PERFORMANCE AND MEAT QUALITY OF TANZANIA SHORTHORN ZEBU CATTLE UNDER FEEDLOT BASED ON LOCAL FEED RESOURCES IN KONGWA DISTRICT, TANZANIA

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ABSTRACT

An on-station feeding experiment was conducted to develop cheap and good quality fattening diets based on locally available feed ingredients: to assess the growth performance, feed utilization efficiency, carcass characteristics, meat quality, and the profitability of cattle finish feeding using diets based on locally available feed resources. A total of 50 Tanzania Shorthorn Zebu bulls belonging to the Gogo stain were used. The bulls had 3 - 4 years of age and average initial weight of 130 kg. The bulls were allotted to five dietary treatments (T_1 – T_5) in a completely randomized design. T_1 to T_4 comprised of concentrate diets based on ingredients from local feed resources whereas T_5 was a control treatment with normal grazing without supplementation. The ingredients of fattening diets were maize bran (MB), rice polishing (RP), molasses (MO), and sunflower seed cake (SSC). The composition of the diets were as follows; T_1 (78% MB, 20% SSC, 1.5% Mineral premix, 0.5% Salt), T_2 (75% MB, 3% RP, 20% SSC, 1.5% Mineral premix, 0.5% Salt), T_3 (53% MB, 20% SSC, 25% MO, 1.5% Mineral premix, 0.5% Salt), T_4 (50% MB, 3% RP, 20% SSC, 25% MO, 1.5% Mineral premix, 0.5% Salt). The results shows that, the bulls subjected to concentrate diets had significantly higher total weight gain ($P < 0.0001$) than the bulls on the control group. Bulls on T_3 had the highest average daily weight gain (1.28 kg/d), followed by those on T_1 (1.07 kg/d). The bulls subjected to concentrate diets had higher ($P < 0.05$) hot carcass weight, empty body weight, dressing percentage and proportion of internal organs than the bulls on control group. Cooking loss (CL) and meat toughness as measured by Warner-Bratzler shear force (WBSF) were higher ($P < 0.05$) in the bulls on the control group than in bulls on concentrate diets. Bulls on the control group had more than 10% unit higher cooking loss than the bulls on concentrate diets. Among the bulls on concentrate diets, T_1 (67.11 Ncm^{-2}) and T_3 (66.64 Ncm^{-2})had slightly lower meat toughness than T_2 and T_4. The cooking loss (CL) values for meat aged for 1 day was

8% unit higher (P = 0.0001) than the average CL values (26.81 %) of meat aged for 5 and 10 days. On the other hand, the WBSF values (76.13 Ncm^{-2}) for the meat aged for 1 day was more than 40 Ncm^{-2} higher than that of the meat aged for 5 and 10 days. Increasing postmortem storage time up to 10 days decreased shear force of meat from bulls on concentrate and the control group from 70.6 Ncm^{-2} to 23.57 Ncm^{-2} and 98.1 Ncm^{-2} to 23.57 Ncm^{-2}, respectively. The relative lightness (L^*) was about 8 units lower (P = 0.0014) in *LD* muscle from bulls on control group than in bulls on concentrate diets. Bulls on concentrate diets had on average lower CP value and more than twice as higher values in %EE than the bulls on control group. The bulls fed T_4 had the highest (P = 0.05) cost per unit weight gain (3,243.7 TZS) and lowest Gross Margin (162,531 TZS) whereas those on T_1 had the lowest cost per unit weight gain (2,374.4 TZS) and T_3 had the highest Gross Margin (235,471 TZS). Treatment diet T_1 was found to be the best than the other diets. It is concluded that, knowledge on the nutritive value of locally available feed resources allows for formulation of a balanced diet for fattening indigenous beef cattle to produce good quality and tender beef at affordable prices.

DECLARATION

I, **SANING'O GABRIEL KIMIREI,** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution

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Saning'o Gabriel Kimirei Date

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Prof. S.W. Chenyambuga Date

(Supervisor)

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Dr. Mushi, D. E. Date

(Supervisor)

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DEDICATION

This work is dedicated to my family, my son Olaashilaa, my daughter Supat and my beautiful wife Naomi who tirelessly takes care of our family during my absence and for her valuable encouragement and patience throughout my study.

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ADG	Average Daily Gain
ADL	Acid detergent lignin
AFI	Average Feed Intakes
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
APBP	Agro-Processing By-Products
CF	Crude Fat
Cl	Cooking Loss
CL	Carcass Length
CP	Crude Protein
DM	Dry Matter
DM/ha	Dry Matter per hectare
DMI	Dry matter intake
DP	Dressing Percentage
EBW	Empty Body Weight
EE	Ether Extract
EE	Ether extract
ESW	Estimated Slaughter Weight
FCR	Feed Conversion Ratio
FLW	Final Live Weight
GDP	Gross Domestic Product

GDP	Gros Domestic Product
GIT	Gastro-Intestinal Tract
GLM	General Liner Model
GM	Gross Margin
ha	hectare
HCW	Hot Carcass Weight
HLC	Hind Leg Circumference
HLL	Hind Leg Length
IMF	Intramuscular Fat
Lab	L* lightness, a* Redness, b* Yellowness
LD	*Longissimus dorsi*
LSD	Least Significant Difference
MB	Maize Brane
MB/MO	Maize bran/Molasses
MB/RP/MO	Maize bran/Rice Polishing/ Molasses
ME	Metabolizable Energy
MJ	Mega Joules
NARCO	National Ranching Company
NCC	Non Carcass Components
NDF	Neutral detergent fiber
OM	Organic matter
pH	Hydrogen Ion Concentration
pHu	Ultimate Hydrogen Ion Concentration
pm	Post-mortem

SCC	Sunflower Seed Cake
SD	Standard Deviation
SEM	Standard Error of the Mean
SUA	Sokoine University of Agriculture
T_1 - T_5	Treatment 1 - 5
TALIRI	Tanzania Livestock Research Institute
TLU	Tropical Livestock Unit
TR	Total Revenue
TSZ	Tanzania Shorthorn Zebu
TVC	Total Variable Costs
W	Weight
WBSF	Warner-Bratzler Shear Force
WHC	Water Holding Capacity

CHAPTER ONE

1.0 INTRODUCTION

1.1 Back Ground Information

Tanzania has 33.9 million cattle, of which 96.2% are indigenous cattle (MLF, 2020). The indigenous cattle in Tanzania comprise of Tanzania Shorthorn Zebu (TSHZ), Boran, and Ankole breeds (Msanga *et al.,* 2002). These indigenous cattle produce about 97% of beef consumed in the country. Beef cattle keeping in Tanzania is one of the major economic activities. It contributes over 50% of the household income of livestock farmers and 5.9% of the national GDP (Kibona *et al* 2021). The beef sub-sector is dominated by traditional ways of keeping livestock. Beef production from the traditional sector is low and inefficient. Tanzania has a potential for growth of beef cattle production since the country has satisfactory condition and enormous land, which can support growth of the sub-sector (Kibona *et al.,* 2021). In recent years, the government has put efforts to commercialize the sub-sector so that it can contribute effectively to household food security and income as well as meeting the increased demand from domestic and international meat markets (MLDF, 2011).

Indigenous cattle kept under traditional sector have low productivity characterized by low herd growth rate (0.54%) and low calving rate (40 – 50 %) (Mwilawa, 2012). In addition, they have low coefficients for traits of economic importance that are characterized by advanced age at weaning (180 – 210 days), low mature weight (200 – 300) and off take rate (8 – 10 %) and low carcass weight (100 – 175 kg) (Mwilawa, 2012). However, the indigenous cattle is the most predominantly available animal resource for beef production in Tanzania as they are hardy and highly adapted to the local environment (Nandonde *et al.*, 2017).

In recent years the opportunity for beef markets has increased in local, regional and international markets and several neighbouring countries have expanded their share for beef market. Increased demand for quality meat in niche markets requires development of appropriate methods for producing quality meat more efficiently (Mushi, 2020). Improved beef production can be achieved through the use of improved breeds that can grow fast and produce better quality beef. In beef production feed is a critical resource that determine the growth of animals and quality of beef. In Tanzania, the main feed resources for cattle are natural pastures available in rangelands, grasslands, woodlands and bush lands. During the dry season, the natural pastures available in these rangeland resources are limited in quantity and their quality is low (Mrema, 2015). Hence, the animals grazing in the rangelands do not get enough nutrients required for maintenance and production. This situation retards the growth of animals during the dry season and prolongs the time taken to reach market weight and, thus, produces tough meat (Mushi, 2020). It has been shown that daily weight gain, dressing percentage and carcass yield of animals raised on high supplementary diets is higher than of those raised on forage system alone (Shija *et al*., 2013), especially during the dry season when the quantity and quality of natural pastures are low.

Several strategies to improve the nutrition of cattle and increase productivity have been suggested. The most common strategy is finish-feeding by supplementing grazing animals with different protein and energy concentrates (Mwilawa, 2012). Most concentrates are comprised of agro-processing by-products (APBP). Agro–processing by–products from cereal grain milling (maize bran, rice polishing), oilseed extraction (sunflower seed cake, cotton seed cake), brewery, sugar production (molasses), fruit and vegetable are produced in significant amount in Tanzania. These agro–processing by-products have a potential value for being used as feedstuffs for ruminants. (Mlote *et al*., 2013; Mushi, 2020).

1.2 Problem Statement and Justification

Beef cattle fattening is a recent undertaking in the county and it is progressively gaining importance in some traditional livestock keeping regions of Tanzania. It is one of the methods for value addition of indigenous cattle breeds that can be used to improve carcass weight and quality for domestic and foreign markets (Mlote *et al*., 2013). It has been clearly demonstrated from the literature that there is a great potential to produce quality beef through nutritional manipulation (Webb, 2004).

Feeding rations with high-energy content improves beef cattle performance and reduces the time spent in the feedlot. Maize grains and molasses are the main supplements used to provide energy to cattle under the feedlot system (Asimwe *et al.,* 2015). However, these energy concentrates are expensive and most traditional feedlot operators cannot afford to use them for cattle fattening. Instead, traditional feedlot operators use rice polishing and maize bran as sources of energy in fattening diet, because they are cheap compared to maize grains and molasses. The major limitation of maize bran is its high demand for use in other livestock, for example, poultry and pigs; this limits its availability. Consequently, feedlot operators under the traditional cattle fattening system use rice polishing, either individually or in combination with sunflower seed cake. The diets used are unbalanced.

Usually finishing of cattle in Tanzania is practiced in the dry season, whereby animals are fed *ad libitum* amount of unbalanced poor quality diets, mainly composed of cereal agro-industrial by-products. This feeding practice is usually uneconomical, taking into account the rising costs of the feeds (Mrema, 2015). Moreover, the types of feedstuff and their amount used to formulate the diets vary considerably among cattle fattening operators. This leads to finished animals to have different meat qualities.

Therefore, there is a need to formulate a cheap and well-balanced diet based on locally available feed resources. Furthermore, there is a need to determine the appropriate combinations of the agro-processing by-products (maize bran, rice polishing, sunflower seed cake and molasses) that are readily available in rural areas and can be used as cattle finish feeding diet. Hence, this study intended to evaluate the inclusion levels of maize bran, rice polishing and molasses as energy sources that can be used in formulation of a balanced diet for fattening cattle at an affordable price.

1.3 Objectives

1.3.1 General Objective

To improve beef production from indigenous cattle during finish-feeding through improved utilization of locally available feed resources.

1.3.2 Specific Objectives

(i) To formulate a good quality and cost-effective diet for cattle finish feeding based on locally available feed resources (maize bran, rice polishing, molasses, sunflower seed cake).

(ii) To assess the growth performance and feed utilization efficiency of Gogo cattle bulls finished on diets based on locally available feed resources (maize bran, rice polishing, molasses, sunflower seed cake).

(iii) To determine the carcass characteristics and meat quality of Gogo cattle bulls finished on diets based on locally available feed resources (maize bran, rice polishing, molasses, sunflower seed cake).

(iv) To determine the profitability of cattle finish feeding using diets based on locally available feed resources (maize bran, rice polishing, molasses, sunflower seed cake).

1.4 Hypotheses

1.4.1 Null Hypotheses

i. There is no significant difference in growth performance and feed utilization efficiency between the bulls finished on balanced diets based on maize bran, rice polishing, molasses, sunflower seed cake and those finished on conventional diet.

ii. There is no significant difference in carcass characteristics and meat quality between the bulls finished on balanced diets based on maize bran, rice polishing, molasses, sunflower seed cake and those finished on conventional diet.

iii. There is no significant difference in profitability of cattle finish-fed using balanced diet based on maize bran, rice polishing, molasses, sunflower seed cake and the conventional cattle finishing diet.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Beef Industry in Tanzania

Tanzania is rich in livestock resources in terms of number and diversity. According to the Ministry of Livestock and Fisheries (MLF, 2020), Tanzania has 33.9 million cattle, 24.1 million goats and 8.5 million sheep. Cattle produce 69% while sheep and goats produce 14% of the meat consumed in the country (MLF, 2020). Most of the beef produced in the country (97%) comes from indigenous cattle kept by pastoral and agro-pastoral communities (Nandonde *et al.,* 2017). Almost everyone in Tanzania consumes red meat and approximately one third of the population is engaged to some degree in the production, processing and sale of red meat (Michael *et al.*, 2017).

Despite the large number of cattle, the country still has not been able to meet its domestic demand for red meat. Meeting this demand, as well as exploiting the opportunities for export of red meat, requires improvement of ruminant livestock productivity. Improvement in livestock productivity is possible only if the limitation of shortage of animal feeds, particularly during the dry season, can be overcome.

2.2 Cattle Fattening Practice in Tanzania

2.2.1 Traditional Feedlotting System

Beef cattle fattening is a recent undertaking in the country, but it is increasingly gaining popularity in some traditional livestock keeping regions of Tanzania (Michael *et al.,* 2017). The beef sub-sector in Tanzania is dominated by indigenous cattle breeds which account for about 94 percent of the national cattle herd. These indigenous cattle are made of Tanzania Shorthorn Zebu (TSHZ), Boran and Ankole (MLDF, 2019). They are well adapted to the prevailing low level of feeding, endemic animal diseases and general poor husbandry practices (Michael *et al.*, 2017).

Traditional feedlotting is the system which partially adopts the features of modern feedlot operations where by local breed of cattle are brought from the farmers normally during the dry season when there is scarcity of green pastures and water. These cattle are kept in yard, treated, grazed and supplied with locally available feed resources i.e. cotton husks, cotton seed cakes, rice polishing, and minerals. The cattle are feed for 3 – 4 months before they are sold for slaughtering (Rangi, 2017).

Fattening using a combination of grazing and supplementation with concentrate diet made from locally available feed resources can improve animal growth performance and can be the best option to fatten cattle under small-scale production system (Frylinck and Webb, 2013). Agro- industrial by-products, for example maize bran, rice polishing and cotton seed hulls can be used as source of energy concentrate while cotton seed cake and sunflower seed cake can be used as sources of protein.

2.2.2 Commercial Feedlot System

As in all commercial enterprises in cattle fattening enterprises, the main purpose is to make a profit (Teklebrhan, 2013). Under improved commercial fattening, large numbers of animals are raised in large farms that are well managed in terms of feeding, breeding and disease control. In Tanzania, this is mainly practiced in National Ranching Company (NARCO) farms owned by the government and other few private feedlot operators in the lake zone regions of Shinyanga and Mwanza. Usually livestock traders are involved in commercial feedlotting with animals ranging from 10 to 800 per feedlots (Mlote *et al.*, 2012). The private feedlot operators initially started as a coping strategy for dry season when pastures become scarce and limited to number of cattle raised in the area. During the dry season cattle become emaciated and don't meet the required slaughter market quality, hence are sold at low market price to feedlots.

Recently, there has been increased motive towards commercialization of beef production driven by increased demand for beef and red meat due to the increase of urban middle class (Lwaho, 2014). In recent years tourism has been growing and the number of hotels, restaurants, supermarkets, and institutions like schools, universities, prisons and hospitals are also increasing and capture a share of the growing market for quality meat (Rangi, 2017). The emergence of traditional feedlots operations in the lake zone regions of Shingyanga and Mwanza was to meet this demand. Feedlot practice have been shown to increase efficiency of quality beef production, adding carcass value and increasing the return to investment when the feed resources are abundant and purchased at relatively low costs. Animal feed is the major cost item among variable costs in a feedlot and accounts for over 70% of the production costs (Mrema, 2015). The increasing cost of feeds has contributed to production failures in most of these commercial fattening enterprises (MLDF, 2009). This necessitates the search for alternative cheaper feed resources that can meet body requirements of beef cattle for production of good quality meat.

2.3 Availability of Feed Resources

Tanzania is endowed with abundant natural resources such as rangelands, grasslands, woodlands and bush and shrub lands which form the main source of animal feeds, including natural grasses and legumes. Additionally, the cultivated land is an important source of feeds in form of crop residues and agro-industrial by-products generated from processing of cereal and legume grains (Mbwambo *et al.,* 2016). Cereal grains and legume agro-industrial by-products are the main supplements used to provide energy and protein concentrates, respectively, to cattle under the feedlot system.

Most ruminant feeds in the country are found in rangelands. It is estimated that only one to two tons DM/ha of forage biomass is available for free range beef production systems in arid and semi-arid areas where traditional cattle fattening is mostly practiced (MLDF, 2010). This amount of forage is not sufficient to promote beef production in traditional sub-sector where livestock feeding relies on grazing only (Mrema, 2015). One tropical livestock unit (TLU) requires an average of three ha per year, a requirement which is far above the current available land for grazing and future (15 years' projection) needs (Mbwambo *et al.,* 2016). Interventions for provision of adequate feeds should focus on improving pasture productivity in the grazing lands, reducing the ruminant livestock population and increasing their productivity.

2.4 Feed Ingredients Used for Cattle Fattening in Tanzania

2.4.1 Maize Bran

Maize bran is widely used in the formulation of animal feeds at both industrial and farm levels. It is a good source of energy in ruminant and non-ruminant rations. The higher energy content of maize bran can be used to increase per cow energy intake and weight gain more effectively than lower energy supplements. It has Dry matter (DM) content of 91.5%, organic matter (OM) 94.9%, crude protein (CP) 10.9%, ether extract (EE) 10.7%, neutral detergent fiber (NDF) 31.9%, and metabolizable energy (ME) content, MJ/kg DM 10.7 (Mlay *et al*., 2005). Maize bran has been used to substitute part of maize grain in diets for beef cattle as it is cheaper compared to maize grains. Studies have shown that maize bran gives better results in feedlot cattle when combined with molasses and urea

(Asimw*e et a*l., 2015). According to Asimw*e et a*l. (2015) maize bran and molasses can substitute maize meal in feedlot diets without reducing meat yield and quality. The major limitations for the use of maize bran could be the availability and relatively higher price compared to other cereal by-products due to competition for its use and high demand, as it is one of the most important ingredients in poultry and pig rations.

2.4.2 Rice Polishing

Rice polishing is a by-product of rice milling industry and is the cheapest source of energy and protein for poultry feeding. It is a good source of proteins, energy, vitamins and minerals. It has dry matter content of 93.6%, crude protein of 7.2%, ether extract of 5.0%, and ME content of 9.0MJ/kg DM. Rice polishing is used as an energy source for cattle finishing diets. Thus, in areas where paddy is produced there is an opportunity of utilizing rice polishing as concentrate feed for cattle production (Khalique *et al*., 2004). However, cattle supplemented with rice polishing have lower performance compared to those supplemented with maize bran, soybean hulls or wheat bran (Osmari *et al.,* 2008). Moreover, practical experience shows that inclusion of high levels of rice polishing in the diet reduces growth rate in cattle. This is probably due to high proportion of rice hulls in the mixture compared to bran and polishing (Mrema, 2015).

Rice polishing contain anti-nutritive factors such as lipases, trypsin inhibitors, haemagglutinin-lectin and phytates, which reduces availability of amino acid and other nutrients to animals. In addition, utilization of rice polishing is limited by the presence of oil ointment, which limits its storage shelf life. The fat content in rice polishing tends to develop rancidity quite rapidly.

2.4.3 Molasses

In sugar cane-growing regions, cane molasses is widely used for fattening cattle as it is often considerably lower in price than grain. It can be a source of quick energy and an excellent source of minerals for farm animals. It contains 74% Dry Matter, 6.5% Crude Protein, 65% Sugar, and 12.5 ME (MJ/kg DM). Molasses inclusion in ruminant diets, increases dry matter intake due to its superior palatability and when its energy is balanced with key nutrients, molasses becomes an excellent supplement for cattle (Mordent*i et a*l., 2021).

Molasses has a stimulating effect on the digestive activity of ruminal microbiota, thus improving both the digestibility of coarse quality forage and dry matter intake (Mordent*i et a*l., 2021). If moderate doses of molasses are used, it can lead to optimization of the ruminal fermentation, improved microbial activity, increased protein synthesis, and reduced ammonia content in the ruminal liquid (Palmonar*i et a*l., 2020).

Molasses is deficient in protein. Protein synthesis by rumen microorganisms can be stimulated by giving proper quantities of molasses and urea in appropriate balance with other dietary components (Mordent*i et a*l., 2019). Molasses also has low nitrogen and sodium, but high calcium, sulphur and potassium contents. It also contains significant quantities of trace minerals such as copper, zinc, iron and manganese (Senthilkuma*r et a*l., 2016).

Molasses can reduce the dusty powdery nature of some finely ground feeds. In this role, it makes a feed mixture more palatable and edible to livestock. It can be added to replace missing sugar and trace minerals and help with fermentation in case of low quality forages, especially those with low sugar levels. Metabolic disease, for example urea toxicity, molasses toxicity and bloat may occur in cattle fed diets in which molasses is used as a supplement – as a vehicle for urea or as the basis of the diet (Senthilkumar *et al*., 2016).

Molasses has a higher value, when it is fed along with some grains, than when molasses alone is fed (Mordenti *et al*., 2019). The benefits of feeding molasses have been demonstrated by numerous researchers (Shirima *et al.*, 2012). There is no doubt that molasses is an excellent source of energy and minerals for ruminants and it can be fed in various ways and is very useful in many situations.

2.4.4 Sunflower seed cake

Sunflower seed cake is a by-product of hot-pressing sunflower seeds to extract oil, and it is used as a high-energy high-protein animal feed (Gregory and Vern, 2002). Sunflower seed cake contains 32 - 36% crude protein, up to 20% crude fiber and up to 10% crude fat. The energy content of its dry matter varies from 10 to 12 MJ/kg, depending largely on the cake's residual fat content (Pedroche, 2015). Sunflower seed cake is a nutritious high-protein feed suitable for inclusion in feed rations of cattle. The fiber in sunflower meal is low in digestibility and may be a disadvantage when balancing rations for non-ruminant and high producing animals. Different studies about anti-nutritional factors in sunflower seeds and meals have been carried out regarding the content of several compounds such as chlorogenic acid, saponin, phytic acid, trypsin inhibitors, and even fiber, which can be found at high levels in sunflower seeds and meals (Mirza *et al*., 2004).

2.5 Feeding Manipulation for Production of Quality Beef

Beef quality can be manipulated through feeding, but the effects and the directions of the effects depend on the tissues studied, the composition of the feed and feeding regime, the duration of the feeding treatment and the age, sex and physiological status of the animal fed or treated (Webb, 2006). Cattle become less efficient and less able to convert feed to muscle or meat as they age. The objective of feedlot is to feed high energy diets so that the animals attain fast average daily gain and achieve slaughter weights at the shortest possible time (Mwilawa, 2012).

Cereal grains, particularly maize grains serve as energy concentrate in fattening diets. Grains contain more energy thus allowing cattle to attain higher growth rates compared to when they are fed only grass or forage. In South Africa, cattle and sheep are generally fattened for short periods to ensure efficient production and to meet market requirements. This is more easily achieved by feeding different proportions of concentrate diets, with or without feed additives and growth promotants that are approved for use in food-producing animals. (Erasmus *et al*., 2013).

2.6 Performance of Animals under Feedlot

Animals in feedlot are fed supplemental feed to promote higher weight gain and improve meat quality. Studies have shown that increasing the number of days on supplementation will increase marbling, yield grade, carcass weight, carcass size and external fat cover as well as meat quality characteristics such as tenderness (Venturin *et al.*, 2016). Mwilawa (2012) indicated that the Tanzania shorthorn zebu and Boran cattle on average can gain 623 and 736 g/day, respectively, when fed with hay and concentrate in a feedlot. Asimw*e* *et a*l.(2015) obtained the average daily weigh gain of 447 g/day when Tanzania shorthorn zebu were fed with high energy diet. Thus, energy content and intake of feedlot finishing diets is very important in maximizing growth of animals under the feedlot.

2.7 Factors that Influence the Performance of Fattened Animals

2.7.1 Feed Conversion Efficiency

Feed conversion efficiency of an animal is a major trait that influences the usage of energy resources and the growth of beef cattle. It is a result of complex biological processes influenced by factors such as climate, feed properties, gut microbe, and individual genetic predisposition (Alemneh and Getabalew, 2019). The peak in efficiency for converting digestible energy into live weight gain in most animals, has been found to occur at around 25 percent of mature body weight. As the animal matures, the ratio of fat to protein in body weight gains increases as the animal spends more energy to produce fats instead of protein and meat; meaning that the efficiency with which it converts dietary energy into body tissues and live weight gains decreases (Mrema, 2015; Mwilawa, 2012).

Studies on livestock species have shown that including feed efficiency as a trait in breeding schemes provides the potential to save feeding costs and resources while increasing productivity of beef cattle (Alemneh and Getabalew, 2019). In Tanzania, traditional cattle fattening uses animals that are older, over four years of age which are brought from livestock market and on average they gain about 0.64 kg/d (Mrema, 2015; Mlote *at al*., 2012). This weight gain is lower compared to on-station results of 0.889 kg/d reported by Mwilawa (2012) for the fattened bulls with the age of 3 to 4 years. These findings show the possibility of increasing feed efficiency and performance through fattening younger animals.

2.7.2 Breed

The carcass and meat quality can be influenced by several factors, for example feed, age and genotype (Alemneh and Getabalew, 2019). In addition, factors associated with meat sensory characteristics i.e. color, cooking losses and tenderness and those related to meat quality i.e. intramuscular fat and fatty acid could also be affected. These parameters are important quality indicators and they have an impact on consumer acceptability.

The growth and carcass composition traits differ between breeds within all farm animal species. As an animal matures, it undergoes an increase in the ratio of muscle to bone, followed by a decrease in muscle growth rate and an increase in the ratio of fat to muscle. However, different breeds differ in their rate of maturation and average mature weight.

The study done by Asizua *et al.* (2009) to compare Ankole, Boran cattle breed and their crosses with Friesian, obtained varying average daily gain (ADG) where, Ankole X Friesian bulls were superior (0.62 g/d) to Ankole (0.56 kg/d) and Ankole x Boran crosses (0.50 g/d) under the same fattening conditions. Thus, the study indicated that improved breeds and crossbreds gain weight faster than native animals, though tropical breeds are more adapted to local climatic conditions, readily available, and can perform like other breeds under good management (Mrema, 2015; Mwilawa, 2012).

2.7.3 Nutrition

Nutrition is often the most important environmental factor affecting the productivity of beef cattle. Nutrition is affected by the type of location, pasture type and seasonal conditions. Management can impact the quality and quantity of nutrition through the use of available by techniques like manipulating stocking rates and use of supplements (Alemneh and Getabalew, 2019).

Feed intake is maximized if the feed eaten provides all the nutrients required by the appropriate rumen microbes and by the tissue of the animal (Asimw*e et a*l., 2015). The efficiency of meat animals in converting feed into meat is generally related to the level of feed intake. The maximum efficiency in converting feed energy into body weight is attained when animals are fed *ad libitum*. When feed energy intake exceeds the amount required for lean tissue growth, the excess is used for fat deposition and thus, animals fed *ad libitum* concentrate diets usually produce more carcass fat and this reflects less efficiency in converting feed to lean meat than the animals fed slightly below *ad libitum* energy intake (Alemneh and Getabalew, 2019). Slight to moderate feed restriction is an effective practice to adjust carcass composition.

Asimwe *et al.* (2016) found difference in weight gain among steers fed different dietary energy concentrations, but similar level of DM intakes. This indicate that the level of energy and protein contained in feeds for cattle fattening should be evaluated and optimally balanced for better performance. Dietary energy of ruminant animals may be restricted conveniently by including variable amounts of fiber in the diet (Mrema, 2015).

Mineral supplementation improves body metabolism and fattening performance. About seven essential minerals (Na, K, Ca, Mg, P, and Cl) are generally required in quite large amounts over 1 g/kg DM of feed provided. These minerals can limit animal performance if their intake does not meet the requirements. Trace minerals are crucial in the immune response to disease and are important to the health and performance of stressed feedlot cattle. Cattle with mineral deficient that enter a feedlot, have higher morbidity and mortality rate and lower feedlot performance (Brady, 2021).

Water is an essential nutrient for all animals. It is important as other nutrients for a well-balanced diet that will help beef cattle to achieve desired level of performance (Mrema, 2015). It is a key nutrient that aids in temperature regulation, growth, digestion, metabolism, and excretion (Ahlber*g et a*l., 2018). Water is available to animals in three forms, free drinking water, water in feed, and water formed via oxidation of organic compounds or metallic water (Lee*s et a*l., 2019). For better growth performance beef cattle should have adequate supply of good quality water. Water requirements of cattle are influenced by ambient conditions, diet type, breed (genotype), weight, and physiological functions (Lee*s et a*l., 2019). Increased water consumptions during hot season can be attributed to increase in urine volume, respiratory tract evaporation, and evaporative heat loss (Bre*w et a*l., 2011). However, an increase in water intake may also be a reflection of ruminants attempting to compensate for heat loads, particularly in un-shaded grazing systems (Ahlber*g et a*l., 2018). Beef production requires a considerable amount of water (Zanett*i et a*l., 2019). Drinking water is an important component of total water demand. In cattle water intake ranges from 8.0% to 9.8% of body weight (Ahlberg *et al.,* 2018). Water intake is closely related to feed intake, and as water intake decreases, so does feed intake and animal performance (Wright, 2007). Accurate estimate of water intake by cattle allows producers to determine water demands, and therefore, ensure water availability for animals (Zanett*i et a*l., 2019).

2.7.4 Climatic Conditions

In tropical countries, cattle performances are highly affected by environmental stress, mainly heat stress, especially in areas where temperatures exceed the upper critical level (18 to 24^0C). Heat stress occur when an animal gains more heat load through metabolic processes and environmental conditions than it can dissipate (Haye*s et a*l., 2017). Animals reactions to their thermal environment are tremendously varied, however, it is clear that the thermal environment influences the health, productivity, and welfare of cattle (Lee*s et* *a*l., 2019). Heat stress reduces feed intake and, therefore, causing low rate of weight gain. The ambient temperature at which dry matter intake (DMI) begins to decline is influenced by diet type and composition, diets with a greater proportion of roughage exhibit more rapid reductions in DMI. Differences in DMI are also influenced by breed (genotype), production status, health status, body condition, and days on feed (Lee*s et a*l., 2019).

Regulation of heat in farm animals has a wide economic implication. During the times of high heat load, absorbable nutrients are diverted from growth and development and directed towards maintaining body temperature. Sheep, cattle and pigs attempt to maintain their body temperature at constant value which is optimum for biological activity (Alemneh and Getabalew, 2019). Beef cattle make their best gains at temperature below 25^0C. In order to reduce heat stress and improve intake, several studies have suggested best and cheap ways of minimizing direct sun radiation and heat stress. Some of them include; use of high energy diets, feeding fattened animals under shade, supply of cool and clean water and altering feeding time to reduce metabolic heat loads during the hottest hours of the day i.e. feeding during the early morning and late evening hours (Tucker, Rogers and Schütz, 2008). However, animals that are adapted to a hot climate usually exhibit reduced growth and reproductive efficiency, which is related with the adaptive mechanisms that ensure survival (Lee*s et a*l., 2019).

2.8 Profitability of Cattle Fattening Enterprise

The objective of fattening is to increase the average daily gain and thereby increase body condition score, dressing percentage and meat quality (Mwilawa, 2012). As in all commercial enterprises, in cattle fattening enterprises the main purpose is to make a profit (Dad*i et a*l., 2017). The cost per unit of production and the price received for the product are the major factors that determine profitability of beef production enterprise. Kibona and Yuejie (2021) documented that for producers to manage the back grounding operation, they need to spend time recording information on costs of production so that they can manage their operations more efficiently and with an eye on profitability. Prices of fattened animals estimated basing on body condition score, sex and body frame size of the animal are not reliable and transparent in determining profitability of fattened animals as they depend on buyer's experience (Mrema, 2015). The best option to determine profitability of beef cattle feedlotting, depending on available infrastructure, is by using average prices per unit live weight (kg) to establish the purchasing prices of fattened cattle since the weights and prices of animals can be fore – determined prior and after fattening, this reduces the chances of making loses (Mrema, 2015).

High growth rate during feedlot finishing requires high energy intake, which is normally obtained from concentrate diets (Weisbjerg, *et al*., 2007). Studies have shown that feed costs account for 70 – 80% of the total costs in cattle fattening (Mwilawa, 2012). and thus when the price of feeds are low there is a possibility of maximizing profit. Normally protein concentrates account for a large proportion of feed costs in feedlot systems. This indicates the need for using alternative feed resources that are cheap but of good quality and can supply the nutrient needed by beef cattle more cost effectively. This is imperative, especially for small-scale farmers for whom low feed cost is critical in improving profit margins (Mwilawa, 2012).

Apart from low costs of feeds, feed utilization efficiency is also an important production parameter that can efficiently be used in beef cattle to maximize profit. Cattle that will convert feed into meat at a high rate are highly desirable for feedlots (Mrema, 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted at Mtanana B Village located at Latitude $6^0 4'0''$ South and Longitude 36^0 34' 0" East in Kongwa District, Dodoma Region (plate 1). Kongwa District is located about 90 km East of Dodoma capital city on Dodoma - Morogoro highway. The District is situated at about 1067 m above sea level and receives rainfall of about 400 to 660 mm per annum. The rainfall pattern is unimodal. The annual temperature varies from a mean minimum of 18^0C to a maximum of 34^0C, depending on the months in a year. The study area is semi-arid with undulating sandy and loamy sand soils. Livestock keeping is the second major economic activity in the District and the District has about 117,598 cattle (Kongwa District Profile, 2012).

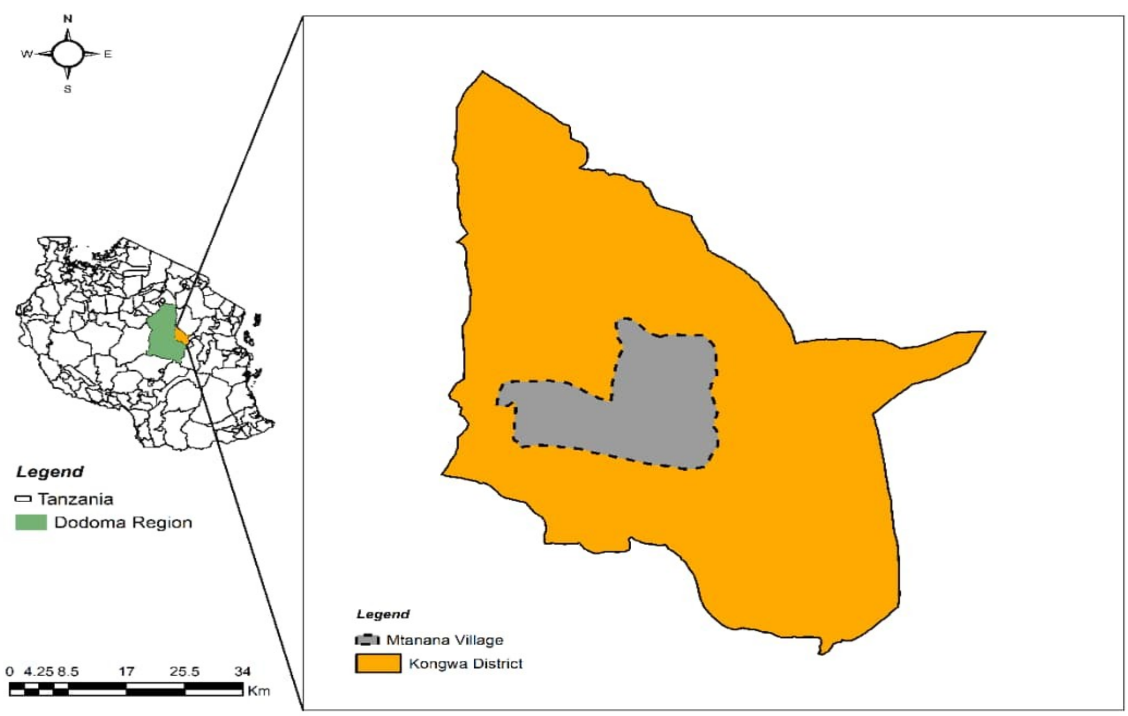

Plate 1: **Map of the study area**

3.2 Experimental Design, Animals and Treatments

Two (2) villages in Kongwa district were involved in the study i.e. Mtatana A and Mtanana B and the selection was based on indigenous cattle population and availability of feed resources in the Village. In each Village five farmers were purposely selected to participate in the study, depending on possession of bulls with the age of three to four years and the willingness to share the responsibilities for operating the feedlot by providing the bulls. The bulls belonged to Gogo strain of the Tanzania Shorthorn Zebu breed. The study involved 50 indigenous Gogo bulls (a strain of Tanzania Shorthorn Zebu breed) which were randomly distributed into ten groups (five groups from each village), each with five animals. Five dietary treatments were tested in this study namely T_1, T_2, T_3, T_4 and T_5. Each treatment was assigned randomly to one group of five bulls. The animals were kept under total confinement, except those receiving the fifth treatment (T_5).

3.3 Feed Materials and Diet Formulation

Hay used as a basal feed in the experiment was purchased from Tanzania Livestock Research Institute (TALIRI) - Kongwa. The hay was mainly made of *Cenchrus ciliaris* with some few pasture species of *Cynodon dactylon, Brachiaria species* and legume i.e. *Clitoria ternatea.* Feed ingredients that were used to formulate the experimental diets included maize bran, molasses, rice polishing, sunflower seed cake, mineral pre-mix and salt. Both Molasses and rice polishing were obtained from Morogoro Region at Mtibwa Sugar Estate and Dumila Village, respectively. The rest of the feeding materials were obtained from milling machines and animal feed shops at Kibaigwa in Kongwa District. Four dietary treatments namely T_1, T_2, T_3 and T_4 were formulated as shown in Table 1. The first treatment (T_1) was made up of maize bran as energy source and sunflower seed cake as the source of protein. The second treatment (T_2) was comprised of maize bran and rice polishing as energy sources and sunflower seed cake as protein source. The third treatment (T_3) was comprised of maize bran and molasses as energy sources and sunflower seed cake as protein source. The fourth treatment (T_4) was composed of maize bran, rice polishing and molasses as energy sources and sunflower seed cake as protein source. The fifth treatment (T_5) was normal grazing without supplementation (control). Each supplementary diet contained mineral pre-mixes, salt and was formulated to meet energy and protein requirements for fattening beef cattle (i.e. 12.5 ME MJ/kg DM and 12% CP) targeting an average daily gain of 1 kg per day. Metabolizable energy (ME) content of feed ingredients and concentrate diet were estimated using the equation by MAFF (1975), that is ME (MJ/kg DM) = 0.012CP + 0.031 EE + 0.005 CF + 0.014 NFE. In addition to the supplementary diets, all animals were fed hay in *ad lib* amount.

3.4 Determination of Chemical Composition of Feeds

The samples of the feed ingredients (molasses, maize bran, rice polishing, sunflower seed cake), formulated diets (T_1, T_2, T_3 and T_4), natural pastures and hay were analyzed for chemical composition. Dry matter, crude fiber, ash, crude protein, and ether extract were analyzed according to the standard proximate analysis procedures of AOAC (2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined by using Ankom fiber analyzer according to Van Soest *et al*. (1991). *In vitro* dry matter and organic matter digestibility were determined using the *in vitro* technique procedure of Tilley and Terry (1963).

3.5 Management of Experimental Animals

The feedlot barn was constructed at Mtanana – B village as shown in plate 2. The barn had four pens and each pen had a size of 20 m x 20 m, which was enough to accommodate 10 bulls. The barn had feeding and resting places. Both feeding and resting places were roofed with iron sheets.

The experimental animals were young bulls aged between three to four years and belonged to Tanzania Shorthorn zebu of Gogo strain. The age of the bulls was estimated based on their dentition. The activities that were done after collecting the animals from the farmers included identification of the animals by ear tagging, screening for diseases, de-worming, and spraying. Deworming to control internal parasites was done on arrival using Albendazole 10% W/V (Bimeda^R – oral suspension) and it was repeated in the mid of the experiment. Spraying with acaricides to control external parasites using Alphatix^R 12.5%EC (Amitraz 125 g/l) was done every after 14 days. Other diseases were treated as they occurred using Oxytetracyline 10% (250 mls to 100 mg/ml). The animals were allocated to their respective treatments randomly. A total of 40 experimental animals were confined in the fattening barn and randomly allocated to four treatments (T_1, T_2, T_3 and T_4). The animals on T_5 remained at homes of participating farmers and they were grazed only. Before data collection, the animals were given an adaptation period of 10 days in order to accustom them to the new feeds as well as the experimental settings. During the last three days of the adaptation period, each animal was weighed and the average weight of the three days was considered as the initial weight. Following the adaptation period, data on body weight and feed intake were collected. The experimental period lasted for 90 days.

Each animal under confinement was supplied with the respective supplementary diet (T_1 = 6.58, T_2 = 6.49, T_3 = 7.46, and T_4 = 6.85 kg) and each supplementary diet was provided at the rate of 3% of the animal body weight. The ration for a day was divided into two equal portions and fed in the morning at 0800 hrs and in the afternoon at 1400 hrs. In addition, *ad–lib* amount of hay and free access to clean water was provided throughout the experimental period. The amount of concentrate diet and hay were weighed before being provided to the animals and also, the amount remaining after feeding were weighed before the next feeding to determine the refusals.

Table 1: Feed ingredients and their proportions in the experimental diet

Feed ingredients	Treatment diets (%)				
	T_1	T_2	T_3	T_4	T_5
Maize bran	78.0	75.0	53.0	50.0	0
Rice polishing	0.0	3.0	0.0	3.0	0
Sunflower seed cake	20.0	20.0	20.0	20.0	0
Molasses	0.0	0.0	25.0	25.0	0
Mineral Premix	1.5	1.5	1.5	1.5	0
Salt	0.5	0.5	0.5	0.5	0
Total	**100**	**100**	**100**	**100**	**0**

T_1= Treatment 1, T_2 = Treatment 2, T_3 = Treatment 3, T_4 = Treatment 4, and T_5 = Treatment 5

3.6 Data Collection

3.6.1 Determination of Feed Intake, Feed Conversion Ratio and Weight gains

Experimental animals were fed in group of five animals for each treatment. The amount of feed provided and the refusals from each treatment were measured daily. The average feed intakes (AFI) in kg DM per animal per day were calculated as the total amount of feed provided minus the amount of feed refusals (kg) divided by the number of animals. Average feed conversion ratio (FCR) per animal in each treatment was calculated as average DM feed intake per animal (kg) divided by average daily weight gain (kg). All experimental animals were weighed in the morning before feeding every after two weeks. Average daily gain (ADG) per animal was calculated as final weight minus initial weight in kg divided by experimental period in days.

3.6.2 Determination of Carcass Characteristics and Meat Quality

At the end of the experiment, five (5) animals from each treatment were randomly selected and taken for slaughter at the National Ranching Company NARCO - Kongwa (Kongwa Ranch) for carcass characteristics and meat quality determination. The bulls were trekked for 6 km from the fattening barn to the ranch abattoir. Upon arrival at the abattoir, the animals were inspected and rested in lairage for about 13 hours prior to slaughter. The animals were stunned and immediately suspended and slaughtered by severing the neck using sharp knife. This was done by an authorized Muslim personnel for the meat to be Halal. The suspended body were bled, skinned and eviscerated.

3.6.2.1 Determination of Non – carcass Components

Non–carcass components, i.e. heart, kidneys, liver, lungs, spleen and diaphragm were removed from the carcass and weighed together. Internal fats (inguinal, renal, ruminal) and heart fats) were removed and weighed together. Gastrointestinal organs (rumen, reticulum, omasum, abomasum) were removed and weighed together. Small intestine and large intestine were weighed together with the gastrointestinal content. Thereafter, compartments were emptied and thoroughly washed, after draining the water the compartment were weighed again. The content of gastrointestinal organ was determined as the difference in weight. The percentage of the different internal organs were calculated relative to the live weight of the animals at slaughter.

3.6.2.2 Determination of Carcass Weight and Dressing Percentage

After slaughtering and removing the non-carcass components, the carcass of each animal was split into two halves (right and left halves) using a meat saw and both halves were weighed to determine hot carcass weight (HCW). Determination of dressing percentage (DP) was done using the following formula: -

DP = (hot carcass weight/ live weight at slaughter) * 100

The right-side carcasses were sold intact while the left side carcasses were used for analysis of carcass characteristics and meat quality. The left side carcasses were kept at room temperature for 10 hours and then transferred to a cold room set at 0 - 4^0C.

3.6.2.3 Linear Carcass Measurements

Linear carcass measurements were taken as shown in plate 3 and as described below.

Carcass length was measured from a cranial side of ischio-pubis symphysis to the middle of the cranial side of the 1^{st} rib. Internal depth of the chest was measured from the downside of medulla channel at the 5^{th} – 6^{th} thoracic vertebrae level to the intersection down the side of external bone with a line through the middle of the internal face of tarso-metatarsal joint and parallel to caudal side of 5^{th} rib. Measuring tape was used to measure carcass length, internal depth of the chest, limb length and limb width.

3.6.3 Measurement of the Meat Quality

Meat quality parameters assessed included carcass temperature, pH, *Longissimus dorsi* (LD) area and carcass composition.

3.6.3.1 Carcass Temperature

Carcass temperature was measured at the 10^{th} rib of the right side of the carcass in the *Longissimus dorsi* (LD) muscle using a digital meat thermometer. The readings were taken at room temperature 45 minutes and 6 hours after slaughter while the readings at 24 hours were taken in the chiller room.

3.6.3.2 Carcass pH

The measurement for carcass pH was done at the same time and location as the measurement of temperature. The pH was measured by inserting a penetrating electrode (Mettler Toledo) in the muscle at 45 minutes, 6, and 24 hrs postmortem using a portable pH-meter.

3.6.3.3 Meat Color

The meat color values were measured on the surface of meat samples with a colorimeter (CR – 410, Minolta Co. LTD., Japan). The color [CIE L* (lightness), a* (redness), and b* (yellowness)] values were obtained after 45 minutes and 24 hours post-mortem. The average of three recordings from each sample was used for statistical analysis.

3.6.3.4 Carcass Tissue Composition

Carcass composition was determined according to Robelin and Geay (1984) method of predicting carcass composition. The 10th rib sample joint of the left side of the carcass was excised. The joint was weighed in kilograms and dissected into fat, lean and bone tissues. The weight of each component (i.e. fat, lean and bone) was then expressed as percentage of the joint weight to obtain the relative distribution of the tissues.

3.6.3.5 Carcass Chemical Composition

Carcass water content was determined as weight loss of a 3 g minced meat dried in an oven at 105^{0}C for 48 h according to AOAC (2000). Ash content was determined by further ashing the dried samples at 600^{0}C in a muffle furnace for 6 h. Total lipid content (g fat/ 100 g sample) was estimated using a 5 g meat sample after a 6 – cycle extraction with petroleum ether in a soxhlet apparatus according to AOAC (2000). Crude protein content was determined using a 1 g sample following the Kjeldahl method as described by the AOAC (2000).

3.6.3.6 Ageing of the Meat

The *Longissimus dorsi* (LD) muscle from each experimental animal was split into three pieces of 5 cm each. These pieces were aged for one, five and 10 days. A piece aged for one day was taken 24 hr post-mortem and sealed using normal sealer and frozen at $^{-}20^{0}$C. The other two pieces were kept in the chilling room at 4^{0}C for five days and 10 days, respectively. After the completion of each ageing time, each sample was removed from the chilling room and transferred to the freezer until analysis.

3.6.3.7 Determination of Cooking Loss and Shear Force

The meat sample was taken on the *Longissimus dorsi* (LD) muscle from the left side of the carcass. From each rear end of the LD muscle, a sample of 2 cm thick, equivalent to 120 g was cut and labeled for determination of cooking loss. The remaining piece was used for assessment of shear force.

The muscles were thawed for one hour and then weighed to get weight one (W_1). Then, they were cooked at 75^{0}C for one hour in a thermostatically controlled water bath. Thereafter, the muscles were left at a room temperature for 2 hours and then removed from PVC bags and blotted dry with the clean towel paper and weighed to get weight two (W2). Cooking loss was determined as percentage cooking loss (%CL). %CL = $(W_1 - W_2)/W_1 * 100$ whereby %CL is percentage cooking loss, W_1 is weight one obtained before cooking, and W_2 is weight two obtained after cooking.

3.6.3.8 Determination of Shear Force

Muscle sample for Warner-Bratzler shear force (WBSF) determination was prepared from the cooked samples by cutting seven cubes, each having a size of 1×1 cm, 5 cm long in fibre direction. Warner Bratzler shear blade attached to Zwick/Roell (Z2.5, Germany) instrument was used to determine the force (Ncm^{-2}) required for shearing through a muscle cube at a right angle to the muscle fibre direction. The Zwick was set with 1 kN load cell with a crosshead speed of 100 mm min^{-1}. The maximum load required to shear through the sample (WB peak force) was determined.

3.6.4 Determination of Profitability of Fattened Cattle

Profitability of cattle fattened under different treatments was determined using gross margin analysis. Gross margin (GM) is the difference between the total revenue earned and the total variable cost incurred i.e. GM = TR-TVC. Where**;** GM = Gross Margin, TR = Total revenue, TVC = Total variable costs. Total revenue (TR) is the total income realized on output produced that is, quantity sold multiplied by price per unit. In this experiment the weight of each bull at the end of the experiment was multiplied by the price of 1 kg live weight to get the selling price of each fattened bull. The selling prices of all bulls in each treatment were added to get the total revenue for each treatment. Variable costs included the costs for the purchase of bulls, feeds, water costs, veterinary drugs, transportation cost, and laborer wages. These were computed for each treatment.

3.7 Statistical analysis

Data were checked for normality by using the Shapiro-Wilk test for normality in R-statistical software. Data on average feed intake (AFI), feed conversion ratio (FCR), final weight (FW), weight gain, average daily gain (ADG), carcass weight, dressing percentage

(DP), weight of non-carcass components and gross margin were subjected to analysis of variance (ANOVA) with post- hoc comparison of means using Tukey's test at 95% confidence interval. The initial weight of each animal was used as a covariate and the treatment was used as the fixed effect in the model. The model used is explained below:-

$Y_{ik} = \mu + T_i + b\,(X_{ik} - X) + E_{ik}$

Where;

Y_{ik} = response of the k^{th} animal from the i^{th} treatment

μ= Overall mean

T_i= effect of the i^{th} treatment

b = Regression of animal final weight on initial weight

X_{ik} = Initial weight of individual animal

X = Mean of animal initial weight

E_{ik} = Random error

Data on meat quality (i.e. effects of treatment and ageing on cooking loss and meat tenderness) were analyzed using the general liner model (GLM) procedure in R – software using the model shown below. Means separation was conducted by using Tukey's test at 95% confidence interval.

GLM model; $y_{ijk} = \mu + X_{1i} + X_{2j} + X_{3k} + \varepsilon_{ijk}$

where by Y_{ijk}= Dependant variables,

μ = general mean,

X_{1i} = Replication effect,

X_{2j} = Treatment effect for j^{th} factor A (Treatment diets),

X_{3k} = Treatment effect for k^{th} factor B (ageing period),

ε_{ijk} = experimental error

CHAPTER FOUR

4.0 RESULTS

4.1 Nutritional Values of the Feed Ingredients and Experimental Diets used for Fattening

4.1.2 Chemical Composition of the Feed Stuffs

Proximate chemical composition of feed ingredients and formulated diets used in the experiment are given in Table 2. The ingredients used for compounding the concentrate diets had crude protein (CP) contents ranging from 106.45 to 220.88 g/kg DM, and metabolizable energy (ME) ranging from 11.04 to 13.21MJ/kg DM. The CP content of the compounded diets ranged from 108.49 to 135.72 g/kg DM, with treatment four diet (T_4) having the lowest CP content and treatment one (T_1) having the highest CP content. The ME of the compounded diets ranged from 12.03 to 12.68 MJ/kg DM, with treatment three (T_3) having numerically the lowest ME and treatment two (T_2) having the highest ME content. The ME content of the hay was 8.61 MJ/kg DM while that of the natural pasture in grazing area was 9.2 MJ/kg DM. The CF of the feed ingredients ranged from 74.45 to 329.34 g/kg DM, with maize bran having the lowest CF and sunflower seed cake having the highest CF. On the other hand, the CF in the compounded diets was highest in treatment one T_1 (117.59 g/kg DM) and lowest in T_4 (87.98 g/kg DM) as depicted in Table 2.

Table 2: Chemical composition of dietary ingredients and formulated diets used in the experiment

Feed ingredients	DM g/kg	CP g/kg DM	EE g/kg DM	CF g/kg DM	NFE g/kg DM	ME (MJ/kg DM)
Hay	926.7	55.23	9.33	327.77	429.935	8.61
NP	925.5	64.98	11.57	274.47	477.772	9.2
MB	955.8	112.16	90.21	74.45	621.408	13.21
RP	965.9	106.45	107.65	167.53	445.512	11.69
SSC	950.0	220.88	114.74	329.34	227.878	11.04
Diet T_1	972.2	135.72	94.6	117.59	530.469	12.58
Diet T_2	969.8	126.14	94.24	105.63	551.329	12.68
Diet T_3	960.8	122.17	65.93	102.97	571.597	12.03
Diet T_4	958.8	108.49	59.45	87.98	606.571	12.08

NP = Natural pasture, MB = Maize bran, RP= Rice polishing, SSC = Sunflower seedcake, DM = Dry matter, CP = Crude protein, EE = Ether extract, CF = Crude fiber, NFE = Nitrogen free extract, ME = Metabolizable energy

4.2 Feed Intake and Growth Performance

Table 3 shows the feed intake, growth performance and killing out characteristics of bulls subjected to four dietary treatments. The initial weight of the bulls subjected to dietary supplementation and of those on the control group were statistically similar (P = 0.0544). The bulls subjected to concentrate supplementation had significantly (P = 0.0001) higher final weight than those on the control group. The bulls that were fed supplementary diets containing molasses (T_3 and T_4) had numerically higher feed intake than their counterparts. The bulls subjected to concentrate supplementation had significantly higher total weight gain (P < 0.0001) than those on the control group. Similarly, the average daily gains of bulls subjected to concentrate diet supplementation were higher (P = 0.0001) than those on the control group. Among the bulls on concentrate diet supplementation, those on T_3 (MB/MO) had the highest average daily weight gain, followed by those on T_1. The bulls subjected to concentrate supplementation had higher hot carcass weight (P = 0.0023) and dressing percentage (P = 0.0001) than those on the control group (Table 3).

Table 3: Effect of treatment diets on growth performance, feed intake and feed conversion ratio of the experimental bulls

	TREATMENT						
Parameter	T_1	T_2	T_3	T_4	**Control**	**SEM**	***P* -value**
Number of bulls	10	10	10	10	10		
Mean initial weight(kg)	129.9	128.6	136.5	131.7	123.1	1.454	0.0544
Mean final weight(kg)	226.6 ^{a}	217.5 ^{a}	250.5^{ab}	217.1 ^{a}	148.5 ^{b}	6.341	0.0001
Mean feed intake kg/DM/day	6.58	6.49	7.46	6.85	-	-	-
Total weight gain (kg)	96.7 ^{a}	88.9 ^{a}	107 ^{a}	85.4^{a}	25.4^{b}	5.273	0.0001
Average daily gain (kg/d)	1.07 ^{ab}	0.93^{b}	1.28^{a}	0.96 ^{a}	0.28^{c}	0.058	0.0001
FCR	6.509	7.35	6.48	7.93	-	0.331	0.3459
Hot carcass weight(kg)	116.11 ^{a}	115.56 ^{a}	123.59 ^{a}	115.66^{a}	72.850^{b}	5.026	0.0023
Dressing Percentage (%)	50.2 ^{a}	50.7 ^{a}	51.3 ^{a}	51 ^{a}	47.1 ^{b}	0.373	0.0001

Means with different superscript in the same row are significantly different (P < 0.05).
T_1 = Treatment one, T_2 = Treatment two, T_3 = Treatment three, T_4 = Treatment four, SE = Standard error of the means.

4.3 Non-Carcass Components

The effect of dietary treatments on non-carcass components of bulls are given in Table 4. Bulls on concentrate supplementation had more than 50 kg higher (P = 0.0072) empty body weight (EBW) compared to the control group. Bulls fed on molasses-based diets (T_3 and T_4) had higher proportion of internal organs (lungs, liver, spleen, heart, and kidneys) than their counterparts. On the other hand, bulls on concentrate diets had higher (P = 0.0109) proportion of internal fat compared to the control group.

Table 4: Effects of treatment diets on weight of non-carcass components

Variables	TREATMENTS						
	T_1	T_2	T_3	T_4	Control	SEM	*P*-value
No. of bulls	10	10	10	10	10	-	-
Full gastrointestinal tract (kg)	27.1	24.2	22.7	23.6	27.7	1.3928	0.7699
Empty gastrointestinal tract (kg)	5.1	5.0	5.3	5.4	4.5	0.1358	0.315
Gut content (kg)	21.9	19.2	17.4	18.2	23.2	1.3712	0.6625
Empty body weight (kg)	212.2^{a}	207.7^{a}	222.5^{a}	208.3^{a}	150.3^{b}	7.4400	0.0072
Small intestine(kg)	11.0	10.1	10.2	11.1	8.9	0.5593	0.7517
Internal Organs(kg)[1]	9.7^{ab}	9.6^{ab}	10.1^{a}	10.3^{a}	7.0^{b}	0.3647	0.0109
Internal Fat (g)	3.5^{a}	5.6^{a}	5.7^{a}	4.5^{a}	0.3^{b}	0.4837	0.0001
Skin (kg)	23.0	21.0	21.4	22.4	17.1	0.7483	0.0969
Feet (kg)	7.9	7.0	7.3	7.6	6.1	0.2088	0.0735
Head (kg)	12.8	12.7	13.1	12.6	11.0	0.3469	0.3738
Tail (kg)	0.63	0.64	0.71	0.65	0.56	0.024	0.4426

[1]internal organs = lungs, liver, spleen, heart, and kidneys. Means with different superscript on the same row are significant different ($P < 0.05$). T_1 = Treatment one, T_2 = Treatment two, T_3 = Treatment three, T_4 = Treatment four, SEM = Standard error of the means.

4.4 Linear Carcass Measurement and Carcass Composition

The effects of dietary treatments on linear carcass measurements and carcass composition are given in Table 5. There was no statistical difference (P = 0.0606) in hind leg circumference, carcass length and rib eye area among the bulls on concentrate supplementation and those on control group. However, the control group had lower (P = 0.0105) chest depth compared to the bulls on concentrate supplementation. On the other hand, the control group had higher proportion of the muscle (P = 0.015) and bone (P = 0.046) but lower proportion of fat than the bulls on concentrate diets.

Table 5: Comparison of the linear carcass measurements and carcass composition of bulls under different dietary treatments

	Treatments						
Parameters	**T_1**	**T_2**	**T_3**	**T_4**	**Control**	**SEM**	***P*-value**
Number of bulls	10	10	10	10	10		
Hind leg circumference (cm)	85.6	85.6	87.3	83.2	74.7	1.5664	0.0606
Carcass length (cm)	99.8	98.0	102.6	98.4	97	1.2710	0.7096
Chest depth (cm)	41.8^{ab}	44.8^{a}	43.8^{a}	42.8^{ab}	39.6^{b}	4.7961	0.0105
Rib eye area (cm^2)	297.6	136.6	200	262.89	115.0	2.3829	0.0515
Muscle (%)	58.12^{ab}	51.88^{b}	62.36^{ab}	60.41^{ab}	70.89^{a}	1.893	0.015
Fat (%)	18.70^{ab}	29.93^{a}	15.68^{b}	18.08^{ab}	0.67^{c}	2.267	0.0001
Bone (%)	23.17^{ab}	18.18^{b}	21.94^{ab}	21.50^{ab}	28.43^{a}	1.118	0.046

Means with different superscript on the same row are significant different ($P < 0.05$)
T_1 = Treatment one, T_2 = Treatment two, T_3 = Treatment three, T_4 = Treatment four, SE = Standard error of the means.

4.5 Meat Quality Characteristics

4.5.1 Cooking Loss and Meat Tenderness

The means of the cooking loss and shear force (WBSF) of *Longissimus dorsi* muscle from the bulls under different dietary treatments and ageing time are given in Table 6. Cooking loss (CL) and meat toughness as measured by WBSF were higher ($P < 0.05$) for the bulls on control group than for bulls on concentrate diet supplementation. The control group had more than 10% unit higher cooking loss than the bulls on concentrate diets. Of the bulls on concentrate diets, T_1 and T_3 had slightly lower WBSF values (67.11 and 66.64 Ncm^{-2}) than T_2 and T_4.

Cooking loss and WBSF values of the *Longissimus dorsi* muscle LD were affected significantly by the ageing time (Table 6). The CL values for meat aged for 1 day was 8% unit higher (P = 0.0001) than the average CL values (26.81 %) of meat aged for 5 and 10 days. On the other hand, the WBSF values (76.13 Ncm^{-2}) for the meat aged for 1 day was more than (40 Ncm^{-2}) higher than that of the meat aged for 5 and 10 days. There was no interaction between treatments and ageing on CL (P = 0.5994) and WBSF (P = 0.0612).

Table 6: Effects of treatment and ageing time on cooking loss and WBSF – shear force of *Longissimus dorsi* muscle of bulls under different dietary treatment

	Variables	
Dietary treatments	**Cooking loss**	**Shear force**
Control	48.18^{a}	98.10^{a}
T_1	30.28^{b}	67.11^{b}
T_2	27.44^{b}	75.37^{ab}
T_3	31.86^{b}	66.64^{b}
T_4	35.52^{b}	73.43^{ab}
SE	1.846	3.662
P – Values	0.0002	0.0256
Ageing time		
Day 1	34.65^{a}	76.13^{a}
Day 5	30.31^{a}	33.15^{b}
Day 10	23.32^{b}	23.57^{c}
SE	1.033	2.977
P-Value	0.0001	0.0001

$^{a\,b\,c}$ Means with a common superscript in the same column are not significantly different (P = 0.05). T_1 = Treatment one, T_2 = Treatment two, T_3 = Treatment three, T_4 = Treatment four, SE = Standard error of the means.

4.6 Post-mortem temperature and pH decline

Figure 1 the meat temperature trend for the bulls subjected to different treatments.

Although the carcass temperature of the control group at 45 min postmortem was slightly lower compared to that of bulls on concentrate supplementation (Figure 1), the difference was not statistically ($P > 0.05$) significant. Similarly, there was no significant difference in post-mortem pH decline between the bulls under concentrate supplementation and those on the control group (Figure 4).

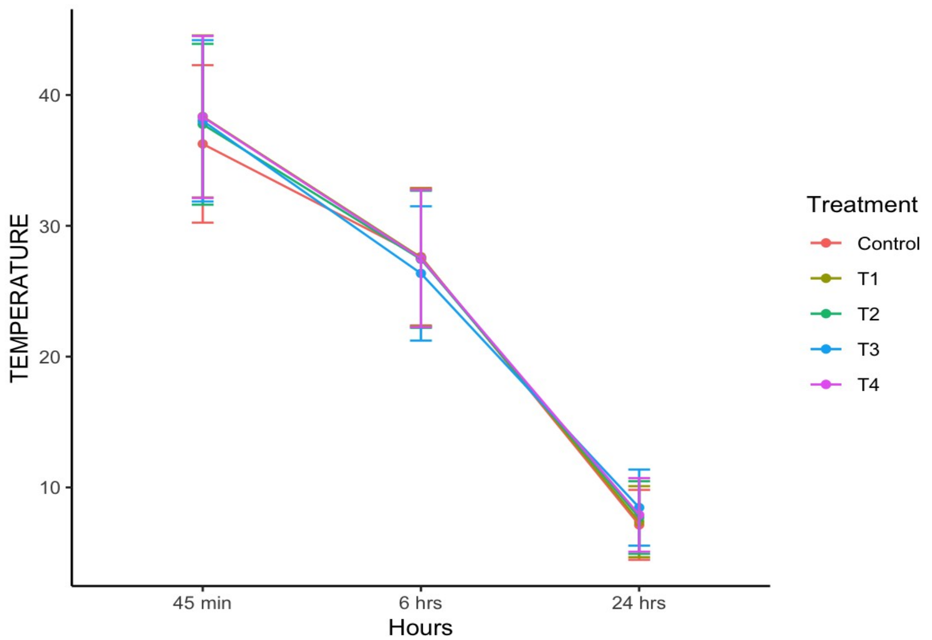

Figure 1: Post-mortem temperature decline in a period of 24 hours

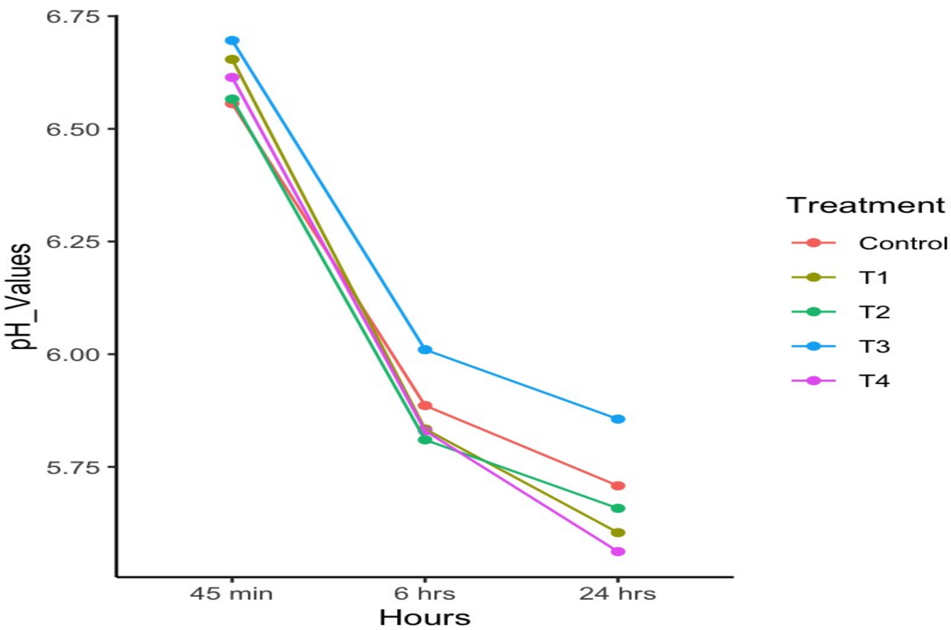

Figure 2: Post-mortem pH decline in a period of 24 hours

4.7 Meat Color

The means for color of the *Longissimus dorsi* (LD) muscle obtained from bulls under different dietary treatments are given in Table 7. The results shows that, relative lightness (*L**) was about 8 units lower (*P* = 0.0014) in *LD* muscle from the bulls on the control group than in bulls on concentrate supplementation. However, LD muscle from the bulls supplemented with different concentrate diets were similar in *L** value. There was no significant difference among dietary treatments with respect to redness (*a**) and yellowness (*b**) meat color.

Table 7: Means of the effect of treatment on meat color of the *Longissimus dorsi* muscles

	Meat color						
	T_1	T_2	T_3	T_4	**Control**	**SEM**	***P*-value**
L*	28.06^a	28.77^a	28.43^a	28.9^a	20.43^b	0.879	0.0014
a*	11.84	13.52	11.87	12.57	10.47	0.606	0.6155
b*	2.77	3.4	3.51	3.59	3.4	0.201	0.7501

Means within the same row with different superscript letters are significantly different at (P<0.05), SEM = standard error of the means, $L*$ = lightness, $a*$ = redness, $b*$ = yellowness, T_1 = Treatment one, T_2 = Treatment two, T_3 = Treatment three, T_4 = Treatment four.

4.8 Chemical Composition of LD muscle

The means of proximate composition of *Longissimus dorsi* muscle from the bulls under different treatment are given in Table 8. The moisture percentage of the *Longissimus dorsi* (LD) muscle did not differ significantly (P = 0.0557) between the bulls on concentrate diet supplementation (60.58%) and those on the control group (68.01%). The LD muscle from bulls on concentrate diet supplementation had on average lower CP value (17.55%) than that of bus on the control group (21.27%). The results shows that there was a significant difference (P = 0.0038) in the percentage Ether Extract (%EE) between the LD muscle of the bulls under concentrate diet supplementation and that of the bulls on the control group whereby, the former group had more than twice as higher %EE values than the latter group. When comparison is made among the bulls under supplementation, the results show that there was slight variation in %EE among the bulls on concentrate diets whereby, animals on T_4 (MB/RP/MO) had numerically the highest EE (18.18 %) while those on T_1 (MB) had the least (11.03%).

Table 8: Proximate composition of *Longissimus dorsi* muscle of the bus under different treatments

	TREATMENT						
Variables	T_1	T_2	T_3	T_4	**Control**	**SEM**	***P*-Value**
Moisture (%)	60.29	62.04	59.97	60.03	68.01	1.097	0.0557
Crude Protein (%)	17.47^{b}	18.01^{b}	17.15^{b}	17.59^{b}	21.27^{a}	0.417	0.0007

Ether Extract (%)	11.03^{ab}	14.64^{a}	14.55^{a}	18.18^{a}	5.21^{b}	1.275	0.0038
Ash (%)	2.06	2.24	2.05	2.06	2.96	0.311	0.0810

Means within the same row with different superscript letters are significantly different at (P < 0.05), SEM = standard error of the means, T_1= Treatment 1, T_2 = Treatment 2, T_3 = Treatment 3 and T_4 = Treatment 4.

4.9 Gross Margin of the Fattened Bulls

The results for gross margin analysis of cattle fattening using different dietary treatments are presented in Table 9. The results show that T_3 (MB/MO) and T_4 (MB/RP/MO) diets had higher (P = 0.0001) feed costs which led to higher total variable costs compared to the rest of the diets. Other variables costs (in Tanzania shillings, TZS) (water costs, labor costs, and veterinary costs) were similar for all treatments (Table 9). There was no statistical difference (P > 0.05) in cost of feed per kg weight gain among the animals supplemented with different concentrate diets. Although not statistically significant, cost of weight gain for T_4 (MB/RP/MO) group was numerically higher than that of other groups fed different concentrate diets.

There was no statistical difference in purchasing price (P = 0.6301) and selling price (P = 0.1019) of the bulls supplemented with different concentrate diets. The average purchasing price and selling price of the experimental bulls were TZS 187,750 and TZS 660,983 respectively. There was significant difference (P = 0.006) in gross margin between the bulls on concentrate diets supplementation. The gross margin for the bulls offered diet T_3 was higher TZS 235,471.00 while T_4 was lower TSZ 162,531.00

Table 9: Gross margin analysis of the bulls fattened under different treatments (values in TZS)

	TREATMENTS					
Parameters	T_1	T_2	T_3	T_4	**SEM**	***P*- Value**

Revenue						
Sales of fattened bulls	657,140	630,750	726,450	629,590	0.648	0.1019
Variable costs						
Purchase price	179,000	179,000	205,000	188,000	7.897	0.6301
Feed Costs	216,085[a]	212,115 [a]	258,729[b]	251,828 [b]	3.327	0.0001
Water cost	6,250	6,250	6,250	6,250	0	0.404
Vet costs	6,000	6,000	6,000	6,000	0	0.404
Labor cost	150,000	150,000	150,000	150,000	0	0.404
Total variable costs	422,353[b]	418,365[b]	490,979[a]	467,078 [ab]	9.134	0.021
Cost of feed/kg gain	2,374.4	2,844.3	2,500.0	3,243.7	1.5077	0.1703
Gross margin	234,805[a]	212,385 [ab]	235,471[a]	162,531[b]	9.816	0.006

Means within the same row with different superscript letters are significantly different at *p* < 0.05, SEM = standard error of the means, T_1 = MB, T_2 = MB/RP, T_3 = MB/MO, T_4 = MB/RP/MO, TZS = Tanzania shillings.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Nutritional Values of the Feed Ingredients used for Fattening

The CP of concentrate diet T_1 (MB) had the highest CP content among the experimental diets. This could be attributed to inclusion level of sunflower seed cake and maize bran. These feed ingredients contained numerically higher CP in relation to the other ingredients. Overall, the CP values observed on different concentrate diets in this study are within the range reported by Cole and Hutcheson, (1990). According to Oliván *et al*. (2004), the CP content in fattening diet should be 110 – 130 g/kg DM to meet protein requirement of fattened cattle.

The numerically higher value of Ether Extract (EE) observed in diets T_1 and T_2 could be attributed to higher inclusion level of maize bran (MB). The other diets, T_3 and T_4 had the recommended level of EE (60 g/kg DM) for mature cattle diets. The metabolizable energy (ME) value of the compounded feed was in the range of 10 to 13MJ/kg DM recommended by NRC (2000) for beef cattle fattening. Thus, these diets have adequate energy content to be used for fattening of beef cattle.

Rice polishing used in this study had CP and EE values that are numerically higher than the value reported by Mrema, (2015), but lower than that reported by Mawona (2010). The observed variation in chemical composition of the rice polishing in this study could be due to efficiencies of milling machines in separating the rice bran and husks.

The maize bran used in this study had CP content that is numerically higher than the CP content of 109 g/kg DM reported by Mlay *et al*. (2005), but lower than 126.5 g/kg DM reported by Kavana and Msangi (2005). The observed EE content in this study was higher than the EE content of 78.2g/kg DM reported by Mrema, (2015), but lower than 107 g/kg DM reported by Mlay *et a*l., (2005). The observed value of CF in this study was higher than the CF of 60.6 g/kg DM reported by Mrema (2015). The variation observed in chemical composition of maize bran could be due to differences in efficiency of milling machine, climatic condition of the study area, and differences in soil fertility. The major limitation of using maize bran in feedlot diets is its availability, which depends on status of maize production.

Sunflower seed cake is a nutritious high-protein feed resource suitable for formulating feed ration for cattle. The CP content of the sunflower seed cake in this study was observed to be lower than the CP of 383 g/kg DM reported by Jabbar *et a*l. (2006) and 232.7 g/kg DM reported by Moyo *et* al. (2014). However, the contents for DM, CF and EE obtained in this study were found to be higher compared to values (DM 895 g/kg DM, CF 137 g/kg DM, EE 77 g/kgDM) reported by Jabbar *et a*l. (2006). The observed DM in this study was lower than the DM of 942 g/kg DM reported by Mlay *et a*l., (2005) whereas the value for CP was lower than the CP of 236 g/kg DM reported by Mrema, (2015). Lardy and Anderson, (2002) reported the CP in sunflower to be 340 g/kg DM and CF to be 210 g/kg DM. Several factors can influence the nutrients of sunflower seed cake including oil content of the seed, extent of hulls removal and efficiency of oil extraction (Lardy and Anderson, 2002). On the other hand, the CP content of the natural pasture that was used by the control bull (grazing only group) was higher than the CP of 50.0 g/kg DM reported by Njau *et al.* (2013). The average CP of 50.0 g/kg DM in pastures is just enough to meet the minimum protein requirements for grazing animals (Njau *et al*., 2013).

5.2 Feed Intake and Growth Performances

The dry matter intake (DMI) of the bulls supplemented with concentrate diets (stall – fed bulls) was within the range of 2.7 – 3.5% reported by Mwilawa *et al*. (2012). The numerically higher feed intake observed in bulls on T_3 and T_4 is attributable to molasses content. Molasses is tasty and bind dusty feeds, therefore it improves palatability of a ration (Hunter, 2012). Molasses contains many minerals including copper, zinc, iron and manganese that are important for optimum animal health and performance (Senthilkumar *et al*., 2016).

All bulls under concentrate diet supplementation had higher weight gain than those on the control group. The higher body weight gain observed in bulls subjected to concentrate diet supplementation could be due to adequate nutrients in the diets which were provided to the animals, thus the animals were able to meet their nutritional requirements for maintenance and body weight gain (Asimwe *et al*., 2015). The weight gain of bulls under concentrate diet supplementation in this study is higher than the weight gain of 0.812 kg/day reported by Mwilawa *et al*. (2012) for Tanzania Shorthorn zebu under similar rearing system and fed molasses based concentrate and hay. The difference could be due to the high level of feed intake, differences in rations formulation and the quality of hay. The weight gain of bulls on concentrate diet supplementation observed this study is similar to the weight gain observed by Luziga (2005) in Boran crosses supplemented with molasses based concentrate. The animals on the control group had the lowest weight gain and this could be due to differences in rearing system and poor quality of the grazed natural pastures. The animals on the control group were grazed in natural pastures and they were trekked from homestead to the grazing area for a distance of eight km back and forth. The trekking consumed a lot of energy that could otherwise being used for growth.

All bulls on concentrate diet supplementation had the same efficiency in converting feed to body weight gain. The results from this study show that the composition of ingredients used to formulated the diets T_1, T_2, T_3, and T_4 were optimal for upholding high weight gain as suggested by O'Kiely (2011) and, thus, the bulls fed these diets had better feed utilization.

The observed higher final live weight (FLW) and hot carcass weight (HCW) for bulls on concentrate diet supplementation compared to that of the control group is attributable to high intake of both energy and protein nutrients. Similar results have been reported by other authors (Asimwe *et al*., 2015; Shirima *et al*., 2016; Mushi, 2020). In this study, bulls on concentrate diet supplementation had similar dressing percentage which was higher than that of the control group. Dressing percentage and live weight are positively correlated (Mwilawa *et a*l., 2012). The observed higher dressing percentage in bulls on concentrate diet supplementation is in agreement with the observations made by Meissn*er et* al. (1995) and Hanekom (2010) who reported that dressing percentage and carcass weight increase with increase in dietary energy concentration. Mwatawala *et al.* (2001) observed low values of DP and higher gut fill for the grazed animals than concentrate fed animals. Results by Mwilaw*a et a*l. (2012) and Jone*s et a*l. (1984) revealed that cattle on a high roughage diet, such as hay, silage or pasture, have a lower dressing percentage than the cattle on a high proportion of grain diet. This could be due to a decrease in the weight of the dressed carcass in relation to the final slaughter weight caused by the higher amount of gastrointestinal (GIT) content. The higher GIT content in grazing animals is caused by the lower passage rate of fibrous feeds, which has lower digestibility than concentrate feeds (Mwilawa *et al.*, 2012).

5.3 Non-carcass Components

Non carcass components contribute to the live weight of an animal (Mohamed, 2004). The lower empty body weight (EBW), internal fat weight and the size of internal organs in the control group than in bulls supplemented with concentrate diets observed in the present study is similar with what was reported by Frylinck *et al.* (2013) and Asimw*e et al*. (2015). Lack of significant difference in weights of full GIT, empty GIT, gut contents, small intestine, skin, feet, head, and tail between the animals under supplementation and those on the control group is similar to results reported by Joy and Defla, (2008) who, studied the influence of feeding system on carcass and non-carcass composition of lambs.

5.4 Linear Carcass Measurements and Carcass Composition

The observed difference in chest depth between the bulls on concentrate diet supplementation and those on the control group could be due to high energy intake for the supplemented groups that resulted into higher live weight and carcass weight in the former than in the latter (McGe*e et a*l., 2007).

The superiority of the bulls under concentrate diet supplementation over the control group with respect to degree of fatness observed in the present study is similar to the findings reported by Oliv*á*n *et a*l. (2004). This could be due to availability of excess energy that was converted into body fat in bulls on concentrate diets (Casasú*s et a*l., 2002). The higher proportion of muscle and bone in the control group compared to the bulls supplemented with concentrate diets indicates higher leanness in the meat of the control group due to low level of energy intake. Similar results were observed by Revilla *et al.* (2021) that as energy intake increases, the muscle and bone percentages in the carcass decrease and fat percentage increases. Ahmed and Babiker (2015) reported that, with decreasing dietary energy, muscle and ash content increase. Similar observation was reported by Shij*a et a*l. (2013) who assessed carcass composition of Boran and Tanzania Shorthorn Zebu steers under different concentrate levels of finish feeding.

5.5 Meat Quality Characteristics

5.5.1 Cooking Loss and Meat Tenderness

The higher cooking loss observed in the control group is attributable to lower degree of fatness. Similar results were observed by Y*u et a*l. (2005). Meat with high fat content exhibits lower water loss upon cooking because of the negative correlation between fat and water contents (Mushi, 2020; Ducket*t et a*l., 2009) and also fat in meat plays a protective role against water loss (Madrug*a et a*l., 2008). Other factors known to affect cooking loss and water holding capacity of meat are ultimate pH, post-mortem protein denaturation and proteolysis (Y*u et a*l., 2005)

The lower value of shear force observed on meat from bulls on concentrate diet supplementation is attributable to high degree of fatness and lower concentration of connective tissue. Stall – fed animals with access to high energy diet produce meat with lower shear force and, hence, meat that is more tender. Andersе*n et al*. (2005) and Mushi *et al*. (2009) reported that, both higher energy intake and reduced exercise due to confinement can contribute to higher level of tenderness in feedlot beef cattle. Animals fed concentrate diets usually have lower concentration of connective tissues per unit weight of muscle bundle (Anderse*n et al.*, 2005). Low concentration of connective tissue is correlated with high meat tenderness (Malti*n et a*l., 2003). The high WBSF value observed for the meat from the bulls on the control group, without supplementation agrees with

Andersen *et al*. (2005) who reported that the diet with low energy such as grass or forage gives rise to muscles with higher shear force values compared to high energy diets fed *ad libitum*. The decreased shear force values in animals fed with high energy diet in the present study signify that meat tenderness improves with concentrate feeding (Mushi, 2020; Mwilawa *et al*., 2012). High energy diets promotes higher *in vivo* protein turn over (Maltin *et al*., 2003) and lower intensity of heat-stable connective tissues per unit muscle weight, which are linked with meat tenderness (Maltin *et al*., 2003). Likewise, animals on high energy diet deposit more fat in muscle bundles, thus lowering the concentration of connective tissues and, consequently, shear force values in beef (Christensen *et al*., 2009; Christensen *et al.,* 2007).

The results from this study shows that as ageing increased, the cooking loss decreased. The mean cooking loss of meat from treated bulls at day 5 ageing was similar with the value (25.8%) reported by Jama *et al*. (2007). Purslow *et al.* (2016) stated that the sarcoplasmic proteins are influential in retaining water in the muscle structure. The increased water loss evident in the aged muscle corresponds to an increase in shrinkage in the diameter of both muscle cells and myofibrils. Liu *et al.* (2015) suppored the hypothesis that sarcoplasmic proteins are influential in providing a networked linkage with each other and with myofibrillar proteins, enabling more water to be trapped in the structure. Cooking loss normally results in the loss of numerous essential minerals and vitamins, which in turn leads to deterioration of the nutritive quality of beef which reflects a financial loss in the beef industry (Mwilawa *et al.,* 2012)

The meat sample aged for one day in the present study had WBSF shear force that was lower for the bulls on concentrate diet supplementation than that of the control group. These values are higher than those reported by Shackelford *et al*. (1997) who classified meat as tender when WBSF values are less than 58 Ncm^{-2}. This implies that, the meat obtained from the bulls in the present study can be categorized as tough when sold immediately on the same day of slaughtered.

The results in this study show that ageing tended to decrease shear force values of *longissimus dorsi* muscle of both bulls on concentrate diet supplementation and on the control group. Similar results were reported by Revilla *et al.* (2021) that as ageing progresses, toughness decreases. Mwilawa *et al*. (2012) found that the ultimate shear force beyond 21 days of ageing is small and may not justify the extra cost of storage and, that the benefit in improving tenderness by ageing the carcass is between two and 10 days. According to Mwilawa (2012), the exact duration of ageing could be determined by the cost of utilities i.e. electricity and space. However, the length of ageing can be determined by the willingness of consumers to pay more for tender meat. The present study shows that, it is likely to decrease shear force values and consequently increase tenderness of meat through supplementation of high energy diet and storage at room temperature for 10 h post-mortem, followed by chilling at 0 – 4^0C for five days.

5.6 Post-mortem temperature and pH decline

The lack of difference in postmortem temperature decline between the meat of the bulls under different dietary groups could indicate similarities in the level of subcutaneous fat tissue. Carcasses with high level of fatness normally tend to have slow rate of temperature decline post-mortem. Other authors (Mushi, 2020, Devine *et a.,* 2014) obtained similar results. The slow rate of cooling of carcass offers protection against cold shortening problem upon accelerated cooling. The storage temperature of 15 ^{0}C for 10 h post-mortem is ideal condition for rigor mortis to take place (Mushi, 2020; Devin*e et a*l., 2014) without causing cold shortening problem (Mushi, 2020). When the muscle is cooled fast to below

10^0C before onset of rigor, cold-shortening occurs due to excessive muscle contraction (Haileslassi*e et* al., 2018).

The similarity in post-mortem pH decline between the bulls on concentrate diet supplementation and those on the control group could be attributed to either good handling of the animals during pre-slaughter to eliminate the difference in glycogen reserve between the two groups or that the animals had enough glycogen reserve required for post-mortem pH decline.

The ultimate pH (pHu) for bulls on concentrate diet supplementation ranged from 5.6 to 5.58. Beef is said to have normal pHu when its pHu ranges between 5.5 and 5.8 (Mushi, 2020; Huff-Lonergan and Lonergan, 2005). The obtained pHu values in this study implies that the bulls on concentrate diet supplementation had sufficient glycogen reserve needed for post-mortem pH decline (Mushi, 2020). When animals are slaughtered, the glycogen in muscles breaks down to form lactic acid through glycolysis and the pH declines due to development of acid in muscle (Haileslassi*e et* al., 2018). A well-handled animal during pre-slaughter breaks down glycogen over a period of 48hrs, and the pH decline from 7.3 to about 5.4 – 5.6 (Mushi, 2020). The observed slightly high pH values for the meat from the bulls on the control group at 24hr post-mortem could be associated with differences in oxidative and glycolytic process. The bulls in the control group probably had slightly less glycogen in their muscle. Mwilaw*a et a*l. (2012) observed similar higher pH values for the meat from grazing animals.

5.7 Meat Color

The lower values for relative lightness (L*) observed in meat from the bulls on the control group indicate dark color of the meat. Similar finding has been reported by Priol*o et* al.

(2001) that meat from cattle raised on grass is darker in color than meat from animals raised on concentrates. The higher value of L* observed in bulls on concentrate diet supplementation may indicate higher degree of fatness. Fat is lighter than muscles and therefore the meat with high fatness tend to have high values for L* (Mancini and Hunt, 2005). On the other hand, the difference in meat lightness between the bulls in the non-supplemented control group and supplemented groups could be partly caused by the slight difference in pH since high pHu meat tends to cause a darker color. High pHu locks up water in meat leading to dry meat surfaces (Hugo *et* al., 2011). Dry meat surface refract light giving rise to dark coloration whereas water on the meat surface reflect light giving rise to higher lightness (Cafferky *et* al., 2019). Priol*o et a*l. (2002) and Razminowic*z et* al. (2006) explained that through hypothesis that pre-slaughter stress and glycogen depletion is more likely to happen to grass – fed than grain – fed steers as the latter are better accustomed to penning and handling. The review conducted by Priol*o et* al. (2001) revealed the difference in percentage of lightness and brightness between animals finished on pasture and their counterparts finished on concentrate that the meat from animals finished on pasture is darker. Webb (2006) and Priolo *et al.* (2001) indicated that factors such as meat ultimate pH, carcass fatness, carcass weight, intramuscular fat content and animal age may influence meat color (Priol*o et* al., 2001).

Physical activity can be considered as a possible factor affecting meat color. The study done by Priol*o et* al. (2001) pointed out the differences on meat color between 3-year old Angus steers finished on a high quality spring pasture and animals finished on feedlot for different durations. The meat color from the grain-finished steers was found to be lighter than that of pasture-finished animals. The author concluded that the differences in meat color is probably due to more physical activity for animals finished in pasture

5.8 Proximate Analysis of LD muscle

The observed low level of water content in *Longissimus dorsi* muscle from the bulls on concentrate diet supplementation could be due to buildup of fat as a result of high energy intake (Mushi, 2020). Similarly, Pflanzer and de Felício, (2011) reported that as the lipid contents increases the moisture diminishes. The lower CP in concentrate fed bulls is also a reflection of higher fat content than in the bulls on the control group. The lower protein level of bulls on concentrate diet supplementation than the bulls on the control group observed in the present study agrees with Shij*a et a*l. (2013). When the percentage of carcass fat increases with increasing concentrate supplementation, protein and moisture content decrease. The average CP content of meat from the bulls on concentrate supplementation observed in the present study is within the range of 15 to 20% reported by other authors, but the value for Ether Extract is higher than the reported range of 5 – 10% (Shij*a et* al. 2013). This could be due to the diet used in the experiment and lipid extraction process from sunflower seeds.

5.9 Gross Margin of the Bulls Fattened using Different Dietary Treatments

The results on gross margin analysis indicate significant difference in gross margin (GM) among treatments. Treatment three (T_3) had higher GM of TZS 235,471 while T_4 had lower GM of TZS 162,531 per animal. These differences could be attributed to differences in individual feed intake, feed conversion ratio as well as final weight which determine the selling price of the bull. The cost of diet was higher in T_3 (MBMO) compared to others treatments. This could be due to the high costs of the ingredients that were used in ration formulation (i.e. molasses). Molasses is abundantly available near sugar possessing industries and thus, feedlots located far away from sugar processing industries face higher costs of molasses transportation.

Although there was no significant differences in cost of feed per kilogram weight gain among the treatments, T_1 had slightly lower cost of feed per kg weight gain. In addition to lower cost, T_1, had higher nutritive value compared to other diets. Therefore, diet T_1 can be used as a finishing feed to yield a unit weight of meat at comparatively lower cost compared to the other diets. Diet T_3 had slightly higher feed cost per kilogram weight gain, but animas fed this diet had higher feed intake and feed conversion ratio.

The total feed cost and purchasing price of the bulls in this study accounted for 54% and 42% of the TVC, respectively. This implies that feed and purchasing price of bulls are important variable costs to consider if profit maximization from feedlot finishing is to be achieved. Other studies on fattening businesses have shown the importance of close monitoring of the price set-up of feeds and fatteners for a profitable, efficient and sustainable beef industry (Malope *et al.*, 2007).

For the grazing cattle the feed total variable costs are usually lower than that of cattle on concentrate supplementation (Weisbjerg *et al.,* 2007). The price of beef from grass-finished cattle is often inexpensive compared with concentrate-fed beef because of observed difference in tenderness, color, juiciness and flavor (Ferench *et al.*, 2001). High energy fed cattle produce more tender and better flavored meat than grass-finished cattle and thus fetch higher price per kg (French *et al.*, 2001). Thus, the results from this study shows economic benefits of using locally available feed resources i.e. maize bran, rice polishing, and molasses as the source of energy and sunflower seedcake as a source of protein in beef cattle fattening.

CHAPTER SIX

6.0 CCONCLUSION AND RECOMMENDATION

Based on the findings of the present study on performance and meat quality of zebu cattle finished on local feed resources in the central part of Tanzania, it can be concluded that; locally available feeding materials such as maize bran, rice polishing, and molasses can serve as the sources of energy and sunflower seed cake as a source of protein. These feed materials can be effectively used to formulate balanced diets that can be used for fattening of local beef cattle. Treatment diet T_3 (Maize bran, Molasses, Sunflower seed cake, mineral premix, salt) was found to be the best than the other diets.

The higher weight gain observed on bulls on concentrate diets than on the grazed one suggests reduced time to attain targeted slaughter weight, increase offtake rate, income, and meat quality of indigenous beef cattle. Therefore, diets formulated from locally available feed resources can be used by farmers in finishing local cattle with good results in terms of growth performance, feed conversion efficiency, carcass characteristics, meat quality, and profit.

Further studies are recommended on developing policy and guidance to facilitate farmers to engage in beef cattle fattening enterprises.

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APPENDICES

Plate 2: Part of the feedlot

Plate 3: Hay barn

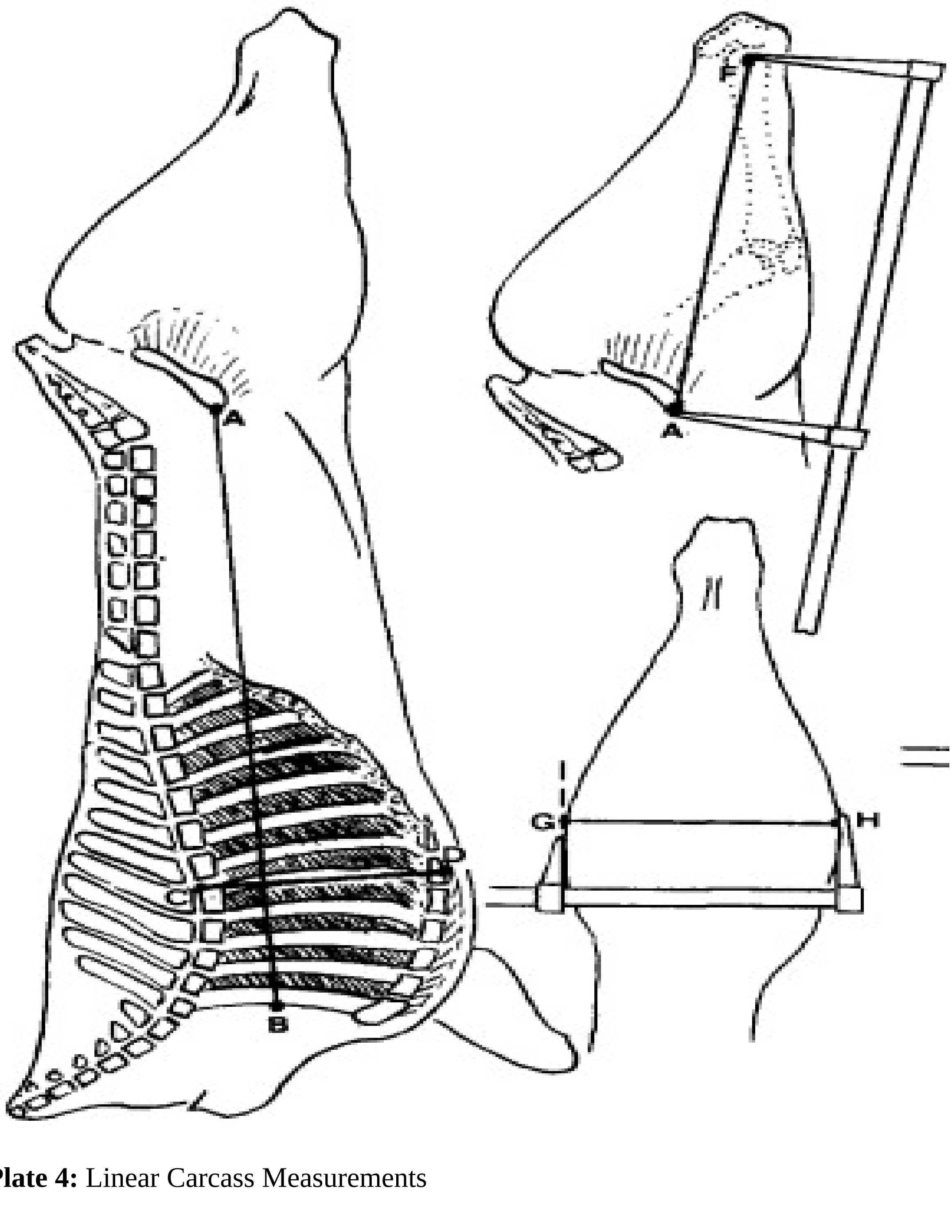

Plate 4: Linear Carcass Measurements

Key: (A – B) Length of the carcass, (C – D) Depth of the chest, (A – F) Length of the leg, (G – H) Maximum width of the leg