In contrast to the results of this study in which significant difference in CP was observed, Salifou *et al.* (2013) found similar DM and CP contents in LT muscle of Borgou, Lagunaire and Zebu Fulani Bulls raised on natural pasture in Benin reflecting breed difference in CP content. Furthermore, the differences observed in the present study, might probably due to pre and post-slaughter factors since the conversion of muscle to meat begins at the time of slaughter (Khasrad *et al.*, 2017).

The higher proportion of EE observed in castrates in the present study is similar to what has been reported in other studies (Rodriguez, 2012; Martí, 2012). However, the value obtained in this study (5.77%) was higher than the value (3.92%) reported by Talpur *et al.* (2012) for cattle while evaluating the nutritional quality of cattle and buffaloes. As stated earlier, the reason for this might be the reduction in muscle growth and/ or the earliness of maturity for castrated animals which lead to increase in fat deposition (Lage *et al.,* 2012; Martí, 2012).

5.3.2 Ultimate pH

These results are in agreement with observation made on Boran and TSZ (Gogo) by Mwilawa *et al.* (2010) where there was no breed difference on immediate pH measured 45 minutes post mortem (pm). However, the ultimate pH (pHu) varied significantly between strains. SW strain had highest pHu whereas the heaviest strains (IR and GG) had the lowest pHu. These results suggest that the heavier strains had higher glycogen reserve pre-slaughter than the lighter ones. According to Heinz and Hautzinger (2007) meat of animals which had depleted their glycogen reserves before slaughtering (after stressful transport/handling in holding pens) will not have a sufficient fall in pH and will be highly prone to bacterial deterioration. The pH is important for the storage life of meat, the lower the pH the less favourable conditions for the growth of harmful bacteria. The higher pHu value could be associated with poor pre-slaughter handling, where in some cases animal truck long distances from primary markets to the slaughter point. On the other hand, Gogo strain had very low pHu (5.59), which makes it better for products which lose water during fabrication and ripening (e.g. raw ham and dry fermented sausages).

The overall mean of pHu (5.74) is higher than the one reported by other authors like 5.55 (Cafferky *et al.*, 2019) and 5.56 (Serra *et al.*, 2004). The mean pHu of TSZ specifically Gogo strain, was studied by Mwilawa *et al.* (2010). The results obtained were similar to those obtained in the current study with pH values of 5.59 and 5.6 at 24 hours and at thaw, respectively. The variation observed in pHu can be due to different nutritional background or handling practices of animals before slaughter. According to Vimiso and Muchenje (2013), poor handling during transportation, lack of water and food availability at the market, poor handling during loading and unloading (slip and fall) are stressful situations which can lead to abnormally high pHu which results in DFD meat and tend to affect overall meat quality. Generally, pHu and pH (thaw) i.e. 5.74 vs. 5.64 for strains falls within the normal range (5.5-5.8) recommended for quality meat (Teke *et al.*, 2014). From quality point of view the typical taste and flavour of beef is achieved after sufficient drop in pH to optimum level. The current study showed that pH of meat was not affected by the sex of the animals. The observed values 5.69 (bulls) to 5.60 (castrates) were higher than 5.49 for bulls and 5.46 for heifers reported by Bureš and Bartoň (2012) and were lower than the observed value of 5.8 for bulls by Janiszewski *et al.* (2015). Indeed, the results from this study should not represent an increased risk of a negative impact of pHu on meat quality since the values were lower than the critical point of 5.8 (Węglarz, 2010 and Teke *et al.,* 2014). According to Bureš and Bartoň (2012), the pH values at 24 hours greater than 5.8 are considered to harm meat quality resulting in a classification of DFD also known as a dark cutting. On the other hand, the observed non-significant difference in pH recorded at thaw and that recorded after 7 and 14 days of ageing may indicate that meat was frozen after rigor had set in and glycolytic processes had ceased.

5.3.3 Meat colour

The differences in L* value among the TSZ strains could probably be associated with their genetic differences. The L*value obtained in present study (40.02, lighter) was higher than the observed values for Polish Red-and-White breed and Simmental breed (Sosin-Bzducha and Puchała, 2017) with an average of 33.75 (darker), but it was slightly lower than the value (42.13) reported by Cafferky *et al.* (2019) for Aberdeen Angus, Belgian Blue, Charolais, Hereford, Limousin, Parthenaise, Salers and Simmental breeds.

Redness (a*) and yellowness (b*) values were influenced by strains in which the lower values for red and yellow colour were found in Mbulu and Iringa Red, respectively. Less a* value of Mbulu indicates lower myoglobin concentration which partly correspond to its lower ESW. Myoglobin concentration increases with age, live weight and physiological activities (Suman and Joseph, 2013). From processing point of view, different myoglobin levels determine the curing capability of meat. As the red curing colour of meat results from a chemical reaction of myoglobin with the curing substance such as nitrite, the curing colour will be more intense where more muscle myoglobin is available (Boles and

Pegg, 2010). On the contrary, Avilés *et al.* (2015) when analysing the effect of breeds on meat quality traits in two continental beef breeds (Limousine and Retinta), found a non-significant effect of breeds on meat colour parameter. In their results much lower values of L* a* and b* were observed.

The higher L* values observed for castrates in the present study are in agreement with Sosin-Bzducha and Puchała (2017). As expected, castration improved meat quality, for instance, pHu, colour and tenderness. According to Martí, (2012) and Dejan *et al.* (2018) the colour of meat from castrated animals had higher values for lightness, redness and yellowness in comparison with meat from bulls.

The differences in colour stability L*, a* and b* of LT muscle was probably caused by differences in ageing period. However, these results corresponded with the study published by Wyrwisz *et al.* (2016) who reported significant increase in L* and b* values during ageing of semimembranosus muscle from day 1 to 21. On the other hand, decrease in redness (16.17 to 14.06) reported in this study was associated with increased mitochondrial function post-mortem leading to low oxygen partial pressure which cause poor blooming. The reason for the higher L* values observed with increased ageing time is associated with higher dripping loss (DL) reported at thaw (6.75), according to Traore *et al.* (2012), the DL which is ≥ 4 is regarded as higher DL. Water on meat surface reflects light resulting to higher lightness as ageing days increased in this study, drip loss decreased and therefore light reflection decreased with concomitant increase in redness value.

There was interaction between strain and ageing days in colour stability. GG, MB, MS and SW had higher L* (lightness) values compared to the IR in day zero, however due to thawing/ageing effect, IR lost water and become as light as other strains. The lightness of GG, IR, MS and SW strains increased by 6-10 units, while that of MB increased by 0.5 units from 0-7 days of ageing. This observation could indicate that the MB strain had high colour stability than IR after ageing. The surface redness of LT muscle of five strains decreased gradually during ageing. In particular, a rapid reduction in redness of SW strain compared to GG strain from 0 day to 14 days was observed, the possible reason for this might be variation in temperature, pH and the amount of available oxygen particularly low oxygen tensions during storage. Lightness and yellowness of all strains except for MB increased dramatically after 7 days of ageing. Generally, freezing and thawing process, as well as variation in temperature during ageing as the result of power outage might have had adverse effects on colour stability, which is likely due to myoglobin denaturation, loss of metmyoglobin reducing activity and lipid oxidation (Suman and Joseph, 2013).

5.3.4 Water holding capacity (WHC)

The similarity in DL among the TSZ strains indicated that DL was not affected by genotype. Similar results were observed by Saccà *et al.* (2018) who found no effect of genotype on drip loss. However, according to Jukna *et al.* (2017), drip loss in meat can vary depending on the cattle breed. The authors found that meat of Charolais breed had the highest drip loss, while the Simmental breed had the lowest. Cafferky *et al.* (2019) suggested that early maturing breeds (such as Angus and Herford) exhibited lower drip loss values in comparison to the larger, late-maturing continental breeds such as Belgian Blue. This is in agreement with lower moisture and higher fat content in early maturing breeds than late maturing ones (Chaiwang *et al.*, 2015). This indicates that early maturing breeds have the potential to have juicier meat and less reduction in yield associated with hanging. Despite TSZ being an early maturing breed, the value obtained in the current study was higher (average of 4.6%) than 2.5% reported by Cafferky *et al.* (2019) for other early maturing breeds. Acute stress prior to slaughter might be the reason for increased drip loss in meat of TSZ.

The significant decrease of DL with meat ageing could probably be associated with changes in muscle structural proteins which normally occurrs when ageing is taking place. These results are similar to the one observed by Farouk *et al.* (2012) when assessing the WHC of aged beef muscle (M. *semimbembranosus*). The authors explained that changes in the muscle structural proteins improve meat WHC with long term ageing due to the disruption of the channels through which water is lost as a result of muscle structural breakdown and the formation of a “sponge effect” that traps the water and prevents it from getting lost (Farouk *et al.*, 2012). Cooking loss paralleled the pattern showed by drip loss. Lack of strain effect on Cl is in agreement with Mwilawa *et al.* (2010) who also observed a non-significant difference in Cl between Boran and TSZ (Gogo). Ageing is one of the factors associated with Cl (%). As ageing days (from 0 to 14) progress, Cl values decrease (24.22 to 20.62). This was expected because as ageing progresses, the WHC of muscle increase. The findings observed are comparable to the finding (22 to 19.3) reported by Asimwe *et al.* (2016) on *M. longissimus thoracis et lumborum* (LL) of TSZ cattle subjected to 3, 6, 9 and 12 ageing days. A different trend of a slight increase in Cl (34.4 to 35.3) was observed by Strydom *et al.* (2016) for four breeds aged from 2 to 36 days. Moreover, a non-significant effect of ageing on Cl was observed by Varela *et al.* (2004) in pasture-fed steers at 24 hours and 7 days of ageing. The differences in observation among studies may be attributed to the different feeding system, ageing time and breeds.

5.3.5 Effect of age, sex and ageing on Warner-Bratzler shear force (WBSF)

Iringa Red showed the highest shear force value and Singida White had the lowest. These findings may indicate that IR strain is marketed at older age than SW. According to Chingala (2018), the meat from an animal with less than 6pi was classified as tender. Moreover, the ether extraction (EE) in the LT muscle of SW strain was numerically higher 6.19% leading to its lower shear force value. The study by Prado *et al.* (2009) considered tenderness as the function of high lipid levels (IMF of *Longissimus* muscle) whereby animals with high IMF% had lower shear force values. The observed highest shear force in Iringa Red and lowest in Singida White could probably due to their differences in age, whereas the former (IR) was the oldest group compared to SW. According to the criteria established by Simmons *et al.* (2006) beef cattle carcass muscles may be classified by their shear force (N) as extremely tough, acceptable and tender with shear force values of above 107.87 N, between 107.87 N to 78.45 N and less than 68.64, respectively. In this study, IR and MB carcasses can be classified as acceptable and SW, GG, MS carcasses classified as tender.

With regard to sex, a highly significant effect was observed in which castrated animals exhibited a WBSF value of approximately 9 N lower than entire bulls. These results are in agreement with Martí (2012). A sex effect on WBSF between entire bulls and steers was also found by Cafferky *et al*. (2019). Differences in meat toughness between sex types were expected. The observed higher tenderness in castrates can be attributed to their high IMF compared to entire bulls. On the other hand, toughness in meat from entire bulls is attributable to hypertrophy of muscle fibres as a function of androgen hormones and an increased sexual activity leading to high levels of collagen within muscles (Mach *et al.*, 2009).

Significant effects of ageing on WBSF of LT muscle of TSZ strains were previously observed by Mwilawa *et al.* (2010) and Asimwe *et al.* (2016). These authors observed that shear force values decreased with ageing days. The significant difference between ageing days observed in TSZ can be due to the influence of post-mortem proteolysis mainly due to calpain activity which causes the degradation of muscle tissue (Bhat *et al.,* 2018). The observed strain × ageing interaction indicates that GG strain attained the desirable tenderness at ageing time of 7 days during which the shear value was below 50 N. IR, MS and SW strains had moderate shear force values (greater than 50 but less than 60 N) at 14 days of ageing. Shear force value of MB strain was still high (greater than 60) by day 14. This implies that for optimum tenderness, meat form GG strain can be aged for 7 days, while, for MS and SW for 14 days and IR and MB strains for more than 14 days.

CHAPTER SIX

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The majority of meat processors, retailers and consumers are aware of what quality beef should be. However, processors and retailers are facing the constraint of getting quality beef due to inadequate beef production management. Investment in quality beef production will enhance beef traders to supply required products.

The results of this study suggested age/maturity of the animal, freshness of the beef as well as hygiene and safety of meat as the general requirement of quality beef preferred by beef stakeholders in the niche market.

Estimated slaughter weight of Tanzania Shorthorn Zebu ranged from 174.6 kg in medium body frame (Mbulu) to 230.1 kg in large body frame strain (Iringa Red) with the overall mean of 201.4 kg. The dressing percentage (hot carcass weight as a percentage of estimated slaughter weight) ranged from 47.1 to 52.9%. Dressing percentage was high in Iringa Red than the rest of the strains.

The proportion of muscle, fat and bone in the carcasses of TSZ strains ranged from 62.92 to 64.14%, 7.43 to 8.11% and 18.57 to 21.95%, respectively. Despite of similar proportions of muscle and carcass fat among strains, entire bulls had higher muscle proportions than entire castrates and castrates had higher fat proportions than entire bulls.

Overall mean of *Longissimus thoracis* (LT) muscle chemical composition was 72.53% moisture, 27.47% dry matter, 22.83% crude protein, 4.56% ash and 4.77% ether extract. Chemical composition varied among strains, dry matter was highest for Singida White strain and crude protein was highest for Mbulu and Maasai. Ether extract was highest for castrated animals than enter bulls.

General physico-chemical properties of the meat from the five strains indicated that Singida White strain had high ultimate pH (5.9) while Gogo had the lowest (5.59) and these were attributed to differences in pre-slaughter handling practices.

Beef colour characteristic towards post-mortem ageing indicate that, Mbulu strain shows high colour stability in lightness (L*), redness (a*) and yellowness (b*) while Gogo strain was more stable only in colour redness (a*). This indicates that Mbulu and Gogo strains will have better storage ability and can be very good in retail display.

For beef tenderness, Singida White strain is likely to have a good eating quality experience (palatability) compared to others probably due to sufficient amount of fat and considerably low shear force value.

Results of beef tenderness with respect to post-mortem ageing showed that Singida White and Gogo strains attained low shear force value at 7 days while Maasai strain had moderate shear force values at that ageing time. For Iringa red and Mbulu strains, some more days (beyond 14) of ageing will be required to bring tenderness to the optimum level.

Castration has positive effects on carcass composition (muscle and fat contents) and meat quality in term of ether extract, pH, colour (lightness) and tenderness. For this case, eating quality is affected positively.

6.2 Recommendations

The actual requirements of quality beef in Tanzania depend on maturity/age of the animals, appearance of beef (freshness) and hygiene and safety. To satisfy the local and external market, livestock keepers and beef stakeholders must consider the mentioned quality attributes.

Among the five strains, the strain with slightly larger body frame Iringa Red, Gogo and Maasai can be selected and used in improving beef productivity in Tanzania. For instance, the high values of slaughter traits and carcass measurements of Iringa Red strain implies that, upon improvement they can obtain high muscle mass thus high carcass weights and cuts.

The ultimate pH (pHu) of TSZ strains fall under normal range of 5.5-5.8, however, in some strains (Singida White, Mbulu and Maasai) it happened to be above 5.8. High pHu of beef can result into dark cutting which is ultimately rejected by consumers at the retail level on the basis of its colour. To optimize the quality of beef, proper pre-slaughter handling practices and feeding of animals with high quality diet to maintain high glycogen levels must be ensured to avoid stress and allow a normal pattern of muscle glycolysis post-mortem, since muscle glycogen affect pH of meat and will later affect the quality of meat.

Beef from TSZ strains can also be improved through post-mortem ageing to improve eating quality for instance, for optimum tenderness Singida White and Gogo need only 7 days of ageing period while Iringa red and Mbulu need more than 14 days ageing period.

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APPENDICES

STRUCTURED QUESTIONNAIRE FOR ASSESSING BEEF QUALITY ATTRIBUTES

Appendix 1: Beef quality attributes questionnaire for meat processing plants owners/processors

No. of enumerator……… Date…………… Name of processing plant …………….

1. What do you understand by the term quality beef? Give possible answer…………….
2. What is the single most important quality attribute that will satisfy the demand of your customers?

(a) Palatability (tenderness, juiciness and flavour) (b) Hygiene and safety (c) Appearance

3. What is the source of quality beef? a) Imports (country of origin and company, if known,…………. b) Local (the place/company if known ,……………..)
4. If imported, what is the reason for not sourcing it locally...
5. What is the reason for purchasing beef from local places

(a) Value for money (b) Easy availability (c) other (specify)

6. Are there any constraints in getting quality beef (Please explain)…..
7. What form of beef you often process? (a)Fresh (b) Chilled (c) Cooked
8. Which form of beef is most preferred…
9. What type of beef product do you process? (a) Beef cuts (b) Sausage (c) Minced (d) Other (specify)……………………………………………..
10. Which beef product is most preferred? ……………………
11. Do you cure beef products? Yes or No…………
12. What kind of curing method do you practise (E.g. Dry curing, wet curing, Injection, Smoking)……………………………………………….
13. Which one is most preferred by consumer? ……………….
14. What is the reason for curing (Colour, preservation, flavour etc……………….
15. Who are your customers? (E.g. supermarket, hotels, restaurants)…………….
16. Are your customers willing to pay more for the quality beef? Yes or No……
17. Can you predict the quantity of quality beef sold per month? ………..
18. Is it possible to meet the demand/quantity of quality beef required per month? Yes or No………

If No what could be the reason for the situation (Give possible answer)…………………

19. When purchasing beef for processing, what are the levels of the following characteristics you prefer that would optimize the satisfaction of your customers? Tick on appropriate choice in space provided.

(a) Marbling –None……., Slightly…... Intense…………

(b) Colour – Bright red………, slightly red………., Dark red………

Subcutaneous fat – Low……, Medium……, High…………

Thank you for your cooperation

Appendix 2: Beef quality attributes questionnaire for retailers (Butchers, supermarkets and hotels)

No. of enumerator……………… Date……………… Name of retailer ………………

1. What do you perceive by the term quality beef? Give any possible answer you have…………………………………………………………

2. What is the most preferred quality attribute among the following? Choose the answer and place a letter on a box provided.

Tenderness

(a) High tenderness, (b) Medium tenderness (c) Low tenderness ☐

Appearance

(a) Freshness (b) Chilled (c) Cooked (d) Frozen ☐

Intramuscular fat (IMF)

(a) High marbled (b) slightly marbled (c) Low marbled ☐

Subcutaneous fat (SCF)

(a) High SCF (b) Medium SCF (c) Low SCF ☐

3. What is the source of the quality beef? a) Imports (country of origin and company, if known,…………. b) Local (the place/company if known ,……………..)
4. If imported, what is the reason for not sourcing it locally? ……..
5. Why do you purchase from such local places

(a) Value for money (b) Hygiene/safety (c) Availability ☐

6. Are there any constrains in getting the desired quality beef? (Please explain)………..
7. What type of beef products do you sell (e.g. cuts, sausage, minced) ………………
8. Among the following, which form is most preferred?

(a) Marinated (b) Smoked (c) Salted (d) other (specify) ☐

Characteristics	Points (1 to 10)									
Colour	1	2	3	4	5	6	7	8	9	10
Intramuscular fat	1	2	3	4	5	6	7	8	9	10
Amount of subcutaneous fat	1	2	3	4	5	6	7	8	9	10
The cut (ribeye, T-bone, sirloin)	1	2	3	4	5	6	7	8	9	10
Nutritional composition	1	2	3	4	5	6	7	8	9	10
Packaging	1	2	3	4	5	6	7	8	9	10
Brand	1	2	3	4	5	6	7	8	9	10
Price	1	2	3	4	5	6	7	8	9	10
Treatment with other ingredients (salt, ginger etc.)	1	2	3	4	5	6	7	8	9	10
Certification	1	2	3	4	5	6	7	8	9	10

9. How important are the following attributes in satisfying customers' demand. Assign 1 (low importance) to 10 (high importance) points to each factor to indicate its importance. Circle the number that best represent your opinion

Thank you for your cooperation!

Appendix 3: Beef quality attributes questionnaire for consumers

No of enumerator……………… Date ……………….

Name of respondent ……………………………. District ……………

1. What do you perceive by the term quality beef? Give any possible answer you have

   …………………………………….

2. What is the single most important attribute you prefer

   (a) Palatability (tenderness, juiciness and flavour) ☐

   (b) Appearance (freshness)

   (c) Hygiene and safety

What are the levels of the following characteristics that would optimize your satisfaction with the product? Tick on appropriate choice in space provided.

Characteristics	**Points (1 to 10)**									
Colour	1	2	3	4	5	6	7	8	9	10
Visible fat	1	2	3	4	5	6	7	8	9	10
Amount of subcutaneous fat	1	2	3	4	5	6	7	8	9	10
The cut (ribeye, T-bone, sirloin)	1	2	3	4	5	6	7	8	9	10
Nutritional composition	1	2	3	4	5	6	7	8	9	10
Packaging	1	2	3	4	5	6	7	8	9	10
Brand	1	2	3	4	5	6	7	8	9	10
Price	1	2	3	4	5	6	7	8	9	10
Processed	1	2	3	4	5	6	7	8	9	10
Place where you can buy (butcher, supermarket)	1	2	3	4	5	6	7	8	9	10

(c) Marbling –None……., Slightly…... Intense………..

(d) Colour – Bright red…….., slightly red………., Dark red………

(e) Subcutaneous fat – Low……, Medium……, High…………

3. How important are the following beef quality attributes you prefer from the product? Assign 1 (low importance) to 10 (high importance) points to each factor to indicate its importance. Circle the number that best represent your opinion.

4. When consuming beef, what are the levels of various characteristics which would optimize your satisfaction with the product? Tick on appropriate space provided.

   (a) Tenderness- Tough……, slightly tender…, extremely tender………

   (b) Juiciness – Dry…………, slightly juicy………..Juicy………….

   (c) Beef flavour – None…... Slightly………., Intense…………

Lastly we would be happy if you will answer some additional questions.

We need some information about consumers and would appreciate it if you could answer the following questions. Please tick to the corresponding answer.

1. **Gender** Female……….. Male…………..
2. **Age** 15-30……., 31-45…... 46- 60………..
3. **In which group do you fit?** Primary education…, Secondary ……., University …, Other (specify)
4. **Occupation** Employed…, Business/self-employed….. other (specify)………
5. **Marital status** Single …., Married………, Divorced………, Widowed…….
6. How many people are there in your household (including yourself)

   Total (1, 2, 3, 4, 5, 6, 7 or more than 7) ……….

   Children who are less than 18 (0, 1, 2, 3, 4 or more than 4) ……….
7. How often do you consume beef/ beef product? State the frequency

   ……….……..……………………………………………………..

Thank you for your cooperation!

Appendix 4: ANOVA tables for various analysed dependent variables

Dependent variable: Heart girth (cm)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	858.6800000	214.6700000	3.33	0.0192	*
SEX	1	46.0800000	46.0800000	0.71	0.4032	
STRAIN*SEX	4	234.5200000	58.6300000	0.91	0.4685	
Error	40	2582.400000	64.560000			
Corrected Total	49	3721.680000				

R-Square	Coeff Var	Root MSE	HG Mean
0.306120	5.819035	8.034924	138.0800

Dependent variable: Estimated slaughter weight (kg)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	17776.82270	4444.20568	3.33	0.0192	*
SEXTYP	1	953.97120	953.97120	0.71	0.4032	
STRAIN*SEXTYP	4	4855.15030	1213.78758	0.91	0.4685	
Error	40	53462.13600	1336.55340			
Corrected Total	49	77048.08020				

R-Square	Coeff Var	Root MSE	ESW Mean
0.306120	18.15563	36.55890	201.3640

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	14456.39850	3614.09963	3.12	0.0251	*
SEXTYP	1	710.64500	710.64500	0.61	0.4379	
STRAIN*SEXTYP	4	3913.23050	978.30763	0.85	0.5050	
Error	40	46305.12600	1157.62815			
Corrected Total	49	65385.40000				

Dependent variable: Empty body weight (kg)

R-Square	Coeff Var	Root MSE	EBW Mean
0.291812	19.84713	34.02393	171.4300

Dependent variable: Hot carcass weight (kg)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	4026.365200	1006.591300	3.05	0.0276	*
SEX	1	264.500000	264.500000	0.80	0.3759	
STRAIN*SEX	4	1483.314000	370.828500	1.12	0.3588	
Error	40	13196.30000	329.90750			
Corrected Total	49	18970.47920				

R-Square	Coeff Var	Root MSE	HCW Mean
0.304377	17.91329	18.16336	101.3960

Dependent variable: Dressing percentage (kg)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	187.0523480	46.7630870	5.32	0.0016	**
SEXTYP	1	0.5940500	0.5940500	0.07	0.7962	
STRAIN*SEXTYP	4	83.7147800	20.9286950	2.38	0.0676	
Error	40	351.4547200	8.7863680			
Corrected Total	49	622.8158980				

R-Square	Coeff Var	Root MSE	DP Mean
0.435700	5.862676	2.964181	50.56020

Dependent variable: Full gastro-intestine tract (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	1144.193572	286.048393	17.34	<.0001	***
SEXTYP	1	3.125000	3.125000	0.19	0.6657	
STRAIN*SEXTYP	4	34.010540	8.502635	0.52	0.7248	
Error	40	659.845880	16.496147			
Corrected Total	49	1841.174992				

R-Square	Coeff Var	Root MSE	FGIT Mean
0.641617	17.86834	4.061545	22.73040

Dependent variable: Empty gastro intestine tract (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	60.92509200	15.23127300	11.86	<.0001	***
SEXTYP	1	0.48807200	0.48807200	0.38	0.5411	
STRAIN*SEXTYP	4	5.14426800	1.28606700	1.00	0.4183	
Error	40	51.3840000	1.2846000			
Corrected Total	49	117.9414320				

R-Square	Coeff Var	Root MSE	EGIT Mean
0.564326	21.52465	1.133402	5.265600

Dependent variable: Small intestine (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
STRAIN	4	13.50362800	3.37590700	1.63	0.1862
SEXTYP	1	3.66663200	3.66663200	1.77	0.1912
STRAIN*SEXTYP	4	3.94738800	0.98684700	0.48	0.7532
Error	40	82.9633200	2.0740830		
Corrected Total	49	104.0809680			

R-Square	Coeff Var	Root MSE	SMALL Mean
0.202896	22.68266	1.440168	6.349200

Dependent variable: Pluck (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	37.87985200	9.46996300	12.71	<.0001	***
SEXTYP	1	1.49645000	1.49645000	2.01	0.1641	
STRAIN*SEXTYP	4	2.18486000	0.54621500	0.73	0.5747	
Error	40	29.79360000	0.74484000			
Corrected Total	49	71.35476200				

R-Square	Coeff Var	Root MSE	PLUCK Mean
0.582458	17.01378	0.863041	5.072600

Dependent variable: Internal fat depot (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	0.47094800	0.11773700	4.75	0.0031	**
SEXTYP	1	0.16820000	0.16820000	6.78	0.0128	*
STRAIN*SEXTYP	4	0.05986000	0.01496500	0.60	0.6623	
Error	40	0.99168000	0.02479200			
Corrected Total	49	1.69068800				

R-Square	Coeff Var	Root MSE	IFD Mean
0.413446	41.78736	0.157455	0.376800

Dependent variable: Feet (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	3.10794800	0.77698700	4.53	0.0041	**
SEXTYP	1	0.13728800	0.13728800	0.80	0.3761	
STRAIN*SEXTYP	4	0.83097200	0.20774300	1.21	0.3207	
Error	40	6.85416000	0.17135400			
Corrected Total	49	10.93036800				

R-Square	Coeff Var	Root MSE	FEET Mean
0.372925	15.44126	0.413949	2.680800

Dependent variable: Head (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	21.89764000	5.47441000	5.32	0.0016	**
SEXTYP	1	2.66343200	2.66343200	2.59	0.1154	
STRAIN*SEXTYP	4	3.70100800	0.92525200	0.90	0.4733	
Error	40	41.14012000	1.02850300			
Corrected Total	49	69.40220000				

R-Square	Coeff Var	Root MSE	HEAD Mean
0.407222	13.47172	1.014151	7.528000

Dependent variable: Tail (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F

STRAIN	4	0.07748800	0.01937200	1.87	0.1339	
SEXTYP	1	0.00028800	0.00028800	0.03	0.8683	
STRAIN*SEXTYP	4	0.02087200	0.00521800	0.50	0.7324	
Error	40	0.41352000	0.01033800			
Corrected Total	49	0.51216800				

R-Square	Coeff Var	Root MSE	TAIL Mean
0.192609	21.21785	0.101676	0.479200

Dependent variable: Skin (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	27.04584800	6.76146200	3.31	0.0197	*
SEXTYP	1	14.48296200	14.48296200	7.09	0.0111	*
STRAIN*SEXTYP	4	23.49772800	5.87443200	2.87	0.0349	*
Error	40	81.7486400	2.0437160			
Corrected Total	49	146.7751780				

R-Square	Coeff Var	Root MSE	SKIN Mean
0.443035	17.19534	1.429586	8.313800

Dependent variable: Hind leg length (cm)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	136.5200000	34.1300000	2.63	0.0486	*
SEX	1	23.1200000	23.1200000	1.78	0.1897	
STRAIN*SEX	4	19.8800000	4.9700000	0.38	0.8197	
Error	40	519.6000000	12.9900000			
Corrected Total	49	699.1200000				

R-Square	Coeff Var	Root MSE	HLL Mean
0.256780	5.885311	3.604164	61.24000

Dependent variable: Hind leg circumference (cm)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	320.7200000	80.1800000	4.02	0.0079	**
SEX	1	15.6800000	15.6800000	0.79	0.3807	
STRAIN*SEX	4	109.1200000	27.2800000	1.37	0.2627	
Error	40	798.400000	19.960000			
Corrected Total	49	1243.920000				

R-Square	Coeff Var	Root MSE	HLC Mean
0.358158	5.881598	4.467662	75.96000

Dependent variable: Carcass length (cm)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	1143.080000	285.770000	4.23	0.0060	**
SEX	1	38.720000	38.720000	0.57	0.4533	
STRAIN*SEX	4	257.480000	64.370000	0.95	0.4435	
Error	40	2700.400000	67.510000			
Corrected Total	49	4139.680000				

R-Square	Coeff Var	Root MSE	CL Mean
0.347679	7.983334	8.216447	102.9200

Dependent variable: Ribeye area (cm²)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
STRAIN	4	330.0892680	82.5223170	2.34	0.0713
SEX	1	64.9344080	64.9344080	1.84	0.1822
STRAIN*SEX	4	123.4783720	30.8695930	0.88	0.4868
Error	40	1409.372720	35.234318		
Corrected Total	49	1927.874768			

R-Square	Coeff Var	Root MSE	RIBEYE Mean
0.268950	12.38421	5.935850	47.93080

Dependent variable: Muscle (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	8.69214800	2.17303700	0.77	0.5514	
SEX	1	37.81020800	37.81020800	13.39	0.0007	***
STRAIN*SEX	4	14.70069200	3.67517300	1.30	0.2859	
Error	40	112.9495200	2.8237380			
Corrected Total	49	174.1525680				

R-Square	Coeff Var	Root MSE	MUSCLE Mean
0.351434	2.645496	1.680398	63.51920

Dependent variable: Fat (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	10.87567200	2.71891800	0.92	0.4618	
SEX	1	34.26264200	34.26264200	11.59	0.0015	**
STRAIN*SEX	4	1.62492800	0.40623200	0.14	0.9674	
Error	40	118.2111200	2.9552780			
Corrected Total	49	164.9743620				

R-Square	Coeff Var	Root MSE	FAT Mean
0.283458	21.09989	1.719092	8.147400

Dependent variable: Bone (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	71.68936800	17.92234200	8.24	<.0001	***
SEX	1	0.24640200	0.24640200	0.11	0.7382	
STRAIN*SEX	4	9.98060800	2.49515200	1.15	0.3486	
Error	40	87.0211600	2.1755290			
Corrected Total	49	168.9375380				

R-Square	Coeff Var	Root MSE	BONE Mean
0.484892	7.131717	1.474967	20.68180

Dependent variable: Dissection loss (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	37.83597200	9.45899300	3.67	0.0123	*
SEX	1	0.63393800	0.63393800	0.25	0.6227	
STRAIN*SEX	4	15.20849200	3.80212300	1.47	0.2279	
Error	40	103.1105600	2.5777640			
Corrected Total	49	156.7889620				

R-Square	Coeff Var	Root MSE	DISSLOSS Mean
0.342361	20.98034	1.605542	7.652600

Dependent variable: Dry Matter (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	139.5189203	34.8797301	7.04	0.0002	***
SEX	1	75.9905030	75.9905030	15.34	0.0004	***
STRAIN*SEX	4	114.2915603	28.5728901	5.77	0.0010	**
Error	38	188.2249150	4.9532872			
Corrected Total	47	546.1007917				

R-Square	Coeff Var	Root MSE	DM Mean
0.655329	8.102537	2.225598	27.46792

Dependent variable: Moisture (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	139.5189203	34.8797301	7.04	0.0002	***
SEX	1	75.9905030	75.9905030	15.34	0.0004	***
STRAIN*SEX	4	114.2915603	28.5728901	5.77	0.0010	**
Error	38	188.2249150	4.9532872			
Corrected Total	47	546.1007917				

R-Square	Coeff Var	Root MSE	MOISTURE Mean
0.655329	3.068433	2.225598	72.53208

Dependent variable: Ash (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	1.36116407	0.34029102	0.77	0.5520	
SEX	1	1.05648107	1.05648107	2.39	0.1305	
STRAIN*SEX	4	5.23839022	1.30959755	2.96	0.0318	*
Error	38	16.80981500	0.44236355			
Corrected Total	47	24.54889792				

R-Square	Coeff Var	Root MSE	ASH Mean
0.315252	14.57430	0.665104	4.563542

Dependent variable: Crude protein (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	51.66417244	12.91604311	4.01	0.0082	**

SEX	1	0.64796298	0.64796298	0.20	0.6563	
STRAIN*SEX	4	9.67769906	2.41942476	0.75	0.5635	
Error	38	122.3944950	3.2209078			
Corrected Total	47	185.9343979				

R-Square	Coeff Var	Root MSE	CP Mean
0.341733	7.861601	1.794689	22.82854

Dependent variable: Ether extract (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	24.17097421	6.04274355	2.11	0.0988	
SEX	1	22.40933333	22.40933333	7.82	0.0081	**
STRAIN*SEX	4	55.84522196	13.96130549	4.87	0.0029	**
Error	38	108.9238000	2.8664158			
Corrected Total	47	215.2891979				

R-Square	Coeff Var	Root MSE	EE Mean
0.494058	35.50455	1.693049	4.768542

Dependent variable: pH at slaughter (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
STRAIN	4	0.68354000	0.17088500	2.25	0.0808
SEX	1	0.05056200	0.05056200	0.67	0.4195
STRAIN*SEX	4	0.10262800	0.02565700	0.34	0.8509
Error	40	3.03912000	0.07597800		
Corrected Total	49	3.87585000			

R-Square	Coeff Var	Root MSE	PHS Mean
0.215883	4.345595	0.275641	6.343000

Dependent variable: pH at 24hours (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
STRAIN	4	0.65355200	0.16338800	5.46	0.0013	**
SEX	1	0.02880000	0.02880000	0.96	0.3325	
STRAIN*SEX	4	0.03684000	0.00921000	0.31	0.8711	
Error	40	1.19692000	0.02992300			
Corrected Total	49	1.91611200				

R-Square	Coeff Var	Root MSE	PHPS Mean
0.375339	3.012376	0.172983	5.742400

Dependent variable: pH at thaw (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	0.04383628	0.02191814	0.70	0.5000	
STRAIN	4	1.06132515	0.26533129	8.44	<.0001	***
SEX	1	0.27935422	0.27935422	8.88	0.0034	**
AGEING*STRAIN	8	0.23264657	0.02908082	0.92	0.4986	
Error	128	4.02604911	0.03145351			
Corrected Total	143	5.64139722				

R-Square	Coeff Var	Root MSE	PH Mean
0.245099	3.137466	0.176957	5.640139

Dependent variable: Lightness (*L)**

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	1103.555335	551.777668	23.45	<.0001	***
STRAIN	4	219.702146	54.925537	2.33	0.0590	
SEX	1	95.918680	95.918680	4.08	0.0456	*
AGEING*STRAIN	8	256.694737	32.086842	1.36	0.2185	
Error	128	3011.357889	23.526234			
Corrected Total	143	4717.083949				

R-Square	Coeff Var	Root MSE	L Mean
0.307188	12.24780	4.902020	40.02368

Dependent variable: Redness (a*)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	183.8372933	91.9186466	13.60	<.0001	***
STRAIN	4	71.3897338	17.8474335	2.64	0.0368	*
SEX	1	22.2189845	22.2189845	3.29	0.0722	
AGEING*STRAIN	8	116.5195504	14.5649438	2.15	0.0352	*
Error	128	865.191976	6.759312			
Corrected Total	143	1254.698916				

R-Square	Coeff Var	Root MSE	A Mean
0.217572	18.38235	2.686721	14.61576

Dependent variable: Yellowness (b*)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	263.7193266	131.8596633	24.47	<.0001	***
STRAIN	4	64.9055722	16.2263931	3.01	0.0206	*
SEX	1	2.9714880	2.9714880	0.55	0.4591	
AGEING*STRAIN	8	158.4255834	19.8031979	3.68	0.0007	***
Error	128	689.646112	5.387860			
Corrected Total	143	1196.925673				

R-Square	Coeff Var	Root MSE	B Mean
0.291458	27.42923	2.497163	9.104021

Dependent variable: Drip loss (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	347.9515631	173.9757816	92.48	<.0001	***
STRAIN	4	8.9752518	2.2438129	1.19	0.3172	
SEX	1	2.5416338	2.5416338	1.35	0.2472	
AGEING*STRAIN	8	41.6913406	5.2114176	2.77	0.0074	**
Error	128	240.7847840	1.8811311			
Corrected Total	143	651.6827000				

R-Square	Coeff Var	Root MSE	DL Mean

0.566543	31.47277	1.441191	4.579167

Dependent variable: Cooking loss (%)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	402.5321972	201.2660986	15.79	<.0001	***
STRAIN	4	54.8117910	13.7029478	1.08	0.3715	
SEX	1	37.8349761	37.8349761	2.97	0.0873	
AGEING*STRAIN	8	99.4695004	12.4336875	0.98	0.4580	
Error	128	1631.058796	12.742647			
Corrected Total	143	2230.951616				

R-Square	Coeff Var	Root MSE	CL Mean
0.210156	16.10082	3.546731	22.02826

Dependent variable: Warner- Bratzler shear Force (N)

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
AGEING	2	142330.2416	71165.1208	172.78	<.001	***
STRAIN	4	80009.0464	20002.2616	48.56	<.001	***
SEX	1	20993.7536	20993.7536	50.97	<.001	***
AGEING*STRAIN	8	39913.7521	4989.2190	12.11	<.001	***
Error	1081	445239.7649	411.8777			
Corrected Total	1096	735749.5046				

R-Square	Coeff Var	Root MSE	WBSF Mean
0.394849	32.54736	20.29477	62.35457