

**STUDIES ON PERFORMANCE AND MEAT QUALITY OF INDIGENOUS
CATTLE FINISHED ON AGRO PROCESSING BY PRODUCTS**

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**A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY OF
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EXTENDED ABSTRACT

The demand for quality meat is vastly increasing in Tanzania due to expanding market. The attempts to improve meat quality by finishing animals in feedlot using maize grain was unsuccessful due to strong competition with humans for the grains thus alternative feed resources were sought. This study was done with the objective of improving the quantity and quality of meat produced from Tanzania Shorthorn Zebu (TSZ) cattle using agro processing by products. Two experiments were performed to assess the effects of diets containing different agro processing by products on performance and the optimum duration for TSZ cattle to stay in the feedlot. In Experiment One, forty five steers (2.5-3.0 years of age and 200 ± 5 kg initial body weight) were randomly allocated to five diets containing agro processing by products. The diets were formulated as molasses based, (molasses with either hominy feed-HFMO or rice polishing -RPMO) or maize meal based (maize meal with either hominy feed -HFMM or rice polishing RPMM), and a control diet of maize meal with molasses -MMMO. The steers were fed the respective diet together with hay and drinking water *adlibitum* for 90 days after which all were slaughtered and data on carcass characteristics, meat yield and quality were recorded. In Experiment two, fifty steers (3 years of age and 183 ± 4 kg initial body weight) were kept in feedlot for 0 (P_0), 25 (P_{25}), 50 (P_{50}), 75 (P_{75}) and 100 (P_{100}) days to assess the appropriate period for TSZ cattle to stay in feedlot (n= 10 per period tested). All animals in (P_{25}) to (P_{100}) were fed on HFMO, hay and drinking water on *adlibitum* basis and data on feed intake and weight gain were recorded. After each feeding period all animals were slaughtered and data on carcass characteristics, meat yield and quality were recorded. Warner Bratzler shear force (WBSF) values were determined on *m. longissimus thoracis et lumborum* aged for 3, 6, 9 and 12 days at 0°C. The obtained biological values from both experiments were used to evaluate the economic potential of keeping TSZ cattle in feedlot. The intake of

energy ($86 + 2.8$ (SEM) MJ ME/day) and protein ($867 + 29.6$ (SEM) g/day) was higher ($P < 0.05$) for steers on HFMO diet while feed conversion ratio (FCR) was lower ($P < 0.05$) for steers fed on HFMM (7.87) and HFMO (8.09) diets. The average daily weight gain (814 g), final live weight (274 kg), empty body weight (257 kg) and hot carcass weight (143 kg) were significantly higher ($P < 0.05$) for steers fed on molasses based diets (HFMO and RPMO) than their counter parts. Though diets had no influence ($P > 0.05$) on yield of retail cuts, the most tender meat was from steers fed on HFMO diet and meat aged for 9 days. Although the period of stay in feedlot had no effect ($P > 0.05$) on average daily weight gain and FCR, steers on P_{100} had greatest daily dry matter intake (7.58 kg). The empty body weight increased by 61% for steers on P_{100} compared to P_0 steers. The heaviest ($P < 0.05$) hot carcasses (151 kg) and highest dressing percentage (54%) were obtained on P_{100} steers while the lightest carcasses (91.6 kg) were from P_0 steers. Meat from steers under P_{100} and P_{75} had lower ($P < 0.05$) cooking loss and shear force values with faster declined muscle pH than meat from grazing steers (P_0). Feed cost per extra unit of meat was higher (6,100 TSh.) for low metabolisable energy intake (MEI) than for high MEI (3,923 TSh.) while the use of high energy diets with high intake for longer periods reduced the cost by 84% compared to the use of low energy diets with low intake. When meat price do not change with feedlot finishing, only high MEI is profitable, and high profit increments are on 50 to 75 days of stay in feedlot. It can be concluded that agro processing by products can successfully replace maize meal in feedlot finishing diets. Feeding of a diet containing hominy feed with molasses to TSZ cattle kept in feedlot for 75 days and carcass ageing of 9 -12 days are the best options for high quantity and quality meat production.

DECLARATION

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

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LIST OF ABBREVIATIONS AND SYMBOLS

ADF	Acid Detergent Fibre
ADG	Average Daily Gain
ANOVA	Analysis of Variance
°C	Celsius or Degree Centigrade
CF	Crude Fibre
CP	Crude Protein
Cv	Coefficient of Variation
DANIDA	Danish International Development Agency
DASP	Department of Animal Science and Production
DM	Dry Matter
DMA	Dodoma Modern Abattoir
DMI	Dry Matter Intake
DP	Dressing Percentage
EBW	Empty Body Weight
EE	Ether Extract
FCR	Feed Conversion Ratio
GIT	Gastro Intestinal Tract
GLM	General Linear Model
h	Hour
HCW	Hot Carcass Weight
IGMAFU	Income Generation through Market Access and Feed Utilization
LMA	<i>Longissimus</i> Muscle Area
ME	Metabolizable Energy
MJ	Mega Joules

MLDF	Ministry of Livestock Development and Fisheries
N	Newton
NARCO	National Ranching Company
NDF	Neutral Detergent Fibre
NFE	Nitrogen Free Extract
NSGRP	National Strategy for Growth and Reduction of Poverty
OMD	Organic Matter Digestibility
%	Percent
pHu	Ultimate pH
PM	Post-Mortem
P-value	Probability value
R ²	Coefficient of determination
SAS	Statistical Analysis Systems
SEM	Standard Error of the Mean
SUA	Sokoine University of Agriculture
TSh.	Tanzanian Shilling
TSZ	Tanzania Shorthorn Zebu
VETA	Vocational Education Training Authority
VFA	Volatile Fatty Acids
WBSF	Warner Bratzler Shear Force
WHC	Water Holding Capacity

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Livestock production in Tanzania is one of the agricultural activities which significantly contribute to the national economy as well as the economy of individuals involved in it. The majority of rural families depend on livestock for their livelihood whereby, about 41% of rural households practice pastoralism and agro-pastoralism systems (UNIDO, 2012). Livestock production in Tanzania is divided into traditional and modern/commercial production systems; the former is further divided into pastoral and agro-pastoral while the commercial sector is divided into large and small scale sub systems. Tanzania has over 22.8 million cattle, 15.6 million goats and 7.0 million sheep raised in almost all regions in the country (MLDF, 2014). The majority of animals about 98% are kept under traditional system while the commercial production system accounts for only 2% of the total cattle herd (Mlote *et al.*, 2013). Although the traditional system is the main source of meat in the country, the production level of this system is usually low due to poor animal husbandry practices.

Meat consumed in the country or exported is mainly produced from cattle, goats, sheep, poultry and pigs. Among the livestock species, cattle produce most of the meat (55% of total meat), sheep and goats produce 21% and the remaining 24% comes from pigs and poultry (MLDF, 2014). Regardless of the huge livestock population and land resource in the country, the current meat production has increased only by 1.8% from 2012/2013 to 2013/2014 with only 0.8% of country's herd being finished in feedlots (MLDF, 2014). Although the Livestock Development Policy of 2006 puts more emphasis on commercial and sustainable production of quality meat through proper utilization of quality animal

feed resources (MLD, 2006), the sector is still producing sub-optimally, mainly due to low growth rate and lack of finishing strategies. Adoption of feedlot beef finishing would be expected to heighten the livestock contribution to the country's economy by improving the yield and quality of meat produced.

Indigenous cattle are the cattle populations that occurred naturally in a place where they are currently found and have adapted to local environmental conditions of that particular place such that they have acquired unique features which distinguish them from cattle population in another place (Hanotte *et al.*, 2015). Some of the unique features of African indigenous cattle (including indigenous cattle of Tanzania) are horn shapes and size, diseases resistance, climatic stress resistance and tick infestation resistance. The indigenous breeds of cattle used as main source of beef in the country are Tanzania Shorthorn Zebu (TSZ), Boran and Ankole (Plate 1). These breeds are raised under extensive grazing system on natural pastures in communal rangelands. Most communal rangelands in Tanzania are constrained with poor quantity and quality of forage, which varies with seasons (Obusuar and Ahmed, 2010; Selemani, 2014). However, the TSZ cattle are known for their ability to survive under harsh environments, with poor feed resources and high disease challenges. Available evidence shows that locally adapted indigenous breeds including TSZ under poor management practices have low absolute production figures, but their productivity turns out to be high if the production environment and the level of input are taken into consideration (Bayer *et al.*, 2003). Despite their small size, TSZ are suitable for beef production and they respond well to fattening diets by producing acceptable carcasses (Zakaria, 2010; Mwilawa, 2012), suggesting that finishing them in feedlots using locally available agro processing by products is a possible option for providing a cost-effective alternative for improving their growth and carcass characteristics.



Plate 1: Main beef breeds of Tanzania

Cattle fattening/finishing is one of the management strategies employed by beef producers to increase quality and quantity of beef per cattle (Umar *et al.*, 2014). This strategy can only be achieved by feeding proper rations which give maximum weight gains and fattening rates at the lowest cost with minimum digestive upsets. Adding a low percentage of roughage to high concentrate diets helps to prevent digestive upsets and maximizes energy intake of feedlot cattle (Defoor *et al.*, 2002; Galyean and Defoor, 2003; Shivambu *et al.*, 2011). Small roughage ratios (5 to 25% dry matter basis) in high concentrate diets can improve dry matter intake (DMI), average daily gain (ADG) and feed efficiency (Galyean and Defoor, 2003). Concentrate to roughage ratio of about 75:25 or 80:20 can give satisfactory weight gains at minimum health risk, though ratios can vary from 50:50 to 90:10 in concentrate to roughage ratio (Nienaber, 2008).

In America, finishing diets typically consist of concentrate: roughage ratio of 90:10 (Cheng *et al.*, 1998). A survey made by Oliveira and Millen (2014) in Brazil found the average concentrate to roughage ratio of 79:21 in finishing diets. Feeding a high concentrate diet to feedlot cattle increases growth rates, carcass yield and carcass quality (Marino *et al.*, 2006; Shivambu *et al.*, 2011; Hozza *et al.*, 2013). Generally, concentrate diets have greater concentrations of energy and protein, whose proportion in the diets affect the efficiency of tissue deposition (Valente *et al.*, 2014) and have significant influence on quantity and quality of beef produced (Weisbjerg *et al.*, 2007). The dietary energy concentration for fattening cattle is suggested to range from 12.5 to 13.6 MJ ME/kg DM and crude protein of 120 to 140 g/kg under East and Central African conditions (Topps and Oliver, 1993). However, Kearn (1982) suggested dietary energy concentration of 7.95 to 10.01 MJ ME/kg DM for cattle having body weight range of 150-200 kg and gaining at 0.5-1.0 kg/day in developing countries.

Production systems have great influence on quality and quantity of meat produced because of variation in nutrients available to the animal. In extensively managed systems, limited nutrients are available to animals due to poor nutritive values and availability of forages in rangelands (Agastin *et al.*, 2013). Animals under this system usually have low growth rates, poor carcass yield and meat quality. In semi-intensively managed systems, animals are supplemented with concentrate diets after grazing whereas under intensively managed system (Feedlot finishing) cattle are kept in a confined area and are provided with high concentrate diets. Feedlot finished cattle usually have high growth rate, good carcass characteristics and meat quality compared to solely pasture fed cattle (Esterhuizen *et al.*, 2008; Hozza *et al.*, 2013). A study by Asizua (2010) on Ankole cattle in Uganda has shown that feedlot finished cattle had 0.53 kg average daily gain (ADG), 26.5 kg carcass weight, and 1.6 kg internal fat higher than solely pasture fed animals. Another

study by Mwilawa (2012) in Tanzania also showed that feedlot finished TSZ cattle performed better by having 0.7 kg ADG, 64 kg carcass weight and 6.2 kg internal fat more than solely pasture fed animals. In South Africa, Bonsmara cattle finished in feedlot for 120 days were found to have 0.48 kg ADG, 42 kg hot carcass weight (HCW) and 0.66 kg intramuscular fat higher than pasture fed cattle (Esterhuizen *et al.*, 2008). Supplementation can also improve the performance of pasture fed cattle whereby the effect is highly pronounced during the dry season than in the wet season when good quality pastures are available (Table 1).

Table 1: Weight gain, carcass weight and internal fat of Tanzania Shorthorn Zebu and Ankole cattle under different feeding systems

Feeding system	ADG (g)			Carcass weight (kg)			Internal fat (kg)		
	A	B	C	A	B	C	A	B	C
Solely pasture feeding	563	-45	270	98	90	108	1.5	1.7	2.7
Pasture and concentrate supplementation	631	377	550	105	115	126	1.8	3.6	3.3
Intensive feedlot finishing	812	735	800	120	154	134	3.0	7.9	4.3

Source: Mwilawa (2012), A = A study on TSZ cattle fed for 100 days during wet season

Mwilawa (2012), B = A study on TSZ cattle fed for 90 days during dry season

Asizua (2010), C = A study on purebred Ankole cattle fed for 120 days

Feedlot beef finishing is not very common in Tanzania although it has been practiced by the National Ranching Company (NARCO) farms. Currently, few private entrepreneurs in the country have started to practice feedlot finishing but on a small scale (MLDF, 2014). According to recent reports, the number of fattened animals has increased by 13% from 155 206 in 2012/2013 to 175 000 cattle in 2013/2014 (MLDF, 2014). Most of the fattened animals are currently produced by the commercial sector with minimal contribution from the traditional system. However, a study by Mlote *et al.* (2013) has shown that most (93.5%) agro-pastoralists and pastoralists view beef cattle finishing as very important and are willing to practice it, although they are constrained by lack of fattening skills, credit, high fattening costs and scarcity of beef fattening feeds. Providing

feed to animals is a major cost in most beef production enterprises (Kelsey *et al.*, 2010) and therefore proper nutrition is a key component for successful beef production. High energy feeds such as maize grain have been successively used in many developed countries to produce high quality beef. It has been shown that feeding maize meal to beef cattle result into high growth performance (Gaebe *et al.*, 1998; Peter *et al.*, 2000) and good carcass characteristics (Andrae *et al.*, 2001). A study by Geurin *et al.* (1954) reported that steers gained up to 1.2 kg/d when fed on maize based diet. Despite the efficiency of maize grain in beef production its use in developing countries for beef cattle production is uneconomical mainly due to high cost of maize grain. Therefore alternative feed ingredients to maize grain are important to reduce the cost of beef production.

It is possible to reduce beef production costs by feeding balanced rations formulated from less expensive agro processing by products. Agro processing by products are the by products that remains after processing of main products (useful for human consumption) that originates from agriculture. Some of agro processing by products include hominy feed, rice polishing, molasses and cotton seed cake. Rice polishing is a by-product of rice (Paddy) milling and is the cheapest source of energy and protein for livestock feeding (Hossain *et al.*, 2011). It consists of the pericarp, seed coat, nucleus, aleurone layer, germ and part of sub-aleurone layer of starchy endosperm (Juliano, 1988). Hominy feed is a by-product of dry milling of maize grain, consisting of the bran coating and the maize germ and parts of starch particles (Pond *et al.*, 1995). Rice polishing and hominy feed can supply as much digestible nutrients as maize grain and can satisfactorily substitute part of maize grain in concentrate feed for beef production (Matz, 1991).

Hominy feed could substitute up to 45% of the maize grain in cattle finishing diets without compromising performance (Larson *et al.*, 1993). Rice by products has been used

as a source of energy on Bunaji bulls and found to yield high quality carcass with lean meat (less amount of fat) compared to maize by products (Sani *et al.*, 2014). Rice polishing has been found to give consistent results when combined with molasses and urea (Lopez and Preston, 1977).

Molasses is a good source of readily fermentable energy, which increases palatability of diets and binds feed to reduce dustiness in feeds with fine particles. It also has high concentrations of minerals such as calcium, magnesium, potassium, chlorine and sulfur (Stateler, *et al.*, 1995). Molasses has been shown to support growth rates in finishing beef cattle and can give high growth rates of about 1.1 to 1.5 kg/d for Brahman cattle (McCrabb *et al.*, 2000 and Hunter, 2012). Previous experiments have shown advantages in the rate of gain and dry matter utilization from addition of molasses to concentrate diets fed to beef cattle (Brown *et al.*, 1967; Cooper *et al.*, 1978). Another study by Tomkins *et al.*, (2004) showed that inclusion of molasses in feedlot diets increases the potential to produce lean meat without affecting meat quality. Molasses cannot be fed alone due to handling problems and possible toxic effect (such as blindness, excessive salivation and rapid breathing) if fed at very high levels (Van Niekerk, 1981). Hence it has to be mixed with other feed ingredients such as hominy feed and rice polishing.

Molasses is composed mainly of soluble sugars which rapidly ferment in the rumen giving rise to volatile fatty acids (VFA) pattern dominated by butyric acid (Oba, 2011). Butyric acid has stimulatory effects on rumen papillae size and length thus increasing absorptive surface area for nutrients (Moolchand *et al.*, 2013; Cooke, 2006). A study by Juma *et al.* (2014) on Zebu cattle has shown that animals that were supplemented with sugarcane molasses with cereal by products had long rumen papillae which increase absorptive surface area for nutrients. Maize grain is principally composed of starch which

ferments in the rumen giving rise to VFA pattern dominated by propionic acid which is a glucose precursor (Luc *et al.*, 2009). Furthermore, a portion of starch escapes the rumen fermentation, passing directly to the lower intestinal tract where it is digested and absorbed as glucose hence, increasing availability of glucose to the animal (Nagy and Leng, 1980; Peiris *et al.*, 1998; Luc *et al.*, 2009). The increased availability of glucose increases the energetic efficiency and metabolism of glucose resulting in greater fat deposition (Kristensen *et al.*, 2005) consequently influencing meat quality.

Meat quality is the term used to describe properties and perception of meat. It includes attributes such as carcass composition and conformation, eating quality of meat and health status (Maltin *et al.*, 2003). Cutrignelli *et al.* (2008) described meat quality as a set of attributes, related to hygienic, sensorial, structural, nutritional, and technological characteristics. Meat quality means different things to different people between or within countries/regions depending on their cultural background, personal experiences and location. Under Tanzanian context, meat quality refers to “fresh and warm” meat (slaughtered in the same day) without chilling or further processing into different meat cuts (Mushi *et al.*, 2007; Igbhinosa, 2011). More than 95% of domestic demand is for warm mixed meat and the remaining 5% is for high quality meat processed into special cuts and sometimes with proper packaging (UNIDO, 2012). But currently, the demand for this high quality meat which is chilled, processed into special cuts and properly packed is tremendously increasing due to expanding markets (Kamugisha, 2015).

Studies on meat quality have shown that TSZ cattle can produce high quality meat when fed maize meal and molasses diets (Mwilawa, 2012; Zakaria, 2010) however, only limited studies have been done to evaluate the quantity and quality of meat from TSZ cattle finished on diet based on agro processing by products.

Pre-slaughter factors that include nutrition, breed, age, sex, live weight, days on feed and post-slaughter conditions such as rate of rigor development and length of ageing time are among the factors influencing meat quality. Days on feed (period of stay in feedlot) depends on the type and amount of feed as well as the age of the animals (Shirima *et al.*, 2014). The use of young animals is more efficient and produces high quality beef, although it may take longer time to reach slaughter weight. This has an implication on cost of feeding as more feed will be used to the finishing period. On the other hand, the use of too old animals in feedlot may take short time to reach slaughter weight but the high amount of connective tissue (collagen) may be a source of meat toughness consequently reducing the quality of meat (Hopkins *et al.*, 2006). Increasing the number of days on feed for young animals has been found to increase final weight, carcass weight, marbling and fat thickness (Sugimoto *et al.*, 2012) as well as rib eye area and tenderness (Van Koevinger *et al.*, 1995; Stelzleni *et al.*, 2008; Shirima *et al.*, 2012). Thus, research is needed to determine the most appropriate period for TSZ cattle to stay in the feedlot and produce acceptable carcass yield and quality.

Meat tenderness is the most important component of meat quality that influences consumers' satisfaction (Melody *et al.*, 2004; Pen *et al.*, 2012). Meat tenderness is mainly affected by post-mortem process including ageing, which is the practice of holding meat at low temperatures allowing proteolytic enzymes to break down muscle fibres (Miguel *et al.*, 2011). Most changes in meat tenderness occur during the first seven days of ageing, but extending time after one week further improves meat tenderness (Brewer and Novakofski, 2008). Ageing can be used to decrease shear force values during post-mortem storage (Sanudo *et al.*, 2004) indicating improved tenderness of meat. However, limited research data are available with regard to tenderizing effects of ageing on meat produced from TSZ cattle fed on agro processing by products and kept on feedlot for

varying periods. Thus, this study aimed at evaluating the effects of different combinations of agro processing by products on growth performance, carcass characteristics and meat quality of TSZ cattle finished under different periods of stay in feedlot.

1.2 Problem Statement and Justification

1.2.1 Problem statement

Currently, there is a rising interest in production of quality meat in Tanzania, due to expanding markets comprised of tourism, mining industries, hotels and expatriates (Mushi *et al.*, 2007). This has created a huge demand for quality meat production (Kamugisha, 2015). The level of quality meat production in the country is very low at the moment despite the huge number of livestock. This is due to poor animal husbandry practices and lack of finishing strategies. More than 95% of meat produced in the country comes from traditional sector in which animals depend on rangeland forages which are in short supply and have low nutritive values. Few attempts have been done to improve the quantity and quality of meat produced from TSZ cattle using maize grain (Mwilawa, 2012; Luziga, 2005). A recent study on feedlot finishing and fattening in Tanzania has shown that the TSZ cattle responded well to fattening and produced acceptable carcasses when finished on maize meal with molasses based diet (Mwilawa, 2012). Another study by Luziga (2005) on TSZ cattle fed maize meal mixed with molasses for 90 days gave a growth rate of about 0.7 kg/day. Although the use of maize meal in combination with molasses to finish TSZ cattle has a great potential to improve meat quality and quantity its wide use is limited due to competition for the uses of maize grain between humans and livestock. Maize grain is a staple human food in Tanzania and other neighbouring countries, thus its use as feedlot diet can create scarcity of this grain as a result of increased demand. High demand of maize grain increases its price and this result into high production costs for a feedlot enterprise which depend on maize grain (Malope *et al.*,

2007). Thus, it is imperative to assess alternative and cost-effective energy-rich feeds which could be used in feedlot system in place of maize grain which is commonly used for human consumption. Hominy feed and rice polishing are the alternative cheap and readily available agro processing by products that are not consumed by human being and can replace maize grains in feedlot diets. But there is dearth of information on how the use of these agro processing by products influences growth performance, carcass characteristics and meat quality of TSZ cattle. Also there is limited information on the cost-effective use of these by-products and their ultimate impacts on growth performance, carcass yield and meat quality of TSZ. Some studies have been conducted in developing countries focusing on the effects of periods of stay in feedlot for exotic breeds (Van Koeveering *et al.*, 1995; Camfield *et al.*, 1997), but limited information is available for TSZ cattle. Thus, it was the interest of this study to evaluate the effects of different combinations of agro processing by products with molasses or maize meal and also to evaluate the effect of period of stay in the feedlot on growth performance, carcass characteristics and meat quality of TSZ cattle.

1.2.2 Justification of the study

Maize grain with 13.6 MJ ME/kg DM (Doto *et al.*, 2004) energy content has been widely used in developed countries as energy dense feedstuff for finishing beef cattle in feedlots. However, in developing countries including Tanzania, the use of maize grain in feedlot is not practical mainly because of its use as human staple food. Alternatively molasses, a by-product of sugar industry, with energy content of 12.7 MJ ME/kg DM (Drennan *et al.*, 1995) which is comparable to energy levels found in maize grains can be used in feedlots together with other agro processing by products hence, sparing the use of maize grains (Araba and Byers, 2002). Furthermore, there is a substantial amount of agro processing by products produced in the country from cereal grain mills, sugar and oilseed processing

factories which could also be used in feedlot to improve meat production in the country (Nandonde, 2008). However, the use of these feedstuffs in finishing TSZ cattle for the purpose of producing high quality meat is minimal and not well documented. The interest in using hominy feed, rice polishing and molasses as alternatives to maize grain has increased in recent years because of the nutritional values of these by products and the added advantage of reducing the cost of feeding (Freitas *et al.*, 2013). Obtaining high quality beef without creating competition with humans may be through the use of agro processing by products such as molasses, hominy feed, rice polishing and cotton seed cake which are all common and readily available in Tanzania with stable prices throughout the years (Nandonde, 2008).

Maximum use of agro processing by products in beef animal feedlot needs to be explored in Tanzania since substantial quantities of these products are wasted whilst their use in finishing cattle is minimal. The period of stay in feedlot is an important factor to consider in beef cattle fattening because it is associated with differences in response of cattle to feedlot diets, carcass composition and production cost (Owens and Gardner, 2000). This factor is important in determining the quality of meat produced as well as profitability of the feedlot enterprise. In view of the above, this study was carried out to assess the proper period of keeping TSZ cattle on feed in feedlot for profit maximization and quality meat production. The studies described in this thesis evaluated the quantity and quality of meat produced by TSZ under feedlot system using agro processing by products in order to recommend the most cost effective ways of cattle fattening in order to improve the performance of TSZ cattle. The study also assessed the effect of ageing time on meat tenderness and its impact on the quality of meat.

1.3 Study Objectives

1.3.1 Overall objective

To efficiently improve the quantity and quality of meat produced from TSZ cattle under different feedlot conditions.

1.3.2 Specific objectives

The specific objectives were:

- i. To assess the effect of diets based on either maize meal or molasses mixed with other agro processing by products on growth performance and carcass characteristics of TSZ cattle finished on feedlot.
- ii. To assess the effect of diets based on either maize meal or molasses mixed with other agro processing by products on the yield of standard cuts and meat quality of TSZ cattle.
- iii. To determine the appropriate period of stay in feed for optimal growth performance, carcass characteristics and meat quality of feedlot finished TSZ cattle.
- iv. To determine the optimum ageing time of meat from TSZ cattle finished under different conditions.

1.4 Research Hypothesis

The following hypotheses were tested:

- i. Molasses combined with other agro processing by products can substitute maize meal in feedlot diets without reducing daily live weight gain and carcass characteristics of TSZ cattle.

- ii. Molasses combined with other agro processing by products can substitute maize meal in feedlot diets without reducing meat yield and quality.
- iii. Prolonged duration in feedlot improves growth performance, carcass characteristics and meat quality.
- iv. Prolonged ageing period improves meat tenderness.

CHAPTER TWO

2.0 GENERAL METHODOLOGY

2.1 Study Location

The Feedlot study was carried out at the National Ranching Company (NARCO), Kongwa located about 82 km from Dodoma municipality. NARCO Kongwa is geographically located at 6° 03.810' S and 36° 27.296' E in Dodoma region and at an altitude of 1067 m above sea level. The area is semi-arid with mean daily temperature ranging between 23 and 32°C and receiving 254 – 660 mm of rainfall per annum. Slaughtering of animals was done at Dodoma Abattoir (DMA) located about 8 km from Dodoma municipality. Meat cut jointing was carried out at the mini abattoir located at Vocational Education Training Centre (VETA) in Dodoma municipality whereas tenderness and feed analyses were carried out at the Department of Animals Science and Production (DASP), Sokoine University of Agriculture in Morogoro municipality.

2.2 Management of Animals and Feeding of Agro Processing by Products Diets

In achieving objectives (i), (ii) and (iv), a total of forty five (45) Tanzania Shorthorn Zebu steers with the age of 2.5-3.0 years and 200 ± 5 (SE) kg mean body weight were randomly selected from a group of steers at Kongwa ranch. These animals were allowed to graze on the pasture available at the ranch area for a period of one month for backgrounding. The selected steers were randomly allotted to five dietary treatments, making a total of nine animals per treatment. The dietary treatments were maize meal mixed with molasses (MMMO) as a control, hominy feed with molasses (HFMO), rice polishing with molasses (RPMO), hominy feed with maize meal (HFMM) and rice polishing with maize meal (RPM). In addition cotton seed cake, minerals, salt and urea were added to each diet. Throughout the experimental period, each diet was fed to nine

animals which were housed in individual pens at Kongwa ranch feedlot structure (Plate 2).



Plate 2: Tanzania shorthorn Zebu cattle in feedlot at Kongwa ranch

The steers were individually fed on both grass hay and concentrate in separate feeders with access to clean drinking water for 90 days. During the feeding trial, data on growth performance and feed intake were collected.

At the end of the feeding trial, all steers were slaughtered at DMA and data on slaughter and carcass characteristics (Plate 3) were collected. The findings from this study are presented in the attached Manuscript 1.

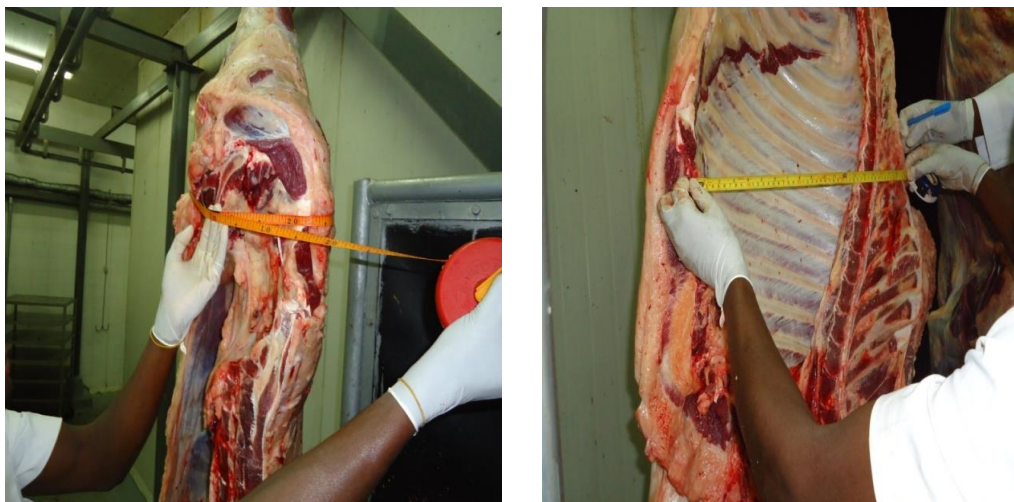


Plate 3: Carcass measurements from Tanzania shorthorn Zebu cattle at Dodoma abattoir

At the abattoir, measurements of some parameters on meat quality were done including muscle pH and temperature, which were measured on the 10th rib of the left side carcass in the *Longissimus thoracis et lumborum* (LL) muscle (Plate 4). After 48 h post-mortem, twenty five (25) right half carcasses were randomly selected among the carcasses of the 45 TSZ steers for retail cut jointing at the mini abattoir located at VETA training centre in Dodoma. The carcasses were divided into fore and hind quarters which were then jointed into nine bone-in retail cuts for hind quarter and eight for fore quarter. After 48 h post-mortem, the LL muscle was removed and samples for cooking loss (CL) and Warner-Bratzler shear force (WBSF) determinations were prepared. Four pieces, approximately nine cm long, from each LL muscle were cut, labelled and placed in a chiller room set at 0 °C for 3, 6, 9 and 12 days for ageing. At the end of each ageing time, samples were taken from the chiller room, vacuum packed in polythene bags and frozen at -20°C in a deep freezer for further analyses of CL and WBSF at the Department of Animal Science and Production (DASP) laboratory in Morogoro. Findings from this experiment are presented in Manuscript 2.



Plate 4: Temperature and pH measurements on carcasses

2.3 Management of Animals in Different Periods of Stay in Feedlot

In achieving objectives (iii) and (iv), a study was conducted and fifty (50) TSZ steers with the age of approximately 3 years and initial weight of 183 ± 4 (SE) kg were used. The study animals were selected from a group of steers bought by Kongwa ranch from different auction markets and farmers surrounding the ranch. The selected steers were randomly distributed into five treatment groups, each with ten steers. The treatments were periods of time the animals stayed on feed in the feedlot, which were P_0 = zero days, P_{25} = 25 days, P_{50} = 50 days, P_{75} = 75 days and P_{100} = 100 days. Ten steers from P_0 (grass-fed) as a control group were immediately transported by truck to DMA for slaughter. The remaining 40 steers were housed randomly in individual pens and assigned to their respective periods of stay in the feedlot. Grass hay and concentrate diet HFMO, made from hominy feed, molasses, cotton seed cake, mineral mix, salt and urea were offered on *ad libitum* basis to all animals in the feedlot using separate feeders. Clean drinking water was also provided on *ad libitum* basis. Data on body weight and feed intake were collected throughout the experimental period. At the end of each fattening period, ten animals from the respective treatment were taken to DMA for slaughter and data on

slaughter and carcass characteristics were collected. After 48 h post-mortem, samples of LL muscle from each animal were prepared for CL and WBSF determinations. Four pieces of LL from each animal were prepared for ageing in a chiller room set at 0°C for 3, 6, 9 and 12 days ageing time. After each ageing time, the samples were packed and frozen for tenderness analysis at DASP laboratory in Morogoro. Data collected are presented in Manuscript 3.

2.4 Economics of Finishing TSZ Cattle in Feedlot

Economic analysis of keeping TSZ cattle in feedlot at varying periods using different agro processing by products was performed based on biological background experienced from the two experiments described above and assumed different economic scenarios. The cost of production was obtained by summing up all variable and fixed costs of producing 1 kg of extra meat. The variable costs included feed cost and other non-feed costs, such as veterinary drugs and labour cost whereas the fixed costs included depreciation cost of building structure. Total profit per kg of extra meat produced was obtained from the difference between price of meat and the total cost of producing that meat. Profit per carcass was obtained by multiplying the profit produced per kg by the amount of extra meat produced while profit per feedlot space per day was obtained by dividing profit per animal carcass with number of days the animal spent in feedlot. Three scenarios were considered based on different assumptions which were made to mimic the beef market situation in Tanzania. The first scenario considered market price of meat at the time of carrying out the experiment. The second scenario considered when the price of meat was assumed to increase by 10% due to feedlot finishing independent of time length and the third scenario considered 5% meat price increase with each 25 days increase in feedlot finishing, mirroring increased quality of the carcass with increased weight gain during the feedlot period. The findings are presented in Manuscript 4.

CHAPTER THREE

3.0 THESIS FINDINGS AND DISCUSSION

3.1 Effects of Diets Based on Agro Processing by Products

3.1.1 Nutritional value of the diets

The ingredients used in compounding diets in the present study had crude protein (CP) content ranging from 41 to 337 g/kg DM, but the diets compounded had CP that ranged from 97 to 145 g/kg DM. The ME contents of the ingredients ranged from 9.0 to 13.3 MJ/kg DM while that of compounded diets ranged from 10.1 to 12.6 MJ/kg DM. The ME contents of the diets were within the range of 10 to 11.6 MJ/kg DM recommended by Rutherglen (1995), except for HFMM diet that had higher values due to inclusion of hominy feed and maize meal both had relatively high ME content.

The CP values for rice polishing were lower than the values reported by Doto *et al.* (2004) and Urassa (2012). Maize meal was also slightly lower in ME content whereas hominy feed had both higher CP and ME compared to those previously reported by Doto *et al.* (2004). However, the CP content of formulated diets were within the recommended range of 110 to 130 g/kg DM in finishing diets for fattening cattle (Gleghorn *et al.*, 2004; Dung *et al.*, 2013), except HFMM diet which its nutritive values were on the higher side (145 g CP/kg DM) and RPMO which had slightly lower CP values (97 g/kg DM). The wide variations in nutritive values of the experimental diets used in the current study and those in the literature are caused by the differences in the nutrient contents of the ingredients used in diet formulations in the previous studies and the actual values of such feedstuffs obtained after laboratory analysis in this study.

3.1.2 Feed intake and growth performance

Concentrate intake and metabolizable energy intake were higher for molasses based diets than for maize meal based diets. High intake on molasses based diets might be associated with palatability and binding effects of molasses which reduced dustiness of hominy feed and rice polishing. Molasses also ferments quickly in the rumen, resulting in very low rumen fill (Broderick and Radloff, 2004; Penner and Oba, 2009; Oba, 2011). Steers fed on molasses mixed with hominy feed (HFMO) diet had the highest ($P < 0.05$) live weight gains and heavier ($P < 0.05$) final weights than those fed on other diets (Plate 5). This could be explained by higher intake of energy and protein. Increased growth rate in response to increased energy intake was expected and has been reported previously in Africa (Asizua *et al.*, 2009; Shirima *et al.*, 2012; Mwilawa, 2012) and in Asia (Xuan Ba *et al.*, 2008; Tangjitwattanachai and Sommart, 2012). The present study also confirmed a fairly linear relationship ($r = 0.71$) between growth rate and ME intake as shown in Manuscript 1 Figure 2. From the same Figure 2, the daily weight gain (g) = $Y = 14.9x - 388$, from this equation it can be interpreted that for 1 MJ above maintenance the animal will grow 14.9 g. But for the animal to grow one kg per day then 67.1MJ is needed (i.e $1000/14.9$). Further, the point where the line crosses the X-axis (i.e $Y = 0$) can be regarded as maintenance requirement (this is an assumption that the graph can be extrapolated).

Thus maintenance requirement will be 26.0 MJ/day where $Y = 14.9x - 388 = 0$. The NRC (2000) shows the energy requirement for Angus cattle to be 48.07 MJ ME/d with maintenance requirement of 24.06 MJ ME/d for a 200 kg live weight cattle gaining at one kg daily. Further more for steers in most central African countries the requirement has been shown to be 55.1 MJ ME /day and maintenance requirement of 26.5 MJ ME/d for a 200 live weight steer gaining at one kg per day (Topps and Oliver, 1993). Slight

variations between the calculated requirements from the current study and those reported from literature might have been caused by the experimental errors.

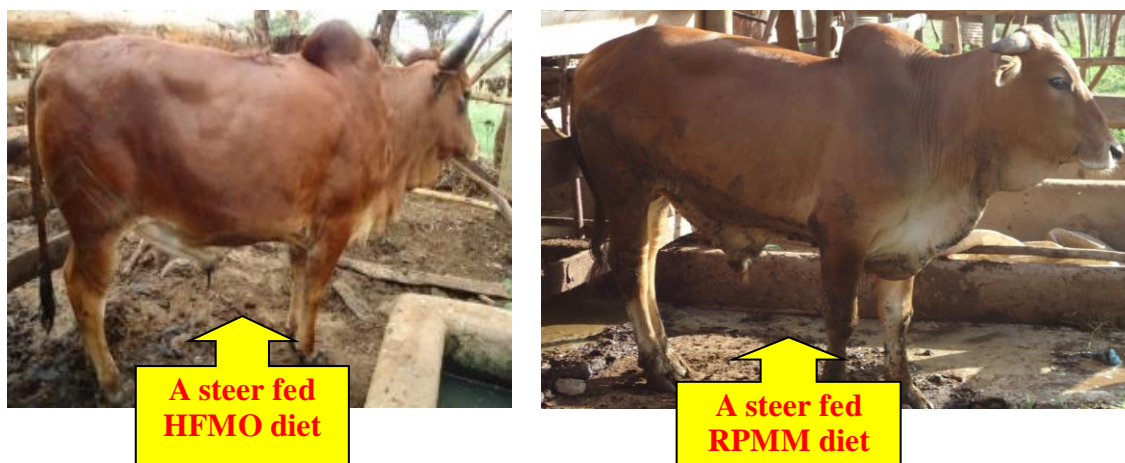


Plate 5: Tanzania shorthorn Zebu cattle fed HFMO and RPMM diets in feedlot

The average daily weight gains of steers in the present study (658 to 919 g/day) are slightly higher than the gains (600 to 833 g/day) reported by Luziga (2005) and Mwilawa (2012) for TSZ steers fed on high molasses based diets. Efficiency of converting feed to body tissue was higher ($P < 0.05$) for steers fed on HFMO (8.09) and HFMM (7.87) than for those fed on other diets, probably due to the relatively high intake of both energy and protein caused by high digestibility of the diets. Hominy feed was more efficiently converted into weight gain than rice polishing. Only eight kg of feed were used to produce one kg weight gain when hominy feed was used compared to eleven kg of feed used to produce one kg weight gain when rice polishing was used. When molasses or maize meal was used the same amount of feed ten kg was required to produce one kg weight gain (Manuscript 1). When energy requirement for gain was assessed, animals fed on hominy feed required 93 MJ ME/kg weight gain while those fed on rice polishing required 108 MJ ME/kg weight gain. From the energy values obtained in the current study, it means 1.5 kg of rice polishing was needed to give the same energy as one kg of

hominy feed, also one kg of molasses was needed to give the same energy as one kg of maize meal.

In conclusion, molasses based diets were more efficient than maize based diets in promoting gain in steers probably because of the influence of both soluble sugars from molasses and starch from hominy feed or rice polishing. Fermentation of soluble sugars is known to give rise to butyric acid (Luc *et al.*, 2009), which is metabolised by the ruminal epithelia to ketones, beta-hydroxybuterate and acetones which are further oxidized by cardiac/skeletal muscles or used for fatty acid synthesis by adipose tissue (Perry and Cecava, 1995; McDonald *et al.*, 2002). On the other hand, the fermentation of starch from hominy feed or rice polishing gives rise to propionic acid which is directed to glucose synthesis in the liver (Cooke, 2006). In addition, a proportion of starch from hominy feed and rice polishing might have escaped ruminal fermentation thereby increasing glucose availability to steers for tissue utilization (Luc *et al.*, 2009). Studies have shown that the efficiency of molasses utilization is improved if the shortage of glucose precursor can be overcome by supplying small amounts of starch sources in the diet to increase ruminal propionic acid concentration and provides additional glucose for absorption from the small intestine (Preston and Leng, 1987; Nagy and Leng, 1980; Peiris *et al.*, 1998).

3.1.3 Slaughter and carcass characteristics

The results also showed that steers fed on HFMO diet had the highest ($P < 0.05$) hot carcass weight (151 kg, HCW) and empty body weight (268 kg, EBW) compared to the steers fed on other diets. The relatively higher slaughter characteristics can be caused by the relatively higher final live weight and lower proportion of the gastro intestinal tract (GIT) content observed on steers fed on HFMO compared to their counterparts. The observed values of EBW are within the range of 263 to 269 kg reported for other zebu

cattle finished under feedlot (Michael *et al.*, 2001; Mwilawa, 2012). The dressing percentage (DP) differed ($P < 0.05$) among steers fed on RPMO, HFMM and RPMM diets with the latter having the lowest mean values. The observed lower DP for steers fed on RPMO and RPMM than of those on MMMO was due to high GIT contents in animals fed on RPMO and RPMM diets when compared to MMMO diet. High GIT content for steers fed diets containing rice polishing (RPMO and RPMM) could be caused by slower passage rate through the GIT due to their relatively high CF contents. The observed DP were within the range of 51 to 53 % reported for Nguni steers (Muchenje *et al.*, 2008; Mapiye *et al.*, 2009), but were higher than the DP of 49 to 50.5% reported for Zebu cattle (Michael *et al.*, 2001; Nalaila, 2005). This was probably due to different diets and feeding systems used, which contributed to differences in GIT contents.

3.1.4 Carcass yield and composition

The dietary treatments were found to have little influence on the yield of different meat cuts. However, when comparisons were made between diets, it was observed that molasses based diets were superior to maize meal diets, and hominy feed was better than rice polishing. The weights of hind and fore quarter, saleable cuts, prime and non-prime cuts as proportion of half carcass weight did not differ ($P > 0.05$) between dietary treatments despite the differences in half carcass weight. It was observed that the amount of trimmed fat increased with increase in growth rates. The animals with the highest growth rate (919 g for HFMO steers) had higher amount of trimmed fat than the animals with the lowest growth rate (639 g for RPMM steers) by 65% (Manuscript 2). The amount of trimmed fat was found to affect the yield of saleable cuts negatively. Increased amount of trimmed fat lowered the amount of saleable cuts, which implies economic losses since excess fat deposits are not part of usable carcass (Kitts, 2011). It is economical and more practical to keep animals that grow faster for a short time in the

feedlot to avoid excess fat. The lack of dietary effects on yield of different wholesale cuts agrees with observation reported in other studies on beef cattle (Fadol and Babiker, 2010; Turki *et al.*, 2011; Duarte *et al.*, 2011) and sheep (Moeini *et al.*, 2013; Suassuna *et al.*, 2014).

Steers fed on HFMO diet had the highest ($P < 0.05$) proportion of internal fat and hind limb circumference followed by those fed on HFMM diet. The general trend showed that carcasses from steers fed on molasses mixed with hominy feed (HFMO) tended to have higher fat thickness levels than those fed on maize meal based diet with rice polishing (RPMM). The observed high hind limb circumference and fat thickness reflects superiority in conformation score associated with high intake of energy. In general, carcasses from all treatments had higher fat contents (21.4 to 27.1%) than the recommended range of 10 to 15% of total carcass weight (Syrstad, 1993), although the preference for fat content vary depending on place and culture.

A study by Kamugisha (2015) on quality beef supply chain efficiency and consumption of quality beef in Tanzania showed that customers from Arusha prefer beef with relatively high fat content than customers from Dar-es-salaam. The observed proportion of dissectible lean (55 to 60%), fat (20 to 27%) and bone (17 to 23%) in the present study are in agreement with the range of lean (56 to 63%), fat (17 to 27%) and bone (16 to 27%) previously reported by Luziga (2005) and Mwilawa (2012) for TSZ steers fed on molasses based diets. From the observed results, it can be concluded that diets formulated based on molasses are superior in finishing Tanzania short horn zebu (TSZ) cattle compared to those formulated based on maize meal in terms of ME intake, growth performance and carcass characteristics.

3.1.5 Meat quality attributes

With regard to meat quality attributes, there was no difference ($P > 0.05$) between dietary treatments on post-mortem muscle temperature and pH decline (Manuscript 2). Lack of dietary effect on pHu values for concentrate fed cattle observed in the present study is in agreement with the findings from other studies (Mapiye *et al.*, 2010; Lage *et al.*, 2012), indicating sufficient glycogen content in the muscles. The average pHu of 5.67 for carcasses in the present study is within the normal and optimal quality range of 5.5 to 5.8 (Silva *et al.*, 1999; Mach *et al.*, 2008). In the present study, the values of cooking loss (CL) and Warner Bratzler shear force (WBSF) for *Longissimus thoracis et lumborum* (LL) were not ($P > 0.05$) influenced by dietary treatments, but were affected ($P < 0.05$) by ageing time. The meat samples from cattle in all treatments were considered tender as the observed WBSF values were less than 50 N (Devitt *et al.*, 2002) and all values are within the range of 41.8 to 50.9 N reported by Mwilawa (2012) on carcasses of TSZ steers fed on concentrate diet. Muscle samples aged for 3 days had higher ($P < 0.05$) values of CL and WBSF compared to the muscles aged for 6, 9 and 12 days. The observed lowest values for both CL and WBSF on meat aged for 9 and 12 days may be associated with enzymatic reactions that disintegrate myofibrillar proteins leading to increasing myofibrillar volume with increasing ageing time (Jama *et al.*, 2008; Ba *et al.*, 2014).

It was observed that dietary treatment and ageing time were two factors that independently affected meat quality characteristics, but jointly influenced the WBSF values which were lower for carcasses from HFMO diet and aged for 9 days. From the observed results, it can be concluded that finishing TSZ cattle on diets based on agro processing by products improved meat quality with no effects on weight of different cuts. Feeding HFMO as finishing diet and ageing meat for nine days could be the most appropriate conditions for producing tender meat from the TSZ steers.

3.2 Effects of Period of Stay in Feedlot

3.2.1 Feed intake and growth performance

The results also showed that steers which stayed in feedlot for a long period (P_{100} days) had the highest ($P < 0.05$) average daily dry matter intake (DMI), followed by those which stayed for 75 (P_{75}), 50 (P_{50}) and 25 (P_{25}) days (Manuscript 3). The DMI as percent of body weight ranged from 2.87 to 3.29 and increased ($P < 0.05$) gradually from shorter (P_{25}) to longer (P_{100}) periods in feedlot. Daily energy and protein intake also increased with advanced number of days in feedlot. Increased daily feed intake with increasing days in feedlot might be caused by the increased live weight, because feed requirements for animals on similar diets are normally considered to be a function of live weight or metabolic body weight (Mustafa *et al.*, 2008; Shirima *et al.*, 2014). It was also observed that growth rate (g/d) was not affected ($P > 0.05$) by days in feedlot. Due to constant live weight gain, there was nearly a linear increase in final live weight and total gain with increasing days in feedlot. The periods of stay in feedlot had no significant effects on feed conversion ratio though the general trend showed that efficiency of feed utilization decreased with prolonged periods of stay in feedlot. This might be caused by increased fat deposition with advanced days of stay in feedlot which requires more feed to produce more energy for fat to be deposited.

3.2.2 Slaughter characteristics and carcass composition

The empty body weight (EBW) increased ($P < 0.05$) from 163 kg (P_0) to 263 kg (P_{100}), implying 61% increase in weight from grazing only (no feedlot, P_0) to 100 days in feedlot. Hot carcass weight (HCW) increased ($P < 0.05$) with increasing days in feedlot. There was an increase of 59 kg (65%) from P_0 to P_{100} and only 13.4 kg (15%) from P_0 to P_{25} . Increased EBW and HCW with increased days in feedlot were caused by superior gains resulting from higher intake of energy from concentrate diet. Intake of any

particular ration with high energy content promotes high body weight gain, which produces fatter carcass and heavier carcasses (Mandell *et al.*, 1998; Sami *et al.*, 2004; Shirima *et al.*, 2014). Increased carcass weight for steers which stayed for a longer period in feedlot was expected because animals were still growing to attain their mature weight, which was estimated to be in the range of 200 - 300 kg (Mpiri, 2004; Das, 2009). Increase in EBW could be explained by the corresponding changes in final live weight and decrease in gut fill due to prolonged concentrate feeding (Mushi *et al.*, 2009; Shirima *et al.*, 2012). The dressing percentage (DP) increased with increasing period of stay in feedlot and ranged from 50 to 54% with P₁₀₀ steers having higher ($P < 0.05$) values than the other groups. This was associated with higher dietary energy consumption, which in turn resulted into higher slaughter weight and increased fatness.

The proportion of non-carcass parts (as percent EBW) decreased ($P < 0.05$) with increasing days in feedlot except for internal fat, which increased with increase in days of stay in feedlot, reflecting higher intake of energy, which is expected to increase fat mass. The proportions of external organs (head, hide, feet, tail and anus) were higher ($P < 0.05$) for grazing animals and for those which stayed for short periods in feedlot (P₂₅) and it decreased with days of stay in feedlot. This conforms to the nature of development of non carcass components which are early maturing tissues, and their proportions decline with advanced age (Lawrence and Fowler, 1997). The results also showed that all carcass measurements increased ($P < 0.05$) with increasing days in feedlot, reflecting growth of both soft and skeletal tissues (Lawrence and Fowler, 1997). Increased *longissimus* muscle area (LMA) with extended feeding period implies increased muscle development for steers kept in feedlot for longer time compared to those directly from grazing. The proportion of internal fat for steers on P₁₀₀ was higher than those under grazing only (P₀).

Also an increase of 10.1 mm fat thickness was observed on carcasses of steers under P₁₀₀ compared to those on grazing only (P₀). This difference was caused by the prolonged intake of high energy diets by steers on feedlot. Intake of energy above the maintenance requirements of the animal is the most important factor affecting the deposition of subcutaneous fat (Sainz and Paganini, 2004). In the present study, the addition of 25 days from P₇₅ to P₁₀₀ increased fat thickness by 4 mm, which is considered as waste because it is undesirable attribute to many beef customers and has to be trimmed off. The current study further showed that steers which stayed for longer periods in feedlot (P₁₀₀) had higher ($P < 0.05$) proportion of fat than those which stayed for shorter period (P₂₅) and those under grazing only P₀ (Plates 6).

Linear increase in carcass fat with increasing days in feedlot is in agreement with Keane and Maloney (2008) who studied the effect of management on beef steers and van der Westhuizen (2010) and Shirima *et al.* (2012) who assessed the effect of period of stay in feedlot on sheep. Steers that stay for a prolonged period in feedlot consume higher amounts of feed which are usually high in energy content thus deposited fat at a higher rate than the pasture fed steers (Sainz and Paganini, 2004; Tabitha, 2012). Excess fat needs to be trimmed off, implying economic loss to beef producers. Fat is very expensive because its deposition requires more energy than protein/lean deposition hence more feed is required to produce a kilogram of fat. Energetically, efficiency of accretion of fat is approximately 1.7 times that of protein but because more water is stored when protein is deposited than when fat is deposited the gain of lean tissue is four times as efficient as accretion of fat tissue (Owens *et al.*, 1995; McGee 2014). Prolonged finishing/fattening period leads to deterioration of feed efficiency while the feed cost per kg live weight and carcass gains increase. Thus, it is necessary to avoid prolonged finishing/fattening periods while ensuring that animals achieve minimum carcass fat contents without affecting

carcass value, hence reducing feed requirements and costs. This can be achieved by putting TSZ cattle in feedlot and feeding them concentrate for only 75 days.



P₀ (direct from grazing no feedlot)

Final slaughter weight = 183 kg

Hot carcass weight = 91.6 kg

Dressing percentage = 50%

Lean percentage = 62.5%



P₁₀₀ (100 Days in feedlot)

Final slaughter weight = 278 kg

Hot carcass weight = 151 kg

Dressing percentage = 54.3%

Lean percentage = 55.8 %

Plate 6: Carcasses of Tanzania shorthorn Zebu steers before and after feedlot finishing

Carcasses from steers under grazing only (P₀) had higher ($P < 0.05$) proportions of lean (6.7%) and bone (6.4%) than those from steers under P₁₀₀ group. The higher proportion of bones from the steers under grazing only was caused by their carcasses being thin as a result of poor quality forage available in the rangelands. For animals under poor nutrition conditions, loss of weight occurs and fat is the first to be affected, followed by muscle while bone is the least affected (Keane and Maloney, 2008; Mushi *et al.*, 2009; Safari *et al.*, 2010). Steers which stayed for a longer period in feedlot had carcasses with lower

($P < 0.05$) lean: fat ratio than the carcasses of steers from grazing only (P_0). This reflects the increase in accumulation of fat with increase in days of stay in feedlot caused by prolonged energy intake. Animals receiving high energy levels accumulate greater amount of fat in their carcasses which lowers lean: fat ratios (Fadol and Babiker, 2010; Shija *et al.*, 2013). The proportions of carcass components in the current study were slightly lower for lean, but higher for fat and bone than the range for lean (63 to 67%), fat (14 to 20%) and bone (17 to 20%) reported in Boran and TSZ steers (Shija *et al.*, 2013). These differences could have arisen from differences in the diets and age of the animals used in the two studies. Generally cattle sold in livestock markets and entering feedlots for fattening in Tanzania are usually with the age of above 6 years and most of them are in poor body conditions due to feeding on poor quality pasture from rangelands (Nandonde, 2008; Mlote *et al.*, 2012). Thus when very old cattle are used in fattening, they produce tougher meat with higher fat content because the excess energy results into fat deposition (Zakaria, 2010).

3.2.3 Meat quality attributes

The results show that the pH of carcasses of steers under feedlot (P_{25} to P_{100}) declined faster ($P < 0.05$) than of those from steers under grazing only (P_0) whose pH values remained above 6 even after 24 h post mortem. This shows depletion of muscle glycogen caused by stress and poor nutrition status of grazing animals before slaughter. Poor pre-slaughter nutrition and stress are among the factors known to deplete muscle glycogen reserve of animals before slaughter (Mushi *et al.*, 2009; Shirima *et al.*, 2013). If glycogen is depleted the extent of post mortem acidification is reduced (high ultimate pH) leading to the production of dark-firm-dry (DFD) meat (Frylinck *et al.*, 2015). The rate of temperature decline was faster ($P < 0.05$) in the first 6 and 24 h post mortem than afterwards. Higher carcass temperatures observed in steers which stayed in feedlot for

longer period could be associated with the increase in carcass fat content since fat acts as an insulator against cooling. Monitoring temperature and pH decline early *post mortem* is useful to enable the diagnosis of pale, soft and exudative (PSE) or dark, firm and dry (DFD) phenomena which result from the combination of rapid pH decline and high temperature in postmortem muscle. Meat with DFD or PSE are prone to spoilage due to rapid bacterial growth and has poor sensory qualities (Frylinck *et al.*, 2015).

Cooking loss (CL) was another meat quality parameter which was affected by number of days in feedlot. Steers on P₁₀₀ and P₇₅ had the lowest ($P < 0.05$) CL values, due to lower water content in the muscles which increases with increase in muscle fatness. Cooking loss is strongly associated with fibres shrinkage which causes loss of meat liquid which results in mass loss (Wyrwisz, 2012). Losses from good quality meat tend to be less than those from poor quality meat (Mitsumoto *et al.*, 1992; Ueda *et al.*, 2007), although the former lose more fat (in view of their greater fat content) but less moisture possibly because of the structural changes caused by the presence of the fat enhancing water-holding capacity (Lawrie and Ledward, 2006). Ageing time had no effect ($P > 0.05$) on cooking losses, but the trend showed decreased cooking loss with increasing ageing time. Increase in days of stay on feedlot was found to decrease values of WBSF. The highest ($P < 0.05$) values were observed for muscles from steers on grazing only (P₀) and those which stayed on feed for shorter periods (P₂₅), probably because of fatness levels which are known to influence tenderness of muscles (Shirima *et al.*, 2013). High value of WBSF for grazing animals compared to concentrate fed animals kept in feedlot has also been reported by Muchakila *et al.* (2014).

The WBSF values decreased ($P < 0.05$) by 35% with increasing ageing time and the least value was observed after 12 days of ageing. The more tender meat was obtained from

steers which stayed in feedlot for P₁₀₀ days and their meat aged for 12 days. Ageing increases tenderization by weakening the structural integrity of the myofibrillar proteins (Hanzelkova *et al.*, 2011; Ba *et al.*, 2014). The increase in meat tenderness for feedlot finished steers as compared to grazing steers has also been reported in the study by Muchakila *et al.* (2014). Meat from grazing animals had low sensory scores for meat quality attributes (such as aroma, juiciness, texture) and overall acceptability when compared to feedlot finished animals (Muchakila *et al.*, 2014). In general, the meat quality parameters for cooked muscles together with other parameters of steers that stayed in feedlot under P₁₀₀ and P₇₅ days were similar. Thus, 75 days of fattening was found to be an ideal period for TSZ cattle to stay in the feedlot since longer stays to 100 days did not increase meat quality attributes of tenderness, but only increased fat thickness.

3.3 Economics of Finishing TSZ Cattle in Feedlot

3.3.1 Derived meat production and energy intake during feedlot finishing

The economic analysis based on simulations of the biological results obtained from the two experiments showed that steers which stayed for short period in feedlot (25 days) with low MEI (55 MJ/day) gained only 11 kg compared to those on grazing only (0 days). This value was doubled (22 kg) for steers on high MEI (85 MJ/day) for the same period of 25 days. Steers on high MEI (85 MJ/day) required only 25 days to attain slaughter weight of 212 kg, a value which required 50 days for animals on low MEI (55 MJ/day). Thus, feeding high energy diets was essential to enable high MEI for rapid body weight gains. The calculated carcass weight increased with increasing energy intake and days of stay in feedlot. Long stay in feedlot (100 days) with high MEI resulted into 58% increase in carcass weight compared to low MEI for which carcass weight increased only by 25%. The amount of extra meat produced from steers on high MEI in all periods of stay in feedlot was more than twice the amount produced from steers on low MEI, showing the

importance of both feed intake and energy concentration of feedlot rations for successful feedlot beef production (Manuscript 4).

3.3.2 Variable and fixed cost of production

The cost values were higher for steers on low MEI than for those on high MEI. Feed cost per extra unit of meat produced from steers on low MEI was increasing as the number of days in feedlot increased, whereas for steers on high MEI the feed cost per extra unit of meat was decreasing with advancement of days in feedlot. This indicates the importance of the use of high energy diets to animals with high intake in order to reduce cost of production. Providing feed to animals is known to be a major variable cost in any beef production project (Herd *et al.*, 2003; Arthur and Herd, 2008). Feed cost contributed more than 50% of total production cost and its percentage increased while that of non-feed decreased with advancement in days of stay in feedlot, but the use of high energy diets and animals with high intake and longer stays in feedlot reduced total cost by 84%.

3.3.3 Profitability analysis in different scenarios

For a scenario where meat prices do not change with feedlot finishing time, it was a loss to keep animals with low MEI in feedlots, whereas for animals with high MEI optimum profit was achieved for a period of between 50 and 75 days of stay in feedlot. Extending the period of stay in feedlot to 100 days resulted into a profit increase but at a decreasing rate. Based on the assumed economic scenarios that the price of meat from feedlot was increased by 10% without considering the length of feedlot finishing time, the profit per kg meat decreased with increase in period of stay in feedlot. This implies that the increase in price of a kg of meat produced was not large enough to offset the cost incurred in producing that extra kg of meat for the steers which stayed for longer period in feedlot. On the other hand, profit per animal carcass was found to increase for steers on high MEI,

but decreased for steers on low MEI, and this was caused by the increase in carcass weight gained. It is the increase in value per kg of the whole carcass during feedlot finishing that offsets the production cost and gives rise to the observed profit (Weisbjerg *et al.*, 2007). When meat price was increased by 5% for each 25 days increase in the duration of stay in feedlot the profit also increased for steers on high MEI having higher values than those on low MEI in all periods of stay. This might be contributed by the extra carcass weight produced from high energy diets.

Thus, the most economical feeding practise irrespective of meat price and finishing period is always feeding high energy diets. The optimum finishing length depends on several factors including consumer's preferences, the price they are willing to pay and the factors that limit production. If the feedlot capacity is limiting and consumers prefer less fat animals it may be economical to finish animals for 25 – 75 days, but for obtaining high final weights 50 – 75 days is the best. Therefore, the appropriate economical period to keep TSZ in feedlot is between 50 and 75 days using diets with high energy and animals with high intake.

The present study was done under intensively managed (feedlot finishing) system where cattle were kept in a confined structure and provided with concentrate diets. If the price of meat produced from this production system does not change the system becomes uneconomical. Alternative to this is a semi intensive system where cattle are supplemented with concentrate diets after grazing (Mwilawa, 2012). Supplementation to grazed cattle is a low cost strategy with very low requirements for other investment costs compared to intensive feedlot finishing system. Supplementation to grazing system boost the yield and quality of meat produced compared to grazing alone system (Mapiye *et al.*, 2010; Asizua, 2010; Mwilawa, 2012). Supplementation effects to pasture fed cattle are

highly pronounced during dry season unlike in wet seasons where very little effects are observed due to high quality and quantity of available pasture (Mwilawa, 2012). A study by Randby *et al.* (2010) showed that with high quality pure grass silage the difference in weight gains between concentrate supplemented and un supplemented cattle was very low, implying that with very high quality pasture concentrate supplementation is not necessary. Thus, supplementation to solely pasture fed animals especially during dry seasons could provide a cost effective alternative to intensive feedlot finishing in situations where price of meat does not change with improved quality of meat produced.

3.4 Conclusions

In conclusion, the current study has revealed that molasses together with other agro processing by products mainly hominy feed can substitute maize meal in feedlot diets without reducing weight gain, carcass characteristics, meat yield and quality. Therefore, hominy feed is an alternative agro processing by product that can successfully replace maize meal in feedlot finishing diets for TSZ cattle. This study has shown that long period of stay in feedlot improves growth performance, carcass characteristics and meat quality with increasing fat content of TSZ. Thus for reducing the excess fat content produced the TSZ with average weight of 180 kg and 3 years of age should be kept in feedlot for 75 days in which they will produce quality meat with reasonable fat content. Also it has been found that prolonged ageing time improves meat tenderness. Thus, meat produced from TSZ cattle fed on molasses and agro processing by products need to be aged for 9-12 days for quality tender meat.

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CHAPTER FOUR

4.0 PAPER 1

Growth performance and carcass characteristics of Tanzania Shorthorn Zebu cattle finished on diets based on molasses or maize grain with rice or maize by-products

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**Growth performance and carcass characteristics of Tanzania Shorthorn Zebu cattle
finished on molasses or maize grain with rice or maize by-products**

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ABSTRACT

Forty five steers (2.5-3.0 years of age and 200 ± 5 (SEM) kg body weight) were allotted randomly into five dietary treatments to assess the effects of finishing Tanzania Shorthorn Zebu (TSZ) cattle in feedlot using either molasses or maize grain together with maize or rice by-products based diets. The diets consisted of hay and concentrate mixtures fed *ad libitum* and with free access to drinking water. Concentrate mixtures were hominy feed with molasses (HFMO), rice polishing with molasses (RPMO), hominy feed with maize meal (HFMM), rice polishing with maize meal (RPMM) and a control of maize meal with molasses (MMMO). All concentrate mixtures contained cotton seed cake, mineral mixture, salt and urea. Each diet was offered to nine steers for 90 days. Feed intake, body weights and carcass characteristics were recorded. The daily total dry matter intake (DMI) was greater ($P < 0.05$) in molasses based diets (7.64 kg DM/day for RPMO and 7.35 kg DM/day for HFMO) than in maize grain based diets. Energy intake was highest ($P < 0.05$) in HFMO (86 MJ ME/day) and lowest in RPMM (69 MJ ME/day). Crude protein intake was highest in HFMO (867 g/day) and lowest in RPMO (725 g/day). Feed conversion ratio (kg feed DM/kg gain) was lower ($P < 0.05$) for steers fed on HFMM (7.87) and

HFMO (8.09) than those fed on MIMO (10.4), RPMM (11.0) and RPMO (11.5). Steers fed on HFMO had the highest ($P<0.05$) daily weight gain (919 g/day), total weight gain (83 kg), final live weight (283 kg), empty body weight (268 kg) and hot carcass weight (151 kg). In addition hind limb circumference (94.5 cm) and proportion of the internal fat (2.7 %) from steers fed on HFMO were higher ($P<0.05$) than those from other diets. There was no difference ($P>0.05$) observed on physical carcass composition between the diets. However all carcasses showed relatively high fat cover (1.1 – 1.6 cm). It is concluded that agro processing by products are good feed resources for finishing TSZ cattle in feedlots with molasses based formulations being superior over maize meal based and hominy feed superior over rice polishing. A combination of molasses and hominy feed (HFMO) gave the highest ME intake, feed conversion efficiency, growth performance and carcass characteristics from TSZ, thus hominy feed could be used successfully as an alternative to maize meal to finish TSZ cattle in feedlot.

Keywords: Weight gain, carcass characteristics, feedlot, agro processing by products.

1 Introduction

Tanzania Shorthorn Zebu cattle (TSZ) make up 95% of the total cattle population in Tanzania and are mainly used for beef production. The herd is extensively managed on rangelands and is heavily affected by seasonal variation in feed supply. Finishing TSZ in feedlots using locally available protein and energy agro processing by products could be a cost-effective option for improving their growth and carcass characteristics. Many agro processing by products such as hominy feed, rice polishing, cotton seed cake and molasses have substantial value as feedstuffs for ruminants (Sindhu et al., 2002). Rice polishing and hominy feed provide both energy and protein and have been found to give consistent results in ruminants when combined with molasses and urea (Lopez and

Preston, 1977; Larson et al., 1993). Tanzania produces substantial quantities of agro processing by-products from cereal grain mills, sugar and oilseed-processing factories (Nandonde, 2008). However, the potential use of these feedstuffs for finishing TSZ cattle in Tanzania is not well documented.

Maize grain is an energy dense feedstuff with 13.6 MJ ME/kg DM (Doto et al., 2004) and is commonly used in feedlot rations in developed countries giving high growth performance (Peter et al., 2000; Gaebe et al., 1998) and good carcass characteristics (Andrae et al., 2001). The major limitation to its use for cattle fattening in Tanzania is the competition with humans for food and its high cost. On the other hand, molasses has high potential to replace maize grains in feedlot diets for beef cattle as source of readily fermentable energy, having 12.7 MJ ME/kg DM comparable to levels found in maize grains (Drennan et al., 1995). Studies using molasses on Brahman cross and Laisind steers have shown high growth rates of 1.06 and 0.73 kg/day, respectively (McCrabb et al., 2000; Cuong et al., 2010). Another study by Hunter (2012) has shown gains of up to 1.4 kg/day by Brahman steers fed on diet with 45 % molasses. Although the use of maize meal in combination with molasses to finish TSZ cattle has been successful in Tanzania (Mwilawa, 2012), there is a need for alternatives to maize meal to reduce feed costs and competition with humans. The aim of this study was to evaluate the effects of different combinations of agro processing by products with molasses or maize meal on growth performance and carcass characteristics of TSZ cattle finished under feedlot.

2.0 Materials and methods

2.1 Site description

The study was carried out at Kongwa National Ranch, located 82 km from Dodoma municipality at an altitude of 1067 m above sea level. The area is semi-arid, receiving 254

– 660 mm of rainfall per annum and mean daily temperature range between 23 and 32°C. The vegetation is mainly grass such as Star grass (*Cynodon plectostachyus*), Rhodes grass (*Chloris gayana*), African foxtail grass (*Cenchrus ciliaris*), Urochloa (*Urochloa mosambiensis*) and Purple three-awn (*Aristida purpurea*) and few legumes mainly Blue-pea (*Clitoria ternatea*) and Tropical Kudzu (*Pueraria phaseoloides*) with some shrubs of acacia spp.

2.2 Experimental design and treatments

A completely randomized design was used in which forty five (45) TSZ steers were randomly allotted to five dietary treatments making a total of nine animals per treatment. The treatments were five diets compounded to contain molasses or maize meal with rice or maize by-products. The molasses based diets were composed of either hominy feed (HFMO) or rice polishing (RPMO) whereas, the maize meal based diets consisted of hominy feed with maize meal (HFMM) or rice polishing with maize meal (RPM). The maize meal mixed with molasses (MMMO) acted as the control diet.

2.3 Source of experimental animals

Forty-five steers (2.5-3.0 years of age, 200 ± 5 (SEM) kg body weight) were selected from a group of Tanzania shorthorn zebu cattle (TZS) purchased from auction markets in Dodoma region and kept at Kongwa ranch. These animals were allowed to graze on the pasture available at the ranch area for a period of one month for back grounding and were vaccinated against Contagious Bovine Pleural Pneumonia (CBPP) and Foot and Mouth Disease (FMD). They were also dewormed with oral albendazole 10% (Batch No. 1106, Eagle Vet. Tech. Co. Ltd. Chungnam, Korea), with a dosage of 7.5 mls per 50 kg body weight at the start of experiment and thereafter external parasites were controlled by

hand spraying the animals using Vectocid[®] (Batch No. 5209, ceva santeanimale la ballestriere, libourne cedex France, dilution 1ml in 1 liter of water) after every 10 days.

2.4 Sources of experimental feedstuffs and formulations

The grass hay was a mixture of grass with few legumes harvested from the pasture farm at Kongwa ranch. The ingredients for concentrate mixture were molasses purchased from Mtibwa sugar estate, maize meal, hominy feed and rice polishing purchased from Kibaigwa grain market, Dodoma, cotton seed cake purchased from Singida region, and mineral mixture, salt and urea purchased from local Agricultural input suppliers in Dodoma region. The grass hay was used as roughage for all treatments. Concentrates (Table 1) were formulated using literature values for nutritive composition of feedstuffs, mainly the Tanzania Feed Stuff Table for Ruminants (Doto et al., 2004).

2.5 Management of experimental animals and feeding

After the back grounding period all animals were tagged using metal ear tags, weighed and randomly allocated to the five dietary treatments. All animals had a preliminary period of 7 days, during which the initial weight of each animal was recorded as the average weights taken for last three consecutive days of the preliminary period. During the experimental period, which lasted for 90 days, animals were weighed fortnightly and at the end of the feeding trial the final weight of each animal was obtained by taking the average live weights recorded for three consecutive days. Throughout the experimental period, animals were housed in individual pens and were fed individually with grass hay and concentrate in separate feeders allowing refusal rates of 20% and 10% for grass hay and concentrates, respectively. Access to water was *ad libitum*. The amount of grass hay and concentrate on offer and refusals were weighed daily. Average daily gain was

calculated as final weight minus initial weight divided by the number of days on the experiment. Feed conversion ratio was calculated as the amount of feed consumed (kg DM) per kg body weight gain.

2.6 Slaughtering procedures

At the end of the feeding trial, animals were transported by truck to Dodoma abattoir (82km) in Dodoma municipality, in two batches and slaughtered within an interval of one day. The animals were fasted for 24 hours prior to slaughter with access to fresh water. The animals were stunned using electrical stunner, slaughtered and suspended on an overhead rail system for bleeding, de-hiding and evisceration. The head was removed at the atlanto-occipital joint, the forefeet were severed at the knee joint between the carpal and metacarpal bones and the hind feet was severed at the hock joint between the tarsal and metatarsals.

2.7 Slaughter and carcass measurements

After evisceration the digestive tract (full and empty) was weighed and the differences between full and empty tracts were taken as the weight of gut fill gastro intestinal tract (GIT) content. Empty body weight (EBW) was taken as the difference between final weight and weight of gut fill. Non-carcass components (hide, head, feet, tail, spleen, pluck and kidney) were also removed and weighed. The carcasses were separated into left and right sides using an electrical saw. The two sides were weighed within 45 minutes post-mortem to determine hot carcass weight (HCW) which was used to derive the dressing percentage (DP) as $(\text{HCW}/\text{final weight}) \times 100$. Linear carcass measurements were taken on the left half carcass within the first hour after slaughter. Carcass length, hind leg length, chest depth and hind leg circumference were measured using a tape

measure (Figure 1) while fat thickness was measured using a ruler on the 10th rib. The carcasses were kept at room temperature for 10 hrs and were then transferred to a chilling room set at 0°C. After 48 hours post mortem the left side half carcasses were removed from the chilling room for the removal of the 6th rib joint, which was extracted by a straight cut perpendicular to the vertebral axis, from the middle of each inter-costal space to the vertebrae, weighed and then dissected into muscle, fat and bone. The weight of each tissue was recorded for determination of carcass composition. *Longissimus thoracis et lumborum* (LL) area was traced over the 7th rib from left side carcass using a plastic grid.

2.8 Feed analyses

Samples of feedstuffs were dried for 48 hours (70°C) for determination of dry matter (DM), then, ground through a 1 mm screen and stored for subsequent analyses. Proximate components (DM, crude protein (CP), crude fibre (CF), ether extract (EE) and ash) were analysed according to the standard procedures of AOAC (2000). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest et al. (1991). The *in vitro* organic matter digestibility (OMD) of feedstuff ingredients and concentrates mixture was determined as described by Weisbjerg and Hvelplund (1993). Samples were incubated in pepsin and HCl for 24 hours and afterwards incubated in enzyme-acetate buffer for a further 24 hours. Residues were combusted to determine *in vitro* OM digestibility. The *in vitro* organic matter digestibility of hay was determined according to Tilley and Terry (1963). Samples were incubated in rumen fluid for 48 hours followed by 48 hours digestion in pepsin and HCl and residues were combusted to determine *in vitro* organic matter digestibility. Metabolisable energy (ME) contents of feed ingredients and concentrate diet were estimated using the equation of MAFF (1975),

that is $ME \text{ (MJ/kg DM)} = 0.012 \text{ CP} + 0.031 \text{ EE} + 0.005 \text{ CF} + 0.014 \text{ NFE}$. The ME content of hay was determined by the equation of Mc Donald et al. (2002), that is $ME \text{ (MJ/kg DM)} = 0.016 \text{ DOMD}$, where DOMD = g digestible organic matter per kg dry matter.

2.9 Statistical analysis

Data were analysed using the General Linear Model (GLM) procedures of SAS (Version 9.3; 2002). Experimental diets were considered as fixed effects and each individual animal was considered as the experimental unit for all the parameters assessed. Initial body weight was included into the model as covariate. Linear contrasts were used to compare molasses vs maize meal and hominy feed vs rice polishing. When means were found significant they were separated using the Least Significant Difference (LSD) test.

3.0 Results

3.1 Nutritional values of the diets

The chemical composition of hay, dietary ingredients and compounded diets are given in Tables 2. The ingredients used for compounding the concentrate diets had CP concentration ranging from 41 to 337 g/kg DM, and ME from 9.0 to 13.3 MJ/kg DM. Crude protein concentration of the compounded diets ranged from 97 to 145 g/kg DM, with HFMM having the highest value and RPMO having the lowest CP contents. The RPMM and RPMO diets had higher CF contents than other diets. Metabolisable energy of the compounded diets ranged from 10.1 to 12.6 MJ/kg DM with HFMM having the highest while RPMO and RPMM had the lowest ME contents.

3.2 Feed intake and growth performance

Steers fed on molasses based diets (RPMO and HFMO) had higher ($P<0.05$) concentrate intake than steers on maize meal based diet (HFMM and RPMM) (Table 3). Metabolizable energy intake was higher ($P<0.05$) for steers fed on HFMO diet than other diets. Steers fed on HFMO and HFMM diets had higher ($P<0.05$) CP intake and were more ($P<0.05$) efficient in converting feed to body tissue than those on other diets. Animals fed on a diet containing molasses in combination with hominy feed (HFMO) had the highest ($P<0.05$) live weight gains and heavier ($P<0.05$) final weights than those fed on other diets (Table 3, Fig. 2).

3.3 Slaughter and carcass characteristics

Steers fed on HFMO diet had the highest ($P<0.05$) hot carcass weight (HCW) and empty body weight (EBW), the steers had 32 kg, 23.3 kg, 21.9 kg and 19.2 kg more ($P<0.05$) EBW than those on RPMM, MMMO, RPMO and HFMM, respectively. The dressing percentage (DP) differed ($P<0.05$) between diets with steers fed on RPMO, HFMM and RPMM diets having the lowest mean values (Table 4). Except for internal fat and GIT contents, non-carcass components as proportions of EBW did not differ ($P>0.05$) between dietary treatments. Steers fed on HFMO diet had the highest ($P<0.05$) proportion of internal fat but lowest ($P<0.05$) proportion of GIT contents (Table 4).

3.4 Carcass measurements and composition

Carcasses from steers fed on HFMO had the highest ($P<0.05$) hind limb circumference followed by those fed on HFMM (Table 5). The carcasses from steers on diets containing hominy feed (HFMO, HFMM) tended ($P<0.1$) to have longer carcasses than those fed on diets containing rice polishing (RPMO, RPMM). Steers fed on diets containing hominy

feed (HFMO and HFMM)) had higher ($P<0.05$) proportion of fat and lower proportion of lean in the 6th rib joint than those fed on rice polishing (RPMO and RPMM) (Table 6).

4.0 Discussion

4.1 Nutritional values of the diets

The CP values for rice polishing and cotton seed cake in the current study were lower than the values reported by Doto et al. (2004), particularly for rice polishing. Maize meal was slightly lower in ME content whereas hominy feed was higher in both CP and ME compared to Doto et al. (2004). Such variations could probably be attributed to differences in the sources of the ingredients, processing conditions and the type of the milling machine used as some machines are not effective in separating the husks or bran with other fractions of the grain. Wide variations of CP and ME contents of experimental diets used in the current study were attributed to differences between the literature values of feedstuffs used during diet formulations and the actual values of such feedstuffs obtained after laboratory analysis. However the CP contents of experimental diets were within the range of 110 to 130 g/kg DM recommended by Gleghorn et al. (2004) and Dung et al. (2013) in finishing diets for fattening cattle with an exception of HFMM diet which was on the higher side, and RPMO which was slightly lower in CP (97 g/kg DM). The ME contents of experimental diets were within the range of 10 to 11.6 MJ/kg DM recommended by Rutherglen (1995) except for HFMM diet that had higher ME content due to inclusion of hominy feed and maize meal both with relatively high ME content.

4.2 Feed intake and growth performance

The observed higher DM intake (DMI) for molasses based diets (HFMO and RPMO) compared to other diets may be associated with palatability and binding effects of molasses which reduced dustiness of hominy feed and rice polishing. In addition molasses

is mainly sugar which ferments quickly in the rumen (Oba, 2010) and lead to increased intake of both DM and energy (Preston and Leng, 1987; Penner and Oba, 2009). The increase of DMI in cattle as a result of molasses inclusion in the diets has been reported in other studies (Broderick and Radloff, 2004; Penner and Oba, 2009; Oba, 2010). Similar observation was also reported in Brahman crossbred steers fed tropical grass hay with molasses supplementation (Brown, 1993). Furthermore, molasses feeding is found to change the fermentation pattern by lowering acetate and propionate concentration while favoring the butyrate and lactate concentrations (Heldt et al., 1999). Intra-ruminal infusions of acetate and propionate have been found to depress intake of concentrate diets whereas butyrate have less effects (Simkins et al., 1965). Although rumen concentrations of different volatile fatty acids (VFAs) were not measured in this experiment, it can be speculated that a changed pattern of the proportions of VFAs due to molasses intake might have contributed to the observed higher intake by steers fed on molasses based diets. On the other hand, the slightly higher DMI observed in steers fed on RPMM compared to HFMM could be attributed to the low energy concentration in RP whereby the animals had to consume more to meet their body requirements (Forbes, 2003). The mean DMI of 3.49 % of live weight observed in the present study is slightly higher than the range of 2.9 to 3.3 % of live weight previously reported by Mwilawa (2012) in a feedlot study using Boran and TSZ steers fed on concentrate *ad libitum*.

High weight gain observed for steers fed on HFMO diets than steers fed other diets could be explained by the higher ME and CP intakes. Increased growth as response to increased energy intake is expected and has been reported by Xuan Ba et al. (2008) and Tangjitwattanachai and Sommart (2012) in Asia and by Asizua et al. (2009) and Shirima et al. (2012) in Africa. Results from the present study also showed that growth rate had a close relationship with ME intake as reflected by the determination coefficient ($R^2=0.71$)

value shown in Figure 2. The value is close to 0.85 reported by Mtenga and Madsen (1990) in the intensive analysis of the relationship between energy intake and growth rate in ruminants using the past data recorded in Tanzania. In general the present study demonstrated molasses to be superior over maize meal and hominy feed over rice polishing in promoting gain to steers. Rice mill feeds have been reported to have lower growth promoting effects compared to corn mill products, and Forster et al. (1993) found higher ADG for calves fed on corn bran than on rice bran. This is probably due to the lower organic matter digestibility of rice by products, associated with high silica and crude fibre content in the rice by-products (Ugheoke and Mamat, 2012; Patel, 2005). The observed average daily weight gains of steers in the present study (658 to 919 g/day) were slightly higher than the gains (600 to 833 g/day) reported by Luziga (2005, unpublished) and Mwilawa (2012) for TSZ steers fed on high molasses based diets.

The observed lower FCR for steers fed on HFMO diet (8.09) was probably due to the higher intake of nutrients (ME and CP) attributed to its higher digestibility compared to other diets. Similarly lower FCR of steers fed on HFMM diet (7.87) could also be associated with the relatively high protein content of this diet. Feed conversion ratio (FCR) is normally affected by intake and digestibility of the diet. Lower FCR indicates more efficient feed utilization for body weight gain. When molasses or maize meal were used 10 kg of feed was required to produce one kg weight gain, when hominy feed was used only 8 kg of feed, and when rice polishing was used 11 kg of feed was required to produce one kg weight gain. When energy required for gain was assessed, hominy feed required 93 MJ ME/kg weight gain followed by maize meal (104), then molasses (105) and lastly rice polishing (108). About 1.5 kg of rice polishing was needed to give the same energy as 1 kg of hominy feed. Values of FCR observed in the current study are

lower or within the range (8.3 to 11.8) reported by Mwilawa (2012) and Umunna et al. (1980) on Zebu steers fed concentrate *ad libitum* and by Araba and Byers (2002) for bulls and heifers of Holstein x Friesian fed on cereal/molasses diets.

4.3 Slaughter and carcass characteristics

The lower proportions of GIT content observed in steers fed HFMO diet is attributable to the lower fibre content of this diet compared to other diets. Similar observations have been reported by other workers (Mushi et al. 2009; Shirima et al., 2014). The values of EBW obtained in the present study were within the range of 263 to 269 kg reported by Mwilawa (2012) on TSZ steers and Michael et al. (2001) for Zebu oxen fed on medium and high supplementation levels. The observed lower mean values of DP for steers fed on RPMO and RPMM than those from MMMO was due to higher GIT contents in animals fed those diets when compared to MMMO diet. The high GIT content of steers on diets with rice polishing (RPMO and RPMM) was probably associated with a slower passage rate through the GIT due to high CF contents. The difference in GIT content among steers on different diets, however, was subtle due to the long fasting period before slaughter, thereby increasing DP and probably decreasing difference between diets. Dressing percentage is affected by slaughter weight and the diet influencing the amount of gut fill at slaughter (Turki et al., 2011). The values of DP obtained in the present study were within the range of 51 to 53 % previously reported in Nguni steers (Muchenje et al., 2008; Mapiye et al., 2009). However, the observed DP were higher than the range of 49 to 50.5% reported by Nalaila (2005) on Iringa red steers and Michael et al. (2001) on Zebu oxen. This disagreement could have been brought about by the differences in the diets and feeding systems used which contributed to deviations in GIT contents. The Iringa red steers were grazing, whereas the Zebu oxen were fed teff straw as basal diet and

supplemented with wheat bran. The proportion of fibrous materials fed to these animals might have influenced the size of their GIT contents and thereby their DP as compared to the present study. Further, the long starvation period before slaughter in this study would have resulted in increased DP.

The observed higher hind limb circumference and fat thickness for steers fed on HFMO reflects the superiority in conformation score for steers in this group, associated with the higher intake of both energy and protein as compared to steers from other diets. The influence of high intake of energy and protein on muscle and fat accretion has previously been reported in various studies (Safari et al., 2011 Shirima et al., 2012). The current study showed that carcasses from all treatments had higher fat contents (21.4 to 27.1%) than the range of 10 to 15% of total carcass weight recommended by Syrstad (1993). A higher fat content was reported as an unappealing and undesirable meat attribute. Excess carcass fat implies economic loss to beef producers due to trimmed fat which has less value compared to lean, and further fat require much more energy per unit of gain than lean (9.39 vs. 1.24 kcal/g) (Carstens and Kerley, 2009; Slabbert et al., 1992). The observed proportion of dissectible lean (55 to 60%), fat (20 to 27%) and bone (17 to 23%) in the present study is in agreement with the range of lean (56 to 63%), fat (17 to 27%) and bone (16 to 27%) previously reported by Luziga (2005, unpublished) and Mwilawa (2012) for molasses fed TSZ steers on similar breeds as used in these studies.

5.0 Conclusion

Diets based on molasses and hominy feed are superior for finishing Tanzania shorthorn zebu (TSZ) cattle compared to diets formulated based on maize meal and rice polishing. There is need for further research to determine the optimal feeding period to produce carcasses of acceptable fat content.

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Table 1: Ingredient composition of compounded concentrates (kg/100 kg)

Ingredients	Concentrate mixtures				
	MMMO	HFMO	RPMO	HFMM	RPMM
Maize meal	38	-	-	38	38
Hominy feed	-	40	-	50	-
Rice polishing	-	-	41	-	51
Molasses	47	47	47	-	-
Cotton seed cake	13	11	10	10	09
Mineral mix	1	1	1	1	1
Urea	0.5	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5	0.5

MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal; RPMM, rice polishing with maize meal.

Table 2: Chemical composition of hay, concentrate ingredients and compounded diets

Feeds									OMD	ME
	DM	CP	CF	ASH	EE	NDF	ADF	NFE	(g/kg	(MJ/kg
	(g/kg DM)								OM)	DM)
Grass hay	898	33	400	99	5	762	459	361	301	4.8
Maize meal	903	96	17	58	34	155	25	736	973	12.4
Rice polishing	936	72	250	182	50	495	333	386	507	9.0
Hominy feed	899	114	56	41	122	291	75	587	902	13.3
Molasses	970	41	0	105	0	13	0	844	806	12.0
Cotton seed cake	929	337	194	61	67	423	245	266	739	10.5
MMMO	892	122	36	86	19	141	49	629	940	11.0
HFMO	899	120	47	88	57	170	58	587	939	11.7
RPMO	908	97	116	140	37	227	136	613	769	10.1
HFMM	924	145	54	47	65	243	68	518	929	12.6
RPMM	909	111	136	125	40	352	200	497	724	10.2

DM, dry matter; CP, crude protein; CF, crude fibre; EE, ether extract; NDF, neutral detergent fibre, ADF, acid detergent fibre; NFE, nitrogen free extract; OMD, *in vitro* organic matter digestibility, ME, metabolisable energy.

Table 3: Least-squares means \pm SE for intake and growth performance of Tanzania Shorthorn Zebu steers fed different diets

Variable	Diets					SEM	P-value	P-contrasts	
	MMMO	HFMO	RPMO	HFMM	RPMM			MO-MM	HF-RP
Intake (kg DM/day)									
Hay intake	1.20	1.15	1.24	1.31	1.32	0.06	0.1582	0.0350	0.3258
Conc. intake	5.53 ^d	6.21 ^{ab}	6.40 ^a	4.89 ^d	5.62 ^{bc}	0.22	<0.0002	<0.0001	0.0456
Total intake	6.72 ^{bc}	7.35 ^{ab}	7.64 ^a	6.19 ^c	6.94 ^b	0.24	0.0013	0.0004	0.0365
Intake (% LW)	3.36 ^{bc}	3.68 ^{ab}	3.83 ^a	3.11 ^c	3.48 ^b	0.12	0.0015	0.0005	0.0347
ME intake (MJ /day)	73.89 ^b	86.39 ^a	77.18 ^b	72.83 ^b	69.38 ^b	2.76	0.0013	0.0004	0.0264
CP intake (g/day)	795 ^b	867 ^a	725 ^b	809 ^{ab}	737 ^b	29.6	0.0095	0.4214	0.0007
Weight (kg)									
Initial weight	198	203	199	198	203	5.37	0.93	0.90	0.9152
Final weight	259 ^c	283 ^a	264 ^{bc}	271 ^b	258 ^c	4.12	0.0005	0.04	0.0003
Total gain	59 ^c	83 ^a	64 ^{bc}	71 ^{ab}	58 ^c	4.12	0.0005	0.04	0.0003
Daily gain (g)	658 ^c	919 ^a	709 ^{bc}	791 ^{ab}	639 ^c	0.05	0.0005	0.04	0.0003
FCR (kg feed /kg gain)	10.39 ^a	8.09 ^b	11.48 ^a	7.87 ^b	11.02 ^a	0.57	<0.0001	0.5474	<0.0001

^{abc}Least square means with a common superscript in the same row are not significantly different ($P>0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses vs maize meal; HF-RP, hominy feed vs rice polishing.

Table 4: Least-squares means \pm SE for hot carcass weight, empty body weight, dressing percentage, internal and external organs of Tanzania Shorthorn Zebu steers fed different diets

Variable	Diets					SEM	P-value	P-contrasts	
	MMMO	HFMO	RPMO	HFMM	RPMM			MO-MM	HF-RP
Hot carcass weight (kg)	136 ^{bc}	151 ^a	135 ^{bc}	141 ^b	131 ^c	2.13	<0.0001	0.0024	<0.0001
Empty body weight (kg)	244 ^{bc}	268 ^a	246 ^{bc}	249 ^b	236 ^c	3.99	<0.0001	0.0007	0.0001
Dressing percentage (%)	52.6 ^a	53.4 ^a	51.3 ^b	52.1 ^{ab}	51.0 ^b	0.51	0.0135	0.1374	0.0033
As proportion of empty body weight (%)									
Head, hide, feet, tail, anus	17.4	16.6	16.7	17.6	16.7	0.36	0.1876	0.1463	0.2520
Spleen	0.3	0.3	0.3	0.3	0.3	0.01	0.5429	0.0695	0.0746
Kidney	0.2	0.2	0.3	0.2	0.2	0.01	0.0538	0.0965	0.0746
Pluck	3.7	4.0	3.9	3.9	3.9	0.10	0.2616	0.3607	0.5341
Internal fat	1.9 ^b	2.7 ^a	1.9 ^b	2.5 ^{ab}	2.0 ^b	0.17	0.0019	0.7291	0.0004
GIT full	12.6 ^b	12.4 ^b	14.0 ^{ab}	15.5 ^a	15.7 ^a	0.65	0.0010	0.0008	0.1762
GIT empty	6.3	6.7	6.6	6.3	6.2	0.20	0.4441	0.0823	0.7955
GIT contents	6.3 ^b	5.8 ^b	7.4 ^b	9.2 ^a	9.4 ^a	0.59	0.0001	<0.0001	0.1201

^{abc}Least square means with a common superscript in the same row are not significantly different ($P>0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses vs maize meal; HF-RP, hominy feed vs rice polishing.

Table 5: Least-squares means \pm SE for carcass measurements of Tanzania Shorthorn Zebu steers fed different diets

Variables (cm)	Diets					SEM	P-value	P-contrasts	
	MMMO	HFMO	RPMO	HFM M	RPMM			MO- MM	HF-RP
Carcass length	103	104	103	104	103	0.61	0.4161	0.7377	0.0675
Chest depth	52.4	53.8	53.1	52.0	52.5	1.72	0.6684	0.3279	0.4143
Hind limb circumference	91.5 ^{bc}	94.5 ^a	91.0 ^{bc}	93.6 ^{ab}	90.5 ^c	0.99	0.0254	0.4659	0.0018
Hind limb length	68.5	69.3	69.1	68.9	68.0	0.73	0.7565	0.3193	0.4618
Fat thickness	1.44	1.58	1.47	1.52	1.12	0.12	0.0582	0.0273	0.4618
LMA (cm ²)	26.4	24.8	26.3	24.4	22.8	1.27	0.2539	0.1277	0.9928

^{abc}Least squares means with a common superscript in the same row are not significantly different ($P>0.05$); SEM, standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; LMA= m. *Longissimus thoracis et lumborum* area; MO-MM, molasses vs maize meal; HF-RP, hominy feed vs rice polishing.

Table 6: Least-squares means \pm SE for carcass composition of Tanzania Shorthorn Zebu cattle fed different diets

Variables	Diets					SEM	P- value	P-contrasts	
	MMMO	HFMO	RPMO	HFMM	RPMM			MO-MM	HF-RP
% Composition in 6 th rib joint									
Lean	59.6	54.0	57.3	54.5	57.4	1.51	0.0757	0.8207	0.0488
Fat	21.4	27.1	22.4	23.8	22.3	1.44	0.0673	0.2504	0.0360
Bone	18.8	16.9	19.0	19.0	19.2	0.78	0.2104	0.1449	0.1313
Ratios of 6 th rib joint components									
Lean:Bone	3.2	3.3	3.0	2.9	3.0	0.14	0.4158	0.2335	0.7302
Lean:Fat	2.9	2.0	2.6	2.4	2.6	0.22	0.0775	0.4014	0.0721
(Lean+fat): Bone	4.4	4.9	4.2	4.2	4.2	0.23	0.1612	0.1219	0.1641

SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses vs maize meal; HF-RP, hominy feed vs rice polishing.

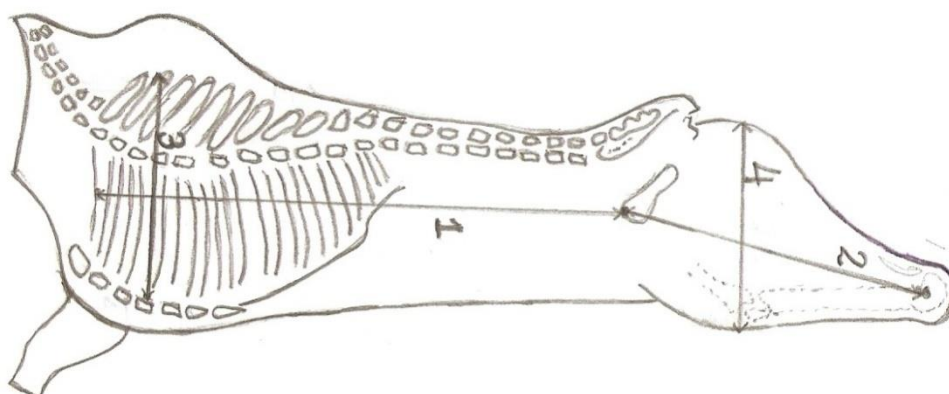


Figure 1: Illustration of carcass measurements, 1: Carcass length, 2: hind leg length, 3: Chest depth, 4: Hind leg circumference (Modified from Lazzaroni and Biagini, 2008)

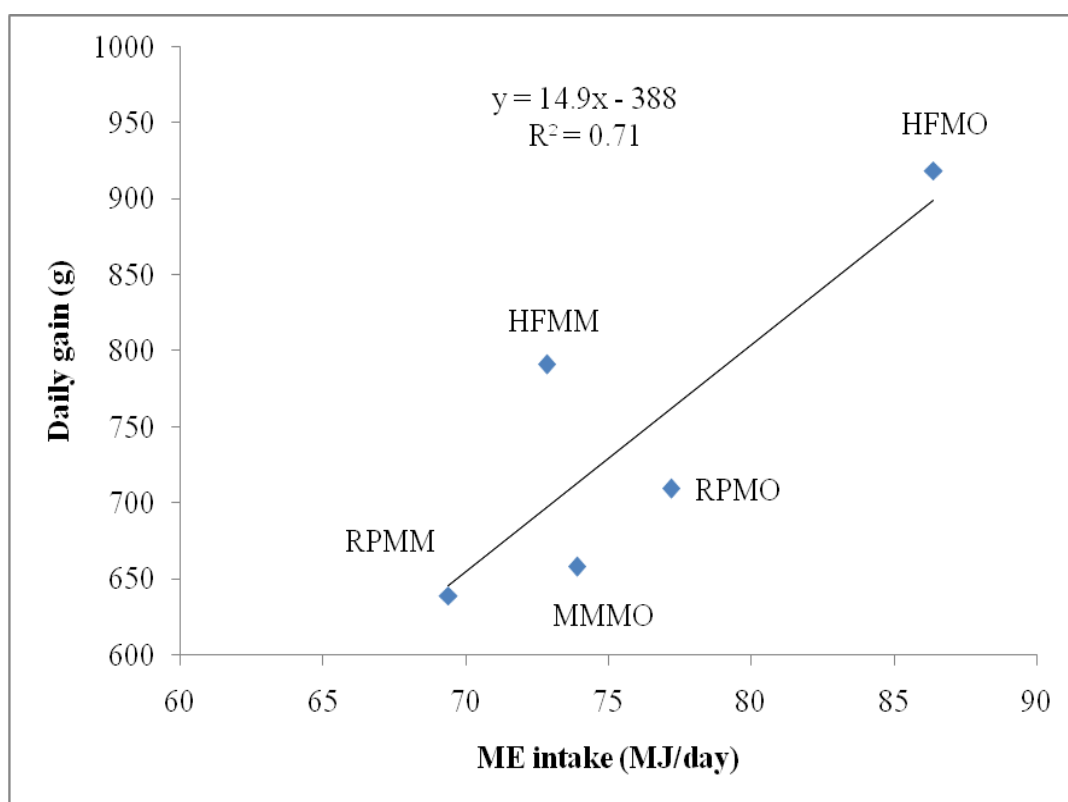


Figure 2: Relationship between growth rate and ME intake; MMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMO, rice polishing with maize meal

CHAPTER FIVE

5.0 PAPER 2

**Meat yield and quality of Tanzania Shorthorn Zebu cattle finished on
molasses/maize grain with agro processing by products**

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Meat yield and quality of Tanzania Shorthorn Zebu cattle finished on molasses/maize meal with agro processing by products

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Abstract: This study was conducted to evaluate the effects of feeding molasses or maize meal with rice or/and maize by-products on yield and quality of meat from Tanzania shorthorn zebu (TSZ) cattle. Forty five steers aged 2.5 to 3.0 years and weighing 200 ± 5.4 kg were allotted into five dietary treatments. The treatments consisted of hominy feed with molasses (HFMO), rice polishing with molasses (RPMO), hominy feed with maize meal (HFMM), rice polishing with maize meal (RPMM) and maize meal with molasses (MMMO). The diets and hay were offered to nine steers for 90 days. Data on live weight, carcass weight, pH, temperature and meat yield were recorded. Cooking loss (CL) and Warner Bratzler shear force (WBSF) values were determined on *m. longissimus thoracis et lumborum* aged for 3, 6, 9 and 12 days. Steers fed diets based on molasses and hominy feed had higher ($P < 0.05$) ME (86.39 MJ/d) and protein (867

g/d) intake, weight gain (919 g/d) and half carcass weight (75.8 kg) compared to those fed on maize meal and rice polishing. Meat of steers from all diets was tender with average WBSF values of 47.9 N cm². CL and WBSF were highest in meat aged for 3 days relative to other times and decreased with ageing time. The WBSF values for meat aged for 9 or 12 days from steers fed HFMO or RPMM diets were similar but lower than those on other dietary treatment combinations. Overall, molasses and hominy feed can be used to replace maize meal in feedlot finishing diets without affecting performance.

Key Words: Agro processing by products, feedlot, retail cuts, steers.

1 Introduction

Meat quality is a complex parameter with varying parameters and is influenced by several intrinsic and extrinsic factors. The intrinsic factors include breed, sex, and slaughter weight, whereas pre and post-slaughter carcass handling, type and feeding level are some of the extrinsic factors (Safari, 2010; Mushi *et al.*, 2009). In Tanzania meat is mainly produced from Tanzania shorthorn zebu (TSZ) cattle which are extensively managed on rangelands. In most of these rangelands, pastures are in short supply with low nutritive values especially during the dry seasons. This results in low animal growth rates and late attainment of slaughter weights. Some studies done in South Africa have reported loss in weight leading to poor body condition which affects meat yield (du Plessis & Hoffman, 2004) and quality (Muchenje *et al.*, 2008). The constraint of poor nutrition in beef production could be minimized by finishing animals in feedlot using diets based on agro processing by products. Rice polishing and hominy feed are agro processing by products that can substitute part of maize grain in concentrate feed for beef cattle (Matz, 1991). A study by Sani *et al.* (2014) on Bunaji bulls fed rice by products as energy source showed rice by products to yield high quality carcass with lean meat (less amount of fat) compared to maize by products. Rice polishing and hominy feed have been found to give consistent results when combined

with molasses and urea (Lopez and Preston, 1977; Larson *et al.*, 1993). A study by Hunter (2012) on beef cattle found that inclusion of sugar cane molasses in feedlot diets has the potential of producing meat with good eating quality. A study in Tanzania by Mwilawa (2012) on beef fattening using maize meal and molasses has shown that TSZ cattle respond well to fattening by increasing carcass quantity from 90 kg for sole grazing group to 154 kg for maize meal and molasses fed group. Similarly, the tenderness of meat as measured by shear force values was improved from 60 Ncm² in the sole grazing group to 45 Ncm² for maize meal and molasses fed group. However, the major limitation of using maize meal as cattle feed in Tanzania is the role it plays as the main food source for humans. Thus, it is of interest to find out alternatives to maize meal as feedlot diet. There is dearth of information on the effects of feeding agro processing by products on meat yield and quality of TSZ cattle. The aim of this study was to assess the yield and quality of meat produced from TSZ cattle finished on molasses or maize meal with rice or maize by-products under feedlot condition.

2.0 Materials and methods

2.1 Animals and diets

A total of 45 TSZ steers aged 2.5-3.0 years with initial body weight 200 ± 5.4 kg (mean + SE) were allocated in a completely randomized design to feedlot experiment performed at Kongwa ranch, located in Dodoma region, central Tanzania. All selected animals were assessed for health and nutritional status prior to the experiment. Five concentrate diets were formulated from different proportions of the raw materials of the agro processing by products to contain hominy feed with molasses (HFMO), rice polishing with molasses (RPMO), hominy feed with maize meal (HFMM), rice polishing with maize meal (RPMM) and a control maize meal with molasses (MMMO). The proportions of the ingredients composition shown in Table 1 were determined by trial and error method using nutritive values of ingredients from feedstuff tables for ruminants developed by Doto *et al.* (2004). Each formulated diet was fed together with hay *ad libitum* to 9 steers for a period of 90

days. All animals were provided with free access of fresh drinking water throughout the experiment and were housed in individual pens. During the experimental period, all animals were weighed after every two weeks and the amount of feed eaten was weighed daily.

Table 1: Physical composition (kg/100 kg), Crude protein (g/kg DM) and Metabolisable energy (MJ/kg DM) levels of the dietary treatments

Ingredients	Compounded diets				
	MMMO	HFMO	RPMO	HFMM	RPMM
Physical composition (kg/100 kg)					
Maize meal	38	-	-	38	38
Hominy feed	-	40	-	50	-
Rice polishing	-	-	41	-	51
Molasses	47	47	47	-	-
Cotton seed cake	13	11	10	10	09
Mineral mix	1	1	1	1	1
Urea	0.5	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5	0.5
Calculated chemical composition					
Crude protein (g/kg DM)	122	120	97	145	111
Metabolisable energy (MJ/kg DM)	11.0	11.7	10.1	12.6	10.2

MMMO: maize meal with molasses; HFMO: hominy feed with molasses; RPMO: rice polishing with molasses; HFMM hominy feed with maize meal; RPMM rice polishing with maize meal.

2.2 Slaughter procedures

After 90 days of feeding, all animals were weighed on three days consecutively to obtain the final body weight and thereafter transported by truck to Dodoma Abattoir (82 km from Kongwa ranch). At the abattoir, the animals were deprived of feed for 24 hours, but had access to fresh drinking water. Slaughtering and dressing of the animals followed the abattoir procedures as described by Bourguet *et al.* (2011). The animals were stunned, slaughtered and suspended on an overhead rail system for bleeding, de-hiding and evisceration. The head was removed at the atlanto-occipital joint and the forefeet and hind feet were removed at the carpal–metacarpal and tarsal–metatarsal joints, respectively. The dressed carcasses were longitudinally halved into two using an electrical saw, weighed within 45 minutes post-mortem to obtain the hot carcass weight.

Temperature and pH measurements were recorded after 45 minutes and 6 hours post-mortem at room temperature then carcasses were transferred to a cold room set at 0°C where further measurements after 24 hours and 48 hours were recorded.

2.3 Fabrication of retail cuts

Twenty five (25) right half carcasses were randomly selected from the total of 45 TSZ steers for retail cuts fabrication. After 48 hours in a chilling room set at 0 °C, the carcasses were weighed to obtain cold carcass weight and then quartered between 10th and 11th ribs into fore and hind quarters. After recording the weights, the hind quarters were fabricated into nine bone-in retail cuts as described by FAO (1991), the cuts were hind shin, topside, silverside, fillet, rump, loin strip, thin flank, wing ribs and thick flank. All visible fat was trimmed and similar procedure was carried out with the fore quarters, which were fabricated into eight bone-in retail cuts as brisket, prime ribs, hump, flat ribs, chuck, shoulder blade, neck and fore shin. The weight of each individual cut was recorded. The retail cuts from the fore and hind quarters were grouped as prime and nonprime cuts based on guidelines issued by VETA (2006). The prime cuts comprised the following cuts: shoulder blade, loin strip, prime ribs, rump, wing ribs, topside, silverside, thick flank and fillet. The nonprime cuts included fore and hind shin, hump, neck, flat ribs, chuck, brisket, and thin flank. The sum of prime and non prime cuts formed the saleable cuts. Waste trimmings comprises of all trimmed meat that is not fit for human consumption including aitch bones.

2.4 Meat quality measurements

2.4.1 Temperature and pH measurements

Temperature and pH of the carcasses were taken at 45 min, 6, 24 and 48 hours post-mortem at the same point on the 10th rib of left side carcass in the *Longissimus thoracis et lumborum* (LL). The temperature was measured by inserting a digital meat

thermometer (FUNKOTION Digital stegetermometer, HA 250K, Japan), while the pH was measured by inserting an electrode (Mettler Toledo) of a portable pH-meter (Knickportamess 911, Germany) in the same muscle. The temperature and pH readings at 45 min and 6 hours post-mortem were taken at room temperature while temperature and pH readings at 24 and 48 hours post-mortem were taken when the carcasses were in the chilling room.

2.4.2 Determination of cooking loss (CL) and Warner-Bratzler shear force (WBSF)

At the abattoir the LL muscle from 7th to 13th rib of the left side carcass was removed 48 hours post-mortem and prepared for cooking loss (CL) and Warner-Bratzler shear force (WBSF) determination. The LL muscle was cut into 4 pieces measuring approximately 9 cm long which were labelled and placed in the chilling room set at 0°C for ageing for 3, 6, 9 and 12 days. After each ageing period the samples were taken from the chilling room, vacuum packed in polythene bags and frozen at -20°C in a deep freezer. Thereafter the samples were transported to the laboratory at the Department of Animal Science and Production of Sokoine University of Agriculture, where CL and WBSF values were determined. The LL muscle samples were thawed at 4 °C overnight, removed from the polythene bags, wiped up with paper towel trimmed down to reduce the size to approx mean weight (W1) of 298 ± 36 g and then re-sealed using a vacuum pack machine. The samples were heated at 75 °C for 1 hour in a thermostatically controlled water bath. The heated samples were left to cool under running tap water for 2 hours, and then transferred to a refrigerator set at 4 °C and stored overnight. The samples were removed from the polythene bags, dried with paper towel and re-weighed (W2). CL was calculated as $((W1-W2)/W1)*100$.

Muscle samples for WBSF assessment were prepared from the cooked samples by cutting seven cubes measuring 1x1x1cm, 5 cm long in fibre direction. Warner Bratzler

shear blade attached to Zwick/Roell (Z2.5, Germany) instrument was used to determine the force (N/cm²) 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.

2.5 Statistical analysis

In data analysis, individual animal was considered as experimental unit in all the variables analysed and initial weight was used as covariate. Linear contrasts were used to compare molasses vs maize meal and hominy feed vs rice polishing. The GLM procedure of SAS (version 9.3; 2002) was used to analyse the data on yield, with dietary treatment as the main effect. The differences were considered significant at $P < 0.05$ and significant means were separated by LSD. For meat quality parameters (CL, WBSF, pH and temperature) dietary treatments, time and their interactions were regarded as fixed effects. The MIXED procedure of SAS (Version 9.3; 2002) was used with repeated statement where compound symmetry was used as covariance structure. Differences were considered significant at $P < 0.05$ and significant means were separated by Turkey-Kramer protection.

3.0 Results

3.1 Nutrient intake, growth rate and carcass yield

Steers from different dietary treatments differed ($P < 0.05$) in nutrient intake, growth rate, final live weight and carcass yield. Steers fed on HFMO diet had higher ($P < 0.05$) values than their counterparts from other diets (Table 2). There was a positive correlation between growth rate and final live weight ($r = 0.99$) and between growth rate and hot/cold carcass weight ($r = 0.89$). It was observed that the amount of trimmed fat increased with increase in growth rates. At the highest growth rate (919 g/day) for HFMO steers the amount of trimmed fat exceeded that of the lowest growth rate (639 g/day) for RPMM steers by 65 %. When expressed as proportion of half carcass weight, hind and

fore quarter weight, saleable cuts, prime and non-prime cuts did not differ ($P>0.05$) between dietary treatments despite the differences in half carcass weight (Table 3). Dietary treatments had no effects ($P>0.05$) on yield of retail cuts as proportion of side carcass weight (Table 4). When comparisons were made between the diets, it was observed that molasses and hominy feed based diets had higher performance in all the parameters measured than maize meal and rice polishing based diets.

Table 2: Performance of Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products

Parameters	Diets					SEM	P-values	P-contrasts	
	MMMO	HFMO	RPMO	HFMM	RPMM			MO-MM	HF-RP
Initial live weight (kg)	198	203	199	198	203	5.37	0.9253	0.8937	0.9263
Final live weight(kg)	259 ^c	283 ^a	264 ^{bc}	271 ^b	258 ^c	4.12	0.0005	0.0368	0.0003
Average daily gain (g)	658 ^c	919 ^a	709 ^{bc}	791 ^{ab}	639 ^c	0.05	0.0005	0.0368	0.0003
ME intake (MJ /day)	73.89 ^b	86.39 ^a	77.18 ^b	72.83 ^b	69.38 ^b	2.76	0.0013	0.0004	0.0264
CP intake (g/day)	795 ^b	867 ^a	725 ^b	809 ^{ab}	737 ^b	29.6	0.0095	0.421	0.0007
Hot half carcass weight (kg)	69.2 ^b	75.8 ^a	68.0 ^b	69.9 ^b	65.8 ^b	1.70	0.0052	0.0339	0.0021
Cold half carcass weight (kg)	67.4 ^b	74.4 ^a	66.2 ^b	68.1 ^b	64.1 ^b	1.70	0.0062	0.0314	0.0019
Chilling shrinkage (%)	2.63	1.93	2.61	2.49	2.55	0.45	0.7872	0.6030	0.4136

^{abc}Least squares means with a common superscript in the same raw are not significantly different ($P>0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

Table 3: Carcass yield from Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products

Parameters	Diets					SEM	P-values	P-contrasts	
	MMMO	HFMO	RPMO	HFMM	RPMM			MO-MM	HF-RP
Carcass yield (% side carcass weight)									
Fore quarter	47.5	48.3	47.8	47.8	46.9	0.87	0.8499	0.4523	0.4015
Hind quarter	49.9	50.0	49.6	49.7	50.6	0.75	0.9418	0.5689	0.6220
Saleable cuts	87.1	85.7	88.5	88.0	87.7	1.20	0.5619	0.5718	0.2897
Prime cuts	46.7	46.4	45.2	46.5	47.6	1.13	0.8286	0.3008	0.9482
Non-prime cuts	40.4	39.3	43.3	41.4	40.1	1.34	0.4659	0.6978	0.3215
Aitch bone	3.08	3.29	3.47	3.12	3.47	0.28	0.7790	0.7927	0.3532
Fat trimmings	4.33 ^b	6.36 ^a	4.18 ^b	4.09 ^b	3.84 ^b	0.59	0.0394	0.0487	0.0488
Waste trimmings	2.50	2.42	1.36	1.99	2.56	0.43	0.4882	0.4112	0.5755
Uncountable loss	0.39	0.29	0.26	0.39	0.12	0.30	0.9689	0.9507	0.6208

^{abc}Least squares means with a common superscript in the same raw are not significantly different ($P>0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

Table 4: Yield of retail cuts from Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products

Parameters	Diets					SEM	P-value	P-contrasts	
	MMMO	HFMO	RPMO	HFMM	RPMM			MO-MM	HF-RP
Prime cuts (% of side carcass weight)									
Shoulder blade	9.60	9.50	8.60	9.60	9.20	0.90	0.9261	0.6869	0.5016
Prime ribs	5.33	5.56	5.93	5.86	5.97	0.40	0.6814	0.6720	0.5082
Wing ribs	2.02	2.44	1.95	1.95	2.05	0.36	0.8007	0.5638	0.5406
Loin strip	7.99	7.99	7.40	8.11	8.90	0.49	0.5435	0.1328	0.8366
Rump	4.02	3.99	3.70	3.58	4.85	0.34	0.2593	0.2934	0.1465
Topside	6.13	6.53	6.24	6.38	6.30	0.23	0.6763	0.8206	0.3606
Silverside	6.36	5.62	6.56	5.99	5.51	0.31	0.1322	0.2536	0.4025
Thick flank	4.25	3.90	3.72	4.28	3.88	0.33	0.5729	0.3919	0.3209
Fillet	0.90	0.94	1.07	0.83	0.89	0.13	0.7032	0.2561	0.3995
Non-prime cuts (% of side carcass weight)									
Fore shine	5.85	5.15	6.78	6.15	5.76	0.93	0.7981	0.9930	0.4458
Hump	2.17	1.79	1.72	2.31	2.30	0.21	0.2103	0.0252	0.8562
Neck	6.58	6.41	6.72	6.80	6.27	0.42	0.9454	0.9434	0.7904
Chuck	4.92	5.17	5.06	5.12	5.59	0.49	0.8979	0.6166	0.6873
Flat ribs	4.25	4.05	4.15	4.21	4.01	0.34	0.9881	0.9710	0.8958
Brisket	7.87	8.20	7.69	7.35	7.09	0.43	0.2896	0.0840	0.3100
Thin flank	3.95	4.50	6.38	4.84	4.51	0.71	0.1901	0.2566	0.2204
Hind shine	4.80	4.01	4.83	4.65	4.54	0.24	0.0920	0.4534	0.1032
SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.									

3.2 Meat quality attributes

3.2.1 Temperature and pH

The dietary treatments had no effects on the rate of decline carcass temperature post-mortem (Figure 1).

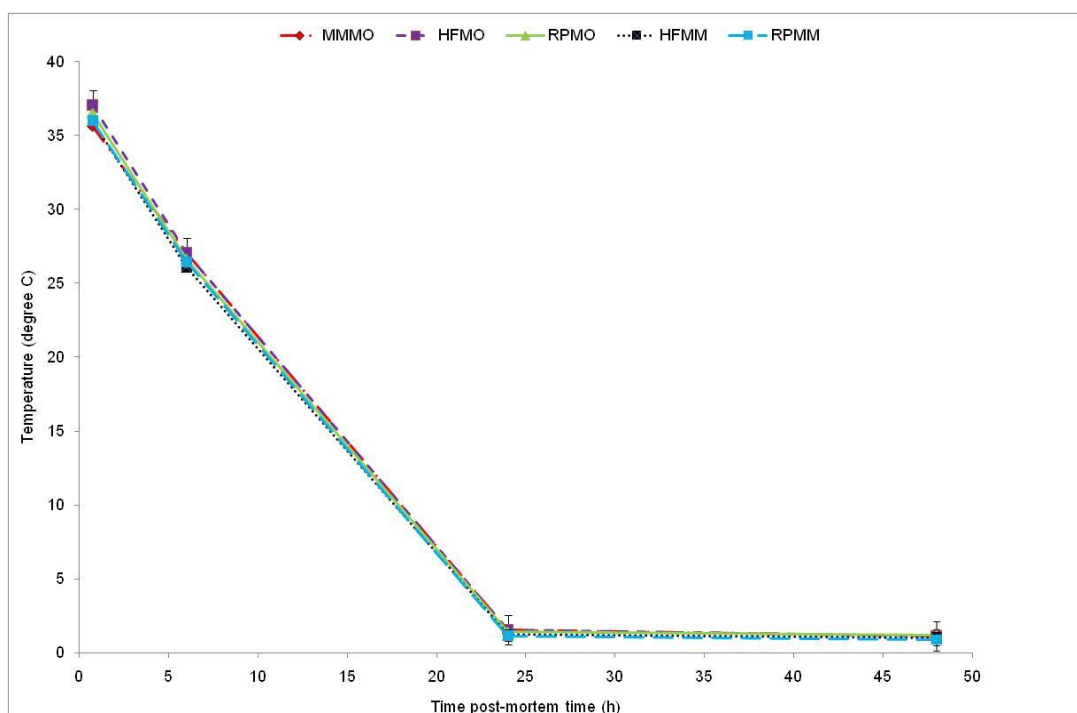


Figure 1: Effect of time change on temperature decline post-mortem for five dietary treatments; P-values: Treatments, 0.3355; Time, <0.0001; treatment*time, 0.7973; MMMO: maize meal with molasses; HFMO: hominy feed with molasses; RPMO: rice polishing with molasses; HFMM: hominy feed with maize meal and RPMM rice polishing with maize meal

The decline in temperature was faster in the first 6-24 hours after which very little change was observed. No difference ($P > 0.05$) was observed between dietary treatments on post-mortem muscle pH decline, but there was a sharp decline in pH values in the first six hours followed by a gradual decrease till ultimate pH (pHu) was attained at 24 hours post-mortem (Figure 2).

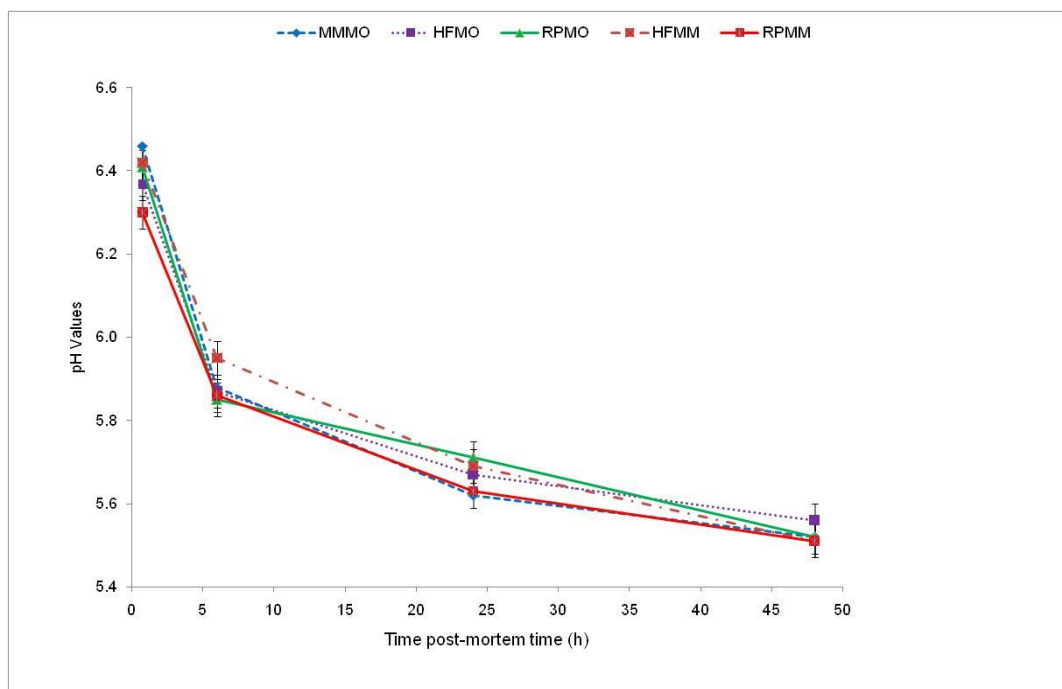


Figure 2: Effect of time change on pH decline post-mortem for five dietary treatments; P-values: Treatments, 0.4714; Time, <0.0001; treatment*time, 0.4313; MMO: maize meal with molasses; HFMO: hominy feed with molasses; RPMO: rice polishing with molasses; HFMM: hominy feed with maize meal and RPMM: rice polishing with maize meal.

3.2.2 Cooking loss (CL) and Warner-Bratzler shear force (WBSF)

The CL and WBSF values of *m. Longissimus thoracis et lumborum* (LL) were not ($P > 0.05$) influenced by dietary treatments, but were affected ($P < 0.05$) by ageing time (Table 5). Higher ($P < 0.05$) CL and WBSF values were observed on muscle aged for 3 days compared to muscles aged for 6, 9 and 12 days. The lowest values for both CL and WBSF were observed on meat aged for 9 and 12 days. An interaction ($P < 0.05$) between dietary treatments and muscle ageing time was observed for WBSF values. The meat from steers fed HFMO or RPMM diets and aged for 9 or 12 days had the lowest WBSF values compared to those from other dietary treatment combinations (Figure 3).

Table 5: Cooking losses and Warner-Bratzler shear force values for Tanzania Shorthorn Zebu steers fed molasses or maize meal with rice or maize by-products

	Cooking loss (%)	Shear force (Ncm ⁻²)
Dietary treatments (T)		
MMMO	21.5	49.0
HFMO	21.0	46.4
RPMO	20.3	50.8
HFMM	19.6	49.4
RPMM	19.7	44.0
SEM	0.82	3.72
P-value	0.42	0.72
Ageing (A, days)		
3	22.0 ^b	53.4 ^c
6	20.3 ^a	48.7 ^b
9	20.1 ^a	45.1 ^a
12	19.3 ^a	44.3 ^a
SEM	0.61	1.70
P-value	0.01	<0.0001
T x A	0.18	<0.0001
P-contrasts (MO-MM)	0.24	0.61
P-contrasts (HF-RP)	0.75	0.89

^{abc}Least squares means with a common superscript in the same row are not significantly different ($P>0.05$); SEM, Standard error of the mean; MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal; MO-MM, molasses versus maize meal; HF-RP, hominy feed versus rice polishing.

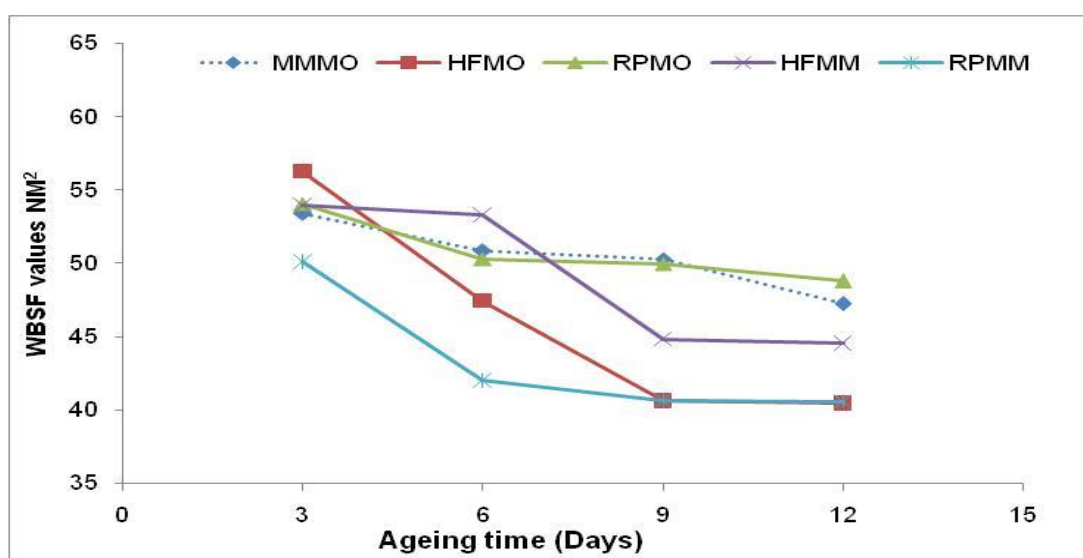


Figure 3: Effect of ageing time on tenderness for the five dietary treatments. P-values: Treatments, 0.7174; ageing time, <0.0001; treatment*ageing time, <0.0001; WBSF, Warner-Bratzler shear force, MMMO, maize meal with molasses; HFMO, hominy feed with molasses; RPMO, rice polishing with molasses; HFMM, hominy feed with maize meal and RPMM, rice polishing with maize meal

4 Discussion

4.1 Carcass yield

The observed higher final body weight and carcass weight for steers fed HFMO diet compared to those fed other diets could be associated with high intake levels of both energy and protein. Steers fed HFMO diet had the highest level of fat deposition (highest amount of trimmed fat). Growth rate and fat deposition are directly related with the level of energy and protein intake as they increase muscle and fat mass (Safari, 2010; Khalid *et al.*, 2012). These findings coincide with observations by Pazdiora *et al.* (2013) who found the degree of fat cover to increase with the body weight of animals. The increase in amount of trimmed fat was found to decrease the amount of saleable cuts which implies economic losses to beef producers, since excess fat deposits are not part of usable carcass under certain market conditions (Kitts, 2011). However, preference for fat content varies with place and culture. Kamugisha (2014) reported that consumers in Arusha, Tanzania showed high preference to meat with high fat content which suggests the need for taking into account preferences of targeted consumers in feedlot finishing.

The observed chilling shrinkage of 2.4% in the present study was comparable to the range of 2.4-2.7% reported by Khalafalla *et al.* (2011) and Fadol and Babiker (2010) in Sudan Baggra bulls, and is slightly above the standard cold shrinkage of 2.0 % in 24 hours chilling (Pascoal *et al.*, 2010). The absence of dietary effects on yield of different retail cuts including primal and non-primal cuts suggests that differences in levels of dietary energy and protein in the present study were not large enough to elucidate differences in yield of retail cuts. Similar findings have been observed in several studies involving beef cattle (Fadol and Babiker, 2010; Turki *et al.*, 2011; Duarte *et al.*, 2011). Other studies have shown that variation in terms of breed (Sharaf Eldin *et al.*, 2013), sex (Lazzaron and Biagini, 2008) and age (Pezdiora *et al.*, 2013) of animals has significant effects on the distribution of cuts.

4.2 Meat quality attributes

4.2.1 Temperature and pH

The rate and extent of decline of muscle pH and temperature during the immediate post-mortem periods influence meat quality development, mainly tenderness (Safari, 2010; Frylinck *et al.*, 2013), because temperature changes can initiate cold or heat shortening. A rapid decline in temperature during the early post-mortem period when muscle pH is still high can cause cold shortening (Frylinck *et al.*, 2013), which will lead to tough meat. In the present study, pH reading reached 6 while the temperature was still high (>26.5 C) which shows unfavourable conditions for cold shortening to occur. Lack of dietary effect on pH values for concentrate fed cattle observed in the present study is in agreement with findings from other studies (Mapiye *et al.*, 2010; Lage *et al.*, 2012). The findings indicate that there was sufficient glycogen content in the muscles of animals in these different dietary treatments which is a primary substrate for lactic acid production responsible for lowering the ultimate pH of meat (Immonen *et al.*, 2000). The average pH_u of 5.67 for carcasses in the present study is within the quality range of 5.5 to 5.8 which is considered normal and optimal for shelf life and eating properties (Silva *et al.*, 1999; Mach *et al.*, 2008).

4.2.2 Cooking loss and Warner-Bratzler shear force

Lack of dietary effects on CL and WBSF concurs with findings of previous studies (Lage *et al.*, 2012; Neto *et al.*, 2012). Cooking loss in muscles depends on ultimate pH, cooking conditions (Mushi *et al.*, 2009), and intramuscular fat content (Safari, 2010). Although intramuscular fat content was not measured in the present study, it can be argued that the magnitude of pH variation was not large enough to elicit differences in CL values. The values observed for CL are comparable to the range of 16.8 to 24.6 % reported by Mwilawa (2012) on TSZ steers fed 100% concentrate, but are slightly lower than the 22.5 to 25.2 % reported by Mapiye *et al.* (2010) on Nguni steers. This deviation may be attributed to differences in feeding systems, breeds and ageing time used in the different

studies. The observed WBSF values are within the range of 41.8 to 50.9 N reported for carcasses of TSZ steers fed concentrate diet with 125 g CP and 12 MJ ME per kg DM (Mwilawa, 2012).

Meat samples from carcasses from cattle in the current study are considered tender as WBSF values are less than 50 N (Devitt *et al.*, 2002). The lowest values for CL and WBSF observed on meat aged for longer durations (9 and 12 days) may be associated with enzymatic reactions that disintegrate the myofibrillar proteins and connective tissue thereby improving water holding capacity by proteins which increases with increasing ageing time (Jama *et al.*, 2008; Ba *et al.*, 2014). The influence of ageing time on CL and WBSF has also been observed in previous studies (Florek *et al.*, 2009; Filipcik *et al.*, 2009).

In general post-mortem storage resulted in decreased CL and WBSF values. Results have shown that dietary treatment and ageing time are two factors that independently affect meat quality characteristics of steers but jointly influenced the WBSF values which decreased most for HFMO and RPMM diets on 9th and 12th days of ageing. Ageing increases tenderization by degrading and weakening structural integrity of myofibrillar proteins brought by the calpain proteolytic enzyme system especially μ -calpain (Safari, 2010; Kemp and Parr, 2012). Also, energy concentration consumed by the animal influences glycogen stores which decrease ultimate muscle pH, and thus influencing meat tenderness (Koger *et al.*, 2010). In addition, high energy diets influence tenderness by increasing intramuscular fat that gives rise to the dilution of muscle structure (Wood *et al.*, 1999; Cardeno *et al.*, 2006). It can be concluded that agro processing by products can be used to replace maize meal in feedlot finishing diets because it has been found to improve the quality of meat produced from TSZ cattle. Molasses based diets were superior to maize meal diets and maize by products performing better than rice by products.

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CHAPTER SIX

6.0 PAPER 3

**Effects of days in feedlot on growth performance, carcass and meat quality
attributes of Tanzania Shorthorn Zebu steers.**

Status: Published in *Tropical Animal Health and Production Journal*.

Effect of days in feedlot on growth performance, carcass and meat quality attributes of Tanzania Shorthorn Zebu steers

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Abstract

A study was conducted using 50 steers (183 ± 4 kg initial body weight, 3 years age) to assess the effects of days in feedlot on performance, carcass characteristics and meat quality of Tanzania Shorthorn Zebu (TSZ) cattle with the aim of determining appropriate finishing period. Periods were 0 days P_0 , 25 days P_{25} , 50 days P_{50} , 75 days P_{75} and 100 days P_{100} with ten animals per period. Steers were housed in individual pens, fed concentrate diet and hay *ad libitum* except for animals in the P_0 group which was slaughtered at the beginning of trial. Long stay in feedlot P_{100} increased concentrate dry matter intake by 2 kg DM/day over short stay P_{25} . The total gain increased ($P < 0.05$) from P_{25} (22.6 kg) to P_{100} steers (95.4 kg). Duration had no influence ($P > 0.05$) on average daily gain (ADG) and feed conversion ratio (FCR) but affected carcass characteristics. Empty body weight (EBW) and hot carcass weight (HCW) increased by 61 % and 65 %, respectively from no feedlot, P_0 to P_{100} . Dressing percentage was high ($P < 0.05$) for P_{100} steers. Carcass measurements, internal fat, fat thickness and carcass total fat were highest ($P < 0.05$) on P_{100} steers and lowest on P_0 steers. Rate of pH decline increased with days in

feedlot while cooking loss and shear force values decreased with length of ageing. Feedlot periods of 75 and 100 days resulted into high intake, carcass measurements and tenderness, but 100 days further increased carcass fatness and fat thickness levels. Thus, for this particular feeding system and animal's condition 75 days is the recommended period to finish TSZ cattle in feedlots.

Keywords: Beef, Carcass, Gain, Period of stay, Quality.

1. Introduction

The meat industry in Tanzania is among components of the livestock sector having potential for improving national income as well as living standards of people involved. Cattle are the most important species in meat production, producing the largest share of red meat in the country (MLDF, 2014). Feedlot diets are usually quite dense in energy to encourage the deposition of fat or marbling in muscles (Price and Berg, 1981), which may be desirable (Yimmongkol, 2009) or undesirable to some consumers if in excess amounts. Days on feed are among the important factors that affect the amount and distribution of fat in the carcass (Sainz and Paganini, 2004). Feeding for a long time is associated with increased fat thickness (Sainz and Paganini, 2004), marbling score, quality grades (Camfield et al., 1997; Owens and Gardner, 2000) and tenderness (Shirima et al., 2013). The indigenous cattle herd in Tanzania is mainly composed of Tanzania Shorthorn Zebu (TSZ) cattle which account for 94% of total beef produced (UNIDO, 2012). Studies on feedlot production have shown that TSZ cattle respond positively to finishing diets and produce quality beef (Mwilawa, 2012; Mlote et al., 2013). However, little information is available on how TSZ respond to numbers of days in feedlot. The aim of this study was to evaluate the effects of number of days in feedlot on growth performance, carcass characteristics and meat quality of TSZ cattle.

Materials and methods

Study locations

The feedlot trial was done at Kongwa National ranch 82 km from Dodoma municipality at an altitude of 1067 m above sea level. The area is semi-arid, with mean daily temperatures ranging between 23 and 32°C and receiving 254 – 660 mm of rainfall per annum. Slaughtering of animals was done at Dodoma Abattoir (DMA) 7 km South West of Dodoma municipality. The laboratory assessments including tenderness studies were done at Sokoine University of Agriculture, in Morogoro municipality 526 m above sea level.

Experimental design and treatments

Fifty (50) TSZ steers aged 3 years with average initial body weight of 183 ± 4 kg were allotted randomly to five treatment groups in a completely randomized design, making a total of ten animals per treatment. The experimental treatments were designated as P₂₅, P₅₀, P₇₅ and P₁₀₀ to represent 25, 50, 75 and 100 days respectively the animals stayed in feedlot. Each animal was considered as an experimental unit which were housed in individual pens for their respectively periods in feedlot. A group of 10 animals from grazing was used as a control group and was designated as P₀.

Experimental animals and their management

The experimental animals were selected from a herd of TSZ steers bought from farmers and different auction markets around Kongwa ranch. The age of steers was 3 years, estimated by dentition basing on the eruption of permanent incisor teeth as described by Pace and Wakeman (1983). The selected steers were ear tagged and the initial body weight of each animal was taken as average from three consecutive days of weighing. The

10 steers from P₀ were immediately taken to DMA abattoir for slaughter. Steers were housed randomly in individual pens for their respective periods where concentrate and grass hay were offered *ad libitum* in separate feeders allowing refusal rate of 10% and 20% for concentrates and grass hay, respectively. The concentrate diet consisted of hominy feed (40%), cotton seed cake (11%), molasses (47%), mineral mixture (1%), salt (0.5%) and urea (0.5%). Chemical composition of individual ingredients and compounded diets are presented in Table 1. The difference between the daily amount of concentrate and hay offered and rejected by each animal was considered as daily feed intake. Animals in feedlot were weighed weekly, and at the end of each period of stay the animals were weighed on three consecutive days, and final body weight (FBW) of each animal was obtained by averaging the weights.

Table 1: Chemical composition of concentrate ingredients, compounded diet and grasshay

Feeds	DM	CP	CF	EE	NDF	ADF	Ash	NFE	OMD	ME
				(g/kg DM)					(g/kg OM)	MJ/kg DM)
Grass hay	901	32	385	10	749	472	99	375	377	4.9
Hominy feed	910	116	62	118	338	72	42	572	928	12.8
Molasses	-	44	-	-	20	-	105	844	806	12.0
Cotton seed cake	924	349	185	75	330	221	66	249	732	10.9
Compounded diet	903	122	51	59	179	63	88	583	939	11.7

DM, dry matter; CP, crude protein; CF, crude fibre; EE, ether extract; NDF, neutral detergent fibre, ADF, acid detergent fibre; NFE, nitrogen free extract; OMD, *in vitro* organic matter digestibility, ME, metabolisable energy.

Slaughtering procedure

At the end of each period of stay, 10 steers were taken to DMA where they were kept in lairage, fasted for 16 hours with free access to clean drinking water prior to slaughter. During the slaughtering process, the animals were stunned, thereafter the neck was severed at the jugular and carotid vessels using a sharp knife. The bodies were suspended on overhead rails for bleeding, de-hiding and evisceration followed by the removal of

head, forefeet and hind feet. The carcasses were separated using an electric saw into left and right side carcasses. The two sides were weighed and added to derive hot carcass weight (HCW). Non-carcass components (hide, head, feet, tail, spleen, pluck and kidney) were removed and weighed. The digestive tract (full and empty) was weighed and the difference between the two was taken as weight of digestive contents. Empty body weight (EBW) was calculated as the difference between the FBW and weight of digestive contents, while the dressing percentage was expressed as ratio of HCW/FBW. The carcasses were left at room temperature for 10 h post-mortem and thereafter taken to the cold room and chilled at 0°C.

Measurements on the carcass

Temperature and pH of the carcasses were taken at 0.45h, 6h, 24h and 48h post-mortem (PM) on the 10th rib of left side carcass in the *Longissimus thoracis et lumborum* (LL). Temperature was measured by inserting a digital meat thermometer (Funkution® Digital stegetermometer), while pH was measured by inserting an electrode (Mettler Toledo) of a portable pH-meter (Knick Portamess® 911, Germany) in the same muscle. Linear carcass measurements including carcass length, chest depth, hind limb length and circumference were taken within one hour PM using a measuring tape. Carcass length was measured from the cranial side of *ischio-pubis symphysis* to the middle of the 1st rib. The chest depth was measured from the side of medullar channel, 5th to 6th thoracic vertebra level down the side of external bone. The hind limb length was from middle of the internal face of *tarso-metatarso* joint to cranial side of *ischio-pubis symphysis* and the hind limb circumference was from cranial side of *ischio-pubis symphysis* surrounding the hind leg to the same point.

Muscle sampling and meat quality analysis

The LL muscle from left side carcass was used for determination of cooking loss (CL) and Warner Bratzler shear force (WBSF). The LL muscle from 7th to 13th rib was removed after 48 h PM, split into 4 pieces measuring approximately 9 cm long. The pieces were used for 3, 6, 9 and 12 days ageing time in a chiller room at 0°C. Thereafter, each sample was packed in PVC bags, sealed and frozen at -20°C until further analysis. During meat quality analysis, LL muscle samples were thawed at 4°C for 24 h, removed from PVC bags, wiped dry with paper towel, weighed (W1) and re-sealed in PVC bags using a vacuum pack machine (Komet Plus Vac 20, Germany). The samples were heated at 75°C for 1 h in a thermostatically controlled water bath, then left to cool under running tap water for 2 hours, thereafter they were transferred to a refrigerator set at 4°C for 24 h. The samples were then removed from the PVC bags, wiped dry with a paper towel and weighed (W2). The CL was calculated as $(W1 - W2) / W1 * 100$. In measuring tenderness, a minimum of twelve cubes measuring 1 x 1 x 1 cm, 5 cm long were prepared from each LL muscle sample such that muscle fibre direction was parallel to the cube length. Warner Bratzler shear blade attached to a Zwick/Roell (Z2.5, Germany) instrument was used to determine the force (N/cm²) required for shearing through a muscle cube at a right angle to the muscle fiber direction. The Zwick was set with 1 kN load cell with a crosshead speed of 100mm/min.

Feed evaluation

Concentrate and hay samples were dried for 48 h (70 °C) for dry matter (DM) determination, ground (1mm screen) and stored for subsequent analyses. The DM, crude protein (CP), crude fibre (CF), ether extract (EE) and ash contents were determined according to the standard procedures of AOAC (2000). Ash content was determined by incinerating the sample at 550°C for 3h in a muffle furnace (Naber N₃ P, W. Germany).

Nitrogen content was determined by Kjeldahl method and CP was calculated as $N \times 6.25$. Ether extract content was extracted with petroleum ether by Soxtech (Soxtech system HT 1043, Sweden) extraction. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to methods described by Van Soest et al. (1991). The *in vitro* organic matter digestibility (OMD) for concentrates was determined as described by Weisbjerg and Hvelplund (1993). Samples were incubated in pepsin and HCl for 24 h and afterwards incubated in enzyme-acetate buffer for a further 24 h. Residues were combusted to determine *in vitro* OM digestibility. The *in vitro* organic matter digestibility of hay was determined according to procedures by Tilley and Terry (1963). Samples of hay were incubated in rumen fluid for 48 h followed by 48 h digestion in pepsin and HCl and residues were combusted to determine *in vitro* organic matter digestibility. Metabolisable energy (ME) contents of concentrate were estimated using the equation of MAFF (1975), as $ME \text{ (MJ/kg DM)} = 0.012 \text{ CP} + 0.031 \text{ EE} + 0.005 \text{ CF} + 0.014 \text{ NFE}$. The ME content of hay was determined by the equation of McDonald et al. (2002), as $ME \text{ (MJ/kg DM)} = 0.016 \text{ DOMD}$, where DOMD = g digestible organic matter per kg dry matter.

Statistical analysis

The General Linear Model (GLM) procedure (SAS version 9.3; 2002) was used in data analysis. Each individual animal was considered as an experimental unit for all the parameters assessed. Initial body weight was used as a covariate in the models. For growth performance and killing out characteristics, days of stay in feedlot was considered as fixed effect with the following model:

$$\text{Model : } Y_{ij} = \mu + P_i + b(A_{ij} - \bar{A}) + e_{ij}$$

In which Y_{ij} = Response variables (intake, weight gain and killing out characteristics); μ = population mean; P_i = fixed effect of days of stay in feedlot ($i = 0, 25, 50, 75$ and 100 days); A_{ij} = initial body weight of j^{th} animal in i^{th} days of stay in feedlot (covariate); e_{ij} = experimental error referring to the j^{th} experimental animal subjected in the i^{th} days of stay in feedlot as fixed effect ($0; \sigma_e^2$).

Meat quality parameters (CL, WBSF, pH and temperature) days of stay in feedlot, ageing time and their interactions were regarded as fixed effects and individual animal was considered as random effect. The MIXED procedure (SAS version 9.3; 2002) was used with repeated statement where compound symmetry was used as covariance structure. Differences were considered significant at $P < 0.05$ and means were separated by Turkey-Kramer protection.

Model: $Y_{ijk} = \mu + P_i + T_j + PT_{ij} + b(A_{ij} - \bar{A}) + e_{ijk}$

In which Y_{ijk} = Measurement of unit meat sample of individual animal; μ = Overall mean; P_i =fixed effect of days of stay in feedlot ($i = 0, 25, 50, 75$ and 100 days); T_j = Fixed effect of time ($j = 3, 6, 9, 12$ days for CL and WBSF and $j = 0.45, 6, 24, 48$ h for pH and temperature); PT_{ij} = Interaction effect of days of stay in feedlot and time; A_{ij} = initial body weight of j^{th} animal in i^{th} days of stay in feedlot (covariate); e_{ijk} = experimental error referring to the k^{th} experimental animal subjected in the j^{th} time and i^{th} days of feedlot as fixed effects ($0; \sigma_e^2$).

Results and discussion

Feed intake and growth performance

The intake of dry matter (DMI), energy and protein increased with increasing days in feedlot. Steers on the longest stay (P₁₀₀) had the highest ($P<0.05$) values followed by steers on P₇₅, P₅₀ and P₂₅ (Table 2). The DMI as percent of body weight increased ($P<0.05$) gradually from P₂₅ to P₁₀₀ days in feedlot, which might be attributed to the increased live body weight, as feed requirements for animals on similar diets are normally considered to be a function of live weight or metabolic body weight (Mustafa et al., 2008; Shirima et al., 2014). Previous studies by Mello et al. (2010) and Porto et al. (2012) have shown that requirements of energy and protein for gain increased with increasing body weight. Average daily gain (ADG) and feed conversion ratio (FCR) were not affected ($P>0.05$) by days in feedlot. However, the general trend showed that FCR values increased with increasing number of days in feedlot implying decreased efficiency of feed utilization. This might be attributed to higher maintenance requirements due to heavier body weights and additional fat deposition in long duration in feedlot which requires more energy for fat deposition. Energetically, efficiency of fat accretion is approximately 1.7 times that of protein but because in deposition of protein (muscle) more water is stored than in deposition of fat, lean tissue gain is four times as efficient as accretion of fat (Owens et al., 1995; Pazdiora et al., 2013; McGee 2014). As expected treatment P₁₀₀ resulted in the highest ($P<0.05$) gain compared to the other groups this might be caused by intake of energy and protein for a long time. These TSZ cattle were 3 years of age and in poor body condition at the start of the experiment. The poor body condition was caused by inadequate energy and protein supply from poor range land pastures. Therefore part of the high growth rate observed could be due to compensatory growth, which is commonly seen when animals are given *ad libitum* access to feed following a period of restricted feeding. (Kristensen et al., 2004). Boleman et al. (1996) reported an increase in body

weight for cull cows fed a high energy and protein diet for 28, 56, and 84 d. There was a nearly linear increase in final live weight and total gain with increasing days in feedlot. These results are in agreement with Van Koeveering et al. (1995), Hicks et al. (1987), Menezes et al. (2014) and Monteiro et al. (2014) who found a linear increase in final live weight with time on feed. The average daily gain of almost 1 kg obtained in the present study compares well with results from feedlot zebu steers of cattle with low mature weight as the TSZ (Butterworth and McNitt, 1984). The average daily ME intake of 72.0 MJ and daily weight gain of 928 g were slightly higher than the CAB recommendations of 56 – 66 MJ ME/day to obtain a weight gain of 1000 g/day for a 200 kg steer of cattle of small breeds, when fed a diet of similar energy concentration (CAB, 1980). This difference might have been caused by breed differences between the two studies.

Table 2: Least squares means \pm SE for feed intake and growth performance of steers under different periods in feedlot

Variables	Days in feedlot					SE	P-value
	0	25	50	75	100		
Intake(kg DM/day)							
Hay	-	1.23	1.32	1.13	1.17	0.06	0.1144
Concentrate	-	4.35 ^c	5.72 ^b	6.04 ^{ab}	6.41 ^a	0.19	<0.0001
Total intake	-	5.58 ^b	7.04 ^a	7.17 ^a	7.58 ^a	0.19	<0.0001
Total (% live weight)	-	2.87 ^c	3.22 ^b	3.26 ^{ab}	3.29 ^a	0.09	<0.0009
ME intake (MJ /day)	-	56.9 ^c	73.4 ^b	76.2 ^{ab}	80.7 ^a	2.24	<0.0001
Crude protein intake (g/day)	-	570 ^c	740 ^b	772 ^{ab}	820 ^a	23.2	<0.0001
Weight gain (kg)							
Initial live weight	183	180	180	187	184	3.31	0.5887
Final live weight	183 ^e	206 ^d	230 ^c	251 ^b	278 ^a	2.77	<0.0001
Daily gain	-	0.918	0.946	0.898	0.952	0.05	0.8882
Total gain	-	22.6 ^d	47.0 ^c	67.8 ^b	95.4 ^a	3.10	<0.0001
FCR (kg feed /kg gain)	-	6.08	7.44	7.98	8.00	0.57	0.0558

Least squares means with different superscript in the same row are statistically different ($P < 0.05$); SE, Standard error

Slaughter characteristics

Days in feedlot had significant ($P < 0.05$) effects on slaughter characteristics (Table 3). The EBW increased by 61% for animals on grazing (no feedlot, P_0) to P_{100} days in feedlot.

This increase in EBW mass could be explained by the corresponding changes in final live weight and gut fill. Gut fill is known to increase with high proportion of fibrous feeds than concentrate feeds (Mushi et al., 2009; Shirima et al., 2012). In the present study the GIT content decreased with increasing time on concentrate feeding. The observed carcass weight increase for steers in P₁₀₀ than their counterparts was caused by their superior gains from longer accessibility and higher intake of both energy and protein from the concentrate diet. Intake of any particular ration with high energy and protein promotes growth, which will produce fatter carcass with high carcass weights (Sami et al., 2004; Shirima et al., 2014). Linear increase in HCW with extended days in feedlot observed in the current study was in agreement with the findings by van der Westhuizen et al. (2010), Vasconcelos et al. (2008) and Monteiro et al. (2014), who also found a linear response. The dressing percentage (DP) ranged from 50% to 54% with P₁₀₀ having higher ($P<0.05$) DP than steers from other periods. This was associated with higher dietary energy consumption, slaughter weight and increased fatness. Increase in DP was expected because dressing percent generally increases with increased carcass fatness, which normally increases when days on high concentrate diet are increased (Vasconcelos et al., 2008). Furthermore, increase in DP and carcass weight with the increased time in feedlot might be attributed to increased maturity of carcass components (Khalafalla et al., 2011). Carcass components are late maturing tissues so their proportions normally increase with advanced age.

The proportion of non-carcass parts (as % EBW) decreased ($P<0.05$) with increasing days in feedlot with an exception of internal fat, which increased with increasing days in feedlot (Table 3) from 0.9 % for grazing P₀ to 2.9 % for P₁₀₀ steers probably because of higher dietary energy intake which is expected to increase fat mass. The proportion of external organs (head, hide, feet, tail and anus) was higher ($P<0.05$) for grazing and

P₂₅steers than those stayed for longer periods reflecting nature of development of non carcass components being early maturing tissues whose proportions decline with advanced age (Lawrence and Fowler, 1997). Other researchers working on sheep (Shirima et al., 2012 and van der Westhuizen et al., 2010) had also reported the decrease in proportions of non-carcass components with increased days in feedlot. Steers from grazing, P₀ had higher (P<0.05) percentage of empty GIT and gut contents than steers from P₁₀₀ group due to changes from fibrous feed to concentrate. It has also been found previously that increased roughage intake increases energy expenditure by the GIT, which stimulates its pronounced development (Mushi et al., 2009; Shirima et al., 2012).

Table 3: Least squares means \pm SE for slaughter characteristics of steers under different periods in feedlot

Variables	Days in feedlot					SE	P-values
	0	25	50	75	100		
Empty body weight (kg)	163 ^e	190 ^d	214 ^c	236 ^b	263 ^a	2.96	<0.0001
Hot Carcass weight (kg)	91.6 ^e	105 ^d	119 ^c	131 ^b	151 ^a	1.87	<0.0001
Dressing percentage (%)	50.0 ^c	51.0 ^{bc}	51.6 ^b	52.2 ^b	54.3 ^a	0.57	<0.0001
Non carcass components (% EBW)							
Head, hide, feet, tail, anus	20.4 ^a	19.5 ^a	16.7 ^b	17.0 ^b	16.9 ^b	0.38	<0.0001
Spleen	0.3	0.3	0.4	0.3	0.3	0.02	0.2250
Kidney	0.3	0.3	0.3	0.3	0.3	0.0	0.2699
Pluck	4.0	4.1	4.1	4.0	3.9	0.12	0.8283
Internal fat	0.9 ^e	1.5 ^d	1.9 ^c	2.3 ^b	2.9 ^a	0.13	<0.0001
GIT empty	7.8 ^a	6.9 ^b	7.1 ^b	7.0 ^b	6.8 ^b	0.18	0.0014
GIT contents	12.4 ^a	8.6 ^b	7.5 ^{bc}	6.5 ^c	6.0 ^c	0.58	<0.0001

Least squares means with different superscript in the same row are statistically different (P<0.05); SE, Standard error, EBW, Empty body weight, GIT, gastrointestinal tract

All linear carcass measurements increased (P<0.05) with increasing days in feedlot (Table 4) due to growth of both soft and skeletal tissues (Lawrence and Fowler, 1997). Increased *longissimus* muscle area (LMA) with longer feeding period implies increased muscle development for steers kept in feedlot for longer periods compared to those directly from grazing. An increase of 10.1 mm fat thickness was observed for carcasses from P₁₀₀ steers compared to those from grazing, P₀. Long feeding periods before slaughter results into

increased fat thickness (Monteiro et al., 2014) and LMA (Duckett et al., 1993; Silva et al., 2005). A linear increase in fat thickness with advanced days in feedlot was associated with the prolonged high energy intake of animals in feedlot. Intake of energy above the maintenance requirements of the animal is the most important factor affecting deposition of subcutaneous fat (Sainz and Paganini, 2004). In the present study, addition of 25 days from P₇₅ to P₁₀₀ increased fat thickness by 4 mm, which can be considered as waste since excessive fat is undesirable attribute to many beef customers. Furthermore, excess fat is very expensive waste as its extremely energy rich compared to lean due to low water content and high energy content in DM.

Table 4: Least squares means \pm SE for linear carcass measurements of steers under different periods in feedlot

Variables	Days in feedlot					SE	P-value
	0	25	50	75	100		
Carcass length (cm)	100 ^c	100 ^c	101 ^{bc}	103 ^b	106 ^a	0.78	<0.0001
Chest depth (cm)	48.2 ^b	51.6 ^b	50.7 ^b	51.4 ^b	51.9 ^a	0.49	<0.0001
Hind limb circumference (cm)	81.8 ^c	84.1 ^b	85.7 ^b	91.3 ^a	93.0 ^a	0.78	<0.0001
Hind limb length (cm)	65.5 ^c	66.3 ^b	65.8 ^{bc}	67.6 ^{ab}	69.5 ^a	0.67	0.0006
Fat thickness (mm)	4.10 ^c	4.38 ^c	8.39 ^b	10.2 ^b	14.2 ^a	0.80	<0.0001
LMA cm ²	27.3 ^b	32.0 ^a	34.0 ^a	33.3 ^a	35.2 ^a	1.55	0.0072

Least squares means with different superscript in the same row are statistically different (P<0.05); SE, Standard error, LMA, *longissimus* muscle area.

Carcass composition

The percent of lean and bone in the carcass decreased (P<0.05) with increasing days in feedlot (Table 5). Steers from grazing, P₀ had higher (P<0.05) proportions of lean (6.7 %) and bone (6.4%) in their carcasses than those from P₁₀₀. The higher percentage of bone tissue from grazing steers compared to those from feedlot was probably attributed to the thinness of carcasses from the grazing group caused by poor quality of rangeland roughage. Under conditions of poor nutrition loss of weight occurs affecting mostly fat followed by muscle and bone is least affected (Mushi et al., 2009; Safari et al., 2010;

Keane and Moloney, 2008). The percentage of fat increased ($P<0.05$) with progressing days in feedlot, with steers on P₁₀₀ days having high values. Increase in carcass fat with increasing feeding period was associated with prolonged intake of energy. Steers consuming feedlot diets which in most cases are high in energy contents deposit fat at a higher rate than pasture fed steers (Sainz and Panganini, 2004). A linear increase in carcass fat with advanced days on feed was also observed by Keane and Moloney (2008) on beef steers, and van der Westhuisen (2010) and Shirima et al. (2012) on sheep. Another study by Aalhus et al. (1992) on beef cattle found fat content to increase while the carcass lean content decreased with increasing time on feed. The ratio of lean:fat tissues differed significantly between days of stay in feedlot with carcasses from steers on P₁₀₀ having lower ($P<0.05$) values than those from grazing (P₀), reflecting accumulation of fat with advanced days in feedlot caused by prolonged energy intake. Carcasses from animals receiving high energy levels accumulates greater amount of fat and are found to have lower lean:fat ratios (Fadol and Babiker, 2010; Shija et al., 2013;). The observed proportions of carcass components were slightly lower for lean, but higher for fat and bone than the range of lean (63 to 67%), fat (14 to 20%) and bone (17 to 20%) reported for Boran and TSZ steers by Shija et al. (2013). These differences could arise from differences in diet and age of the animals used between the two studies.

Table 5: Least squares means \pm SE for carcass composition of steers under different periods in feedlot

Variables	Days in feedlot					SE	P-value
	0	25	50	75	100		
% in 6 th rib joint							
Lean	62.5 ^a	60.3 ^{ab}	57.0 ^{bc}	57.0 ^{bc}	55.8 ^c	1.56	0.0218
Fat	13.7 ^c	18.8 ^b	23.7 ^a	24.5 ^a	26.8 ^a	1.59	<0.0001
Bone	23.8 ^a	20.8 ^b	19.2 ^b	18.5 ^{bc}	17.4 ^c	0.92	0.0002
Ratios of the 6 th rib joint components							
Lean:Bone	2.75	2.94	3.02	3.11	3.25	0.18	0.3492
Lean:Fat	4.76 ^a	3.68 ^b	2.46 ^c	2.41 ^c	2.13 ^c	0.28	<0.0001
(Lean+fat):Bone	3.35 ^c	3.88 ^{bc}	4.28 ^b	4.46 ^{ab}	4.84 ^a	0.24	0.0007

Least squares means with different superscript in the same row are statistically different ($P<0.05$); SE, Standard error.

Meat quality attributes

The rate of pH decline increased with increasing days in feedlot (Figure 1). Carcasses of feedlot finished steers, P₂₅ to P₁₀₀ had faster ($P < 0.05$) pH decline than those from grazing, P₀ whose pH remained above 6 even after 24 h PM. High pH values from grazing steers show depletion of muscle glycogen which might have been caused by poor nutrition status of these animals before slaughter. Poor pre-slaughter nutrition and stress are among factors known to deplete muscle glycogen reserve of animals before slaughter (Moloney et al., 2011; Shirima et al., 2013; Mushi et al., 2009). The range (5.6 to 5.8) of ultimate muscle pH for steers stayed in feedlot for different periods was within the acceptable range of (5.5 to 5.8) for eating properties (Silva et al., 1999; Mach et al., 2008).

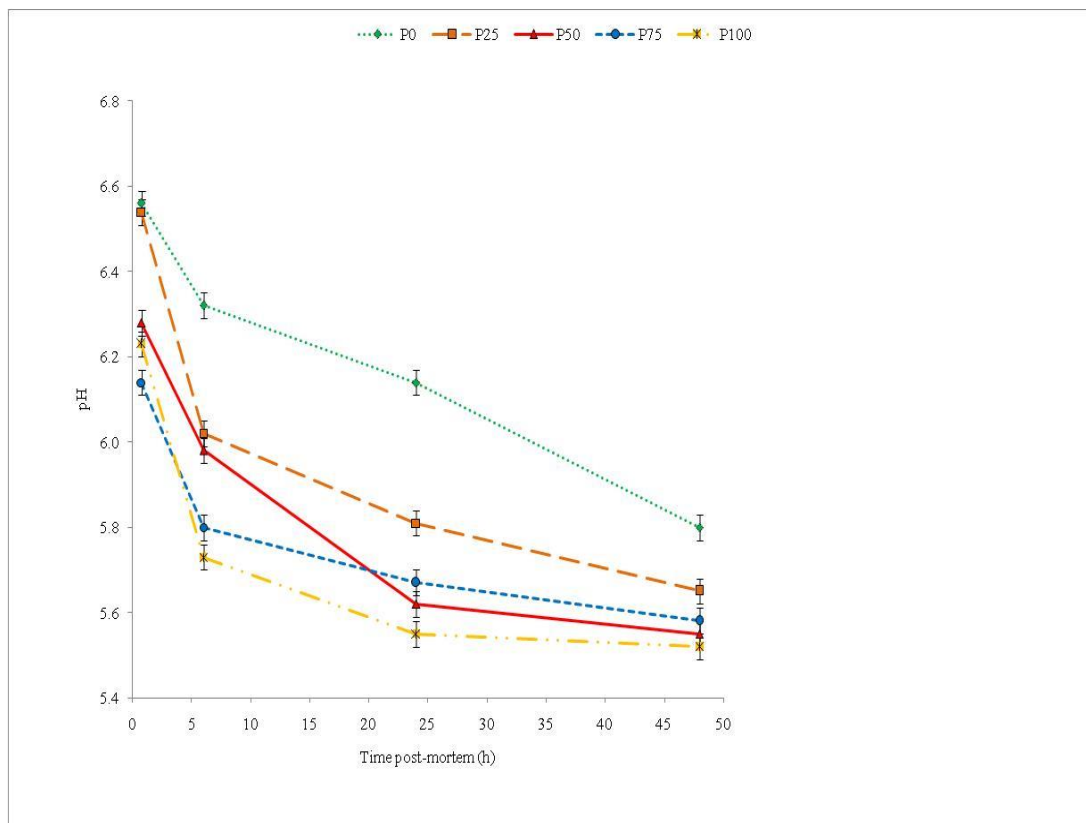


Figure 1: Effect of time change on pH decline post-mortem for different days in feedlot; P-values: days - < 0.0001 ; time - < 0.0001 ; days*time - < 0.0001

The rate of temperature decline was faster ($P < 0.05$) in the first 6 and 24 h PM than afterwards (Figure 2). Carcass temperature measured at 0.45 and 24 h PM for steers from grazing, P_0 was 4.2°C lower ($P < 0.05$) than those from P_{100} . High temperatures with advanced days in feedlot could be associated with the increase in carcass fatness of these steers insulating their carcasses against cooling. Similar trends were observed by May et al. (1992) in steers and Shirima et al. (2013) and van der Westhuizen (2010) in sheep.

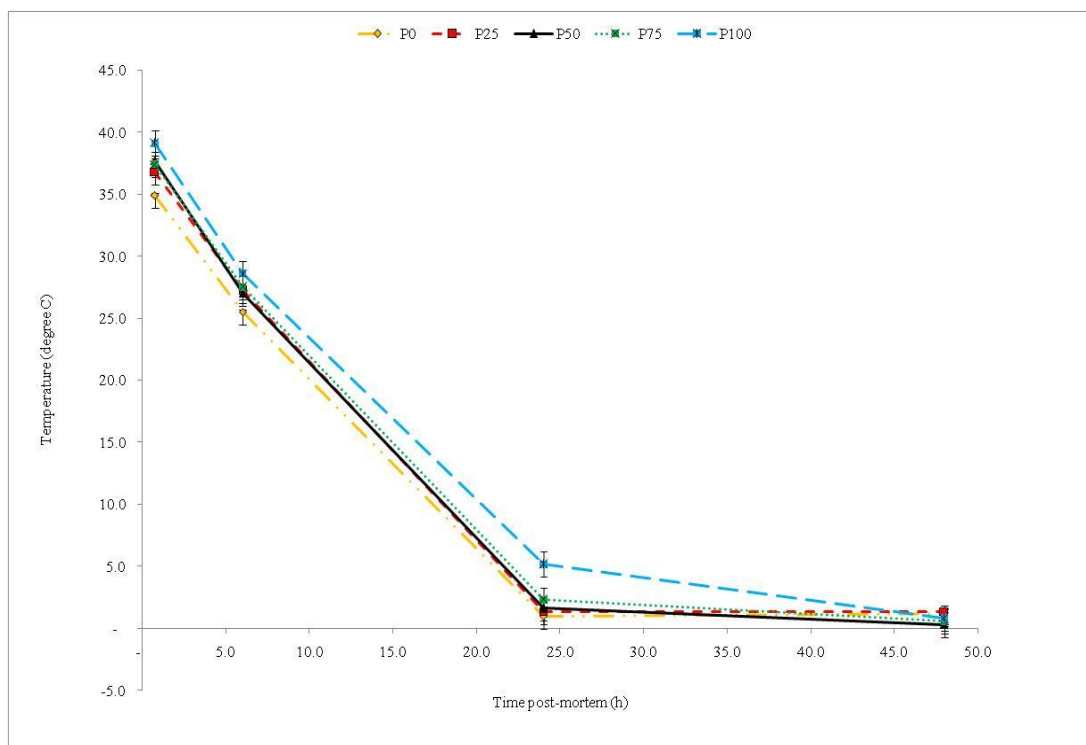


Figure 2: Effect of time change on temperature decline post-mortem for different days in feedlot; P-values: days - < 0.0001 ; time - < 0.0001 ; days*time - < 0.0001

The CL decreased ($P < 0.05$) with increasing days in feedlot (Table 6). Steers from P_{100} and P_{75} had the lowest ($P < 0.05$) CL implying high capability of muscles to hold water which might have been caused by their observed fatter carcasses. CL from fatter meat tends to be less than from lean meat (Mitsumoto et al., 1992; Ueda et al., 2007). Meat with greater fat contents loses less moisture, possibly because the structural changes

caused by the presence of fat enhance water-holding capacity (Lawrie and Ledward, 2006). Honikel (1987) defined water-holding capacity (WHC) as the ability of meat to hold all or part of its own water. The values of WBSF decreased with increasing days in feedlot. The highest ($P<0.05$) values were recorded for muscles samples from grazing, P₀ and P₂₅ steers probably because of low glycogen and fatness levels observed on carcasses of these steers, carcasses from these two groups were found to have similar fat thickness levels. The decrease in shear force values as time on high–energy feed increases has been observed by previous researchers (Aalhus et al., 1992; Boleman et al., 1996; Stelzleni et al., 2008). The WBSF values decreased ($P<0.05$) by 35% with increasing ageing time having the least value after 12 days of ageing. This might be attributed to the disruption of the myofibrillar components which advances with increased ageing time.

Table 6: Least squares means \pm SE for cooking loss and Werner Bratzler shear force value of steers under different periods in feedlot

Days in feedlot (P)	Variables	
	Cooking loss (%)	Shear force (Ncm ⁻²)
P ₀	27.2 ^a	67.8 ^a
P ₂₅	26.8 ^a	61.3 ^a
P ₅₀	26.1 ^a	54.1 ^b
P ₇₅	19.0 ^b	46.5 ^c
P ₁₀₀	15.7 ^b	44.0 ^c
SE	1.4	1.59
P-values	<0.0001	<0.0001
Ageing days (A)		
3	25.4	62.7 ^a
6	24.2	57.7 ^b
9	21.6	52.6 ^c
12	20.6	47.0 ^d
SE	1.3	0.84
P-values	0.0546	<0.0001
P x A	0.8235	<0.0001

Least squares means with different superscript in the same column are statistically different ($P<0.05$); SE, Standard error

Ageing is known to increase tenderization by weakening the structural integrity of the myofibrillar proteins (Ba et al., 2014; Hanzelkova et al., 2011). An interaction ($P<0.05$) between days in feedlot and ageing time was observed for WBSF values (Figure 3), more

tender meat was aged for 12 days from steers that had stayed in feedlot for P₁₀₀. The values for WBSF observed in the current study are close to the value of 60N for grazing and 42N for 100 days feedlot finished TSZ steers observed by Mwilawa (2012). In general meat quality parameters for muscle samples of steers from P₁₀₀ and P₇₅ days were similar.

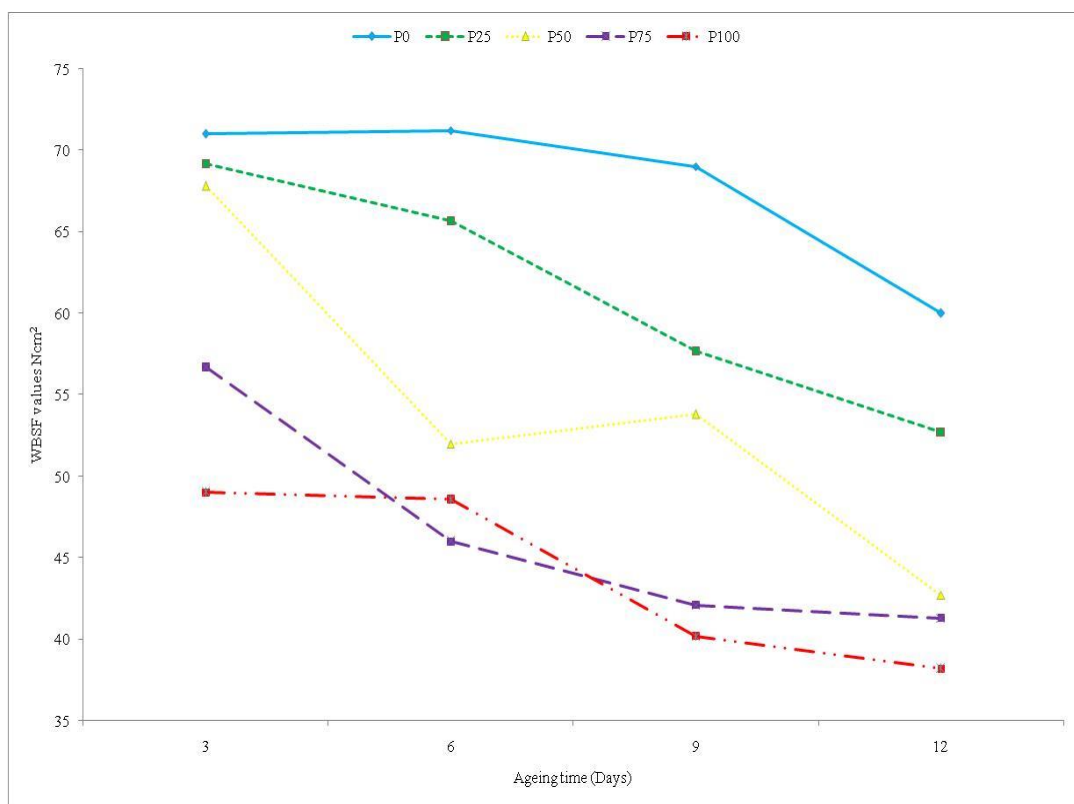


Figure 3: Effect of ageing time on tenderness for different days in feedlot. P-values: days - <0.0001; ageing time - <0.0001; days*ageing time- <0.0001; WBSF, Warner-Bratzler shear force

Conclusion

Growth performance, carcass characteristics and meat quality of TSZ cattle with poor body weight condition can be improved by manipulating number of days in feedlot. An increase of days to 75 and 100 days resulted into increased intake, carcass measurements and tenderness, without changing the rate of gain. But the increase to 100 days resulted

further into substantial increase in carcass fatness and fat thickness contributing to unwanted fat compared to 75 days. Thus for this particular feeding system and animal conditions used in the current study 75 days can be recommended period to keep TSZ cattle in feedlot.

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Conflict of interest

The authors declare that they have no conflict of interest, and this document is their original research work done at Kongwa National ranch, Dodoma, Tanzania. No part of this research has been submitted anywhere for publication.

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CHAPTER SEVEN

7.0 PAPER 4

**Economics of finishing Tanzania Shorthorn Zebu cattle in feedlot and optimum
finishing period**

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Economics of finishing Tanzania Shorthorn Zebu cattle in feedlot and optimum finishing period

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Abstract

Economic potentials of finishing Tanzania Shorthorn Zebu (TSZ) cattle in feedlot was analysed using data obtained from two feedlot experiments carried out at Kongwa ranch in Tanzania. The experiments were done to evaluate the effects of feeding agro processing by products and length of feedlot finishing on live weight, carcass characteristics, meat yield and quality for TSZ cattle. The biological data collected from the two experiments were used as basis for deriving the economic scenarios. The range of days to keep steers in feedlot was set at 0, 25, 50, 75 and 100 days. The dietary metabolisable energy intake (MEI) levels used in the study were 55 MJ/day (Low) and 85 MJ/day (High). The amount of extra meat (34.4 kg) produced from high MEI was more than twice the amount produced from low (15.7 kg) MEI in all days in feedlot. Feed cost (6100 TSh.) increased for low MEI while it decreased (3923 TSh.) for high MEI with advanced days in feedlot. Non-feed costs were higher (4500 TSh.) for short stays than long (2630 TSh.) stays and increased with increased days in feedlot. When there was no change in meat price, high MEI was profitable with increment of 81% profit per kg of extra meat for increase in days from 50 to 75 days in feedlot. Thus, 50 to 75 days appears to be optimum for keeping TSZ cattle in feedlot. When meat price was increased by 10% regardless of finishing length, only profit per animal carcass increased with increasing

days in feedlot for high MEI from 71 800 TSh. in 25 days to 143 000 TSh. in 100 days in feedlot. When meat price was increased by 5% with each increase in feedlot finishing length of 25 days, high profit per animal carcass were realized with long stays (100 days, 238 000 TSh.) than short stays (25 days, 37 600 TSh.). It is concluded that high feeding level is the most economical for cattle finishing irrespective of meat price and finishing length. The optimum finishing length is between 50 and 75 days when price does not change with feedlot finishing while it increases to 100 days when price changes with feedlot finishing length.

Keywords: Cost, Days in feedlot, Energy intake, Profit.

Introduction

Tanzania shorthorn zebu (TSZ) is the dominant breed accounting for 95% of the total cattle population and is a common breed used for beef in the country. The TSZ cattle are known for their ability to survive and produce under harsh environment, poor feeding and high disease challenges (MLDF 2011). Despite their small size, which makes them produce small carcasses, these animals are suitable for beef production in feedlot and they respond well to finishing diets by producing acceptable carcasses (Zakaria 2010; Mwilawa 2012). Finishing beef cattle in feedlots can be economically attractive if low cost feed resources are available as well as animals to finish. Cattle finishing simply refers to the preparation of cattle for marketing which require cattle to gain weight at their maximum potential rate. This involves getting them quickly into a high-energy diet to produce marketable beef in the shortest time possible. Feeding is a major cost in most beef production enterprises (Archer and Bergh 2000; Kelsey et al 2010) and therefore proper nutrition is a key component for successful production. Finishing TSZ cattle in

feedlot using maize or molasses with rice and maize by-products based diet was found to improve growth performance, carcass characteristics and meat quality, mainly tenderness (Asimwe et al 2015a & b). However, evaluation on the economics of keeping TSZ cattle in feedlot for different periods of stay has not been documented.

Finishing period is the number of days required to keep animals on feed for a certain desired weight and meat quality. Increasing number of days on feed will increase marbling, yield grade, carcass weight, carcass size and external fat cover (Van Koeveering et al 1995; Shirima et al 2012) as well as meat tenderness, but it has an implication on feedlot costs. Prolonged number of days in feedlot involves increased amounts of non-pasture feed provided to the animals and thereby increases in production cost (Owens and Gardner 2000). Profit maximization in feedlot project depends on the input/output relationship. The cost of inputs used in the production process and the price received from the finished product are major factors that determine profitability of a feedlot. It may be possible to reduce cost and maximize profit of feedlot by feeding balanced rations from less expensive feed ingredients for a short period. Attempts have been made to promote feedlot production in Tanzania by assessing quality, quantity and price trends of beef animals and feed resources available (Nandonde 2008), but inadequate information is available showing optimum length of period for TSZ cattle to stay in feedlot. Thus the aim of this paper was to report the economics of finishing TSZ cattle on agro processing by product diets under different periods of stay in feedlot using biological data and different assumed scenarios.

Methods

Biological background

The biological background for economic scenarios was mainly based on feedlot experiments carried out at Kongwa ranch Dodoma, Tanzania. The first study evaluated the effects of feeding different agro processing by products to TSZ cattle for 90 days in feedlot and the second evaluated the different periods of stay in feedlot for optimum production of TSZ cattle. In the first experiment, a total of 45 TSZ steers of 2.5-3 years of age and 200 ± 5 kg initial body weight were randomly allotted to five dietary treatments. Dietary treatments were the concentrate diets compounded from different agro processing by products as hominy feed with molasses (HFMO, 86 MJ/day MEI), rice polishing with molasses (RPMO, 77 MJ/day MEI), hominy feed with maize meal (HFMM, 73 MJ/day MEI), rice polishing with maize meal (RPMM, 69MJ/day MEI) and maize meal with molasses (MMMO, 74 MJ/day MEI) as detailed by Asimwe et al (2015a). In the second experiment, fifty (50) TSZ steers aged 3.0 years with 183 ± 4 kg initial body weight were allocated in five periods. The periods of stay in feedlot were P₀ (zero days), P₂₅ (25 days), P₅₀ (50 days), P₇₅ (75 days) and P₁₀₀ (100 days) as detailed by Asimwe et al. (2015b). Animals in the second experiment were fed on HFMO, which performed the best in the first study. At the end of each feeding trial, animals were slaughtered and carcasses were sold at the prevailing market price for normal meat.

Scenarios assumed

Different scenarios were assumed from experience gained in the two experiments carried out at Kongwa ranch Dodoma on TSZ cattle as detailed by Asimwe et al (2015a, b). The reasonable range of days for such animals to stay in feedlot was assumed to be 0, 25, 50, 75 and 100 days. Two extreme conditions in feedlots were to be considered, that is, not finished at all or finished for a short time (few number of days); they would have carcass

with low final weights but with less fat content, and finished for many days resulting in heavy carcasses with higher final weights but possibly with too much fat. Daily metabolisable energy intake (MEI) was assumed based on the actual range of daily MEI observed for TSZ cattle finished in feedlots using different agro processing by product based rations and had stayed in feedlots for different periods (Asimwe et al 2015a, b), where low (55MJ MEI per day) and high (85 MJ MEI per day) levels had been chosen to simulate situations with low and high energy intake, respectively. Daily feed intake was taken as average range of intake values observed for steers from the two experiments. Initial weight was obtained by taking the average initial weights in the two experiments. Average daily gain was derived from the equation on linear relationship between growth rate and MEI for TSZ cattle fed different rations formulated from different agro processing by products used in the first experiment. The equation was $y = 14.9x - 388$, where y is the daily gain (g/day) and x is the respective daily MEI in MJ (Asimwe et al 2015a). The dressing percentage (DP) was derived from the range of DP values observed for TSZ steers in the two experiments.

The marginal meat production and energy intake were derived from biological values. The ME concentration in the total ration was taken from a range of ratios of ME intake to total feed intake for TSZ cattle in the two experiments which was found to be realistic for the two classes of MEI. The cost for 1 MJ of feed was calculated based on the feed cost obtained from the second experiment where hominy feed mixed with molasses (HFMO) was the concentrate mixture used. The price for total mixed ration of 20:80 hay to concentrate ratio was 266 TSh. per kg. The price of agro processing by products differ without considering variations in energy concentration therefore a constant price per MJ seems reasonable according to the prevailing market situation in Tanzania.

The following cost elements were used to compute profitability of finishing TSZ cattle in feedlot for different finishing periods. The cost of production was obtained by summing up all variable and fixed costs of producing a kg of extra meat. The variable costs included the feed and non-feed costs which included labour, medication and slaughter. Medication included the cost for vaccination against Foot and Mouth Disease (FMD), routine control of internal parasites by de-worming and external parasites by hand spraying using Vectocid^R and some antibiotics such as *Oxytetracycline* and penstrep calculated for each period. The labour cost was taken as monthly wages for minimum salary scale used at Kongwa ranch, which was 100,000 TSh. per month (10 hours per day) and was adjusted to the cost of one animal per day by dividing the cost by the number of animals. Labour cost was taken as cost per animal per day, whereas medication cost was taken as cost per animal. Transportation cost was taken as cost incurred for transporting an animal to the abattoir. The fixed cost included depreciation which was calculated from the cost of 10 000 000 TSh. for building a feedlot structure with space for 120 animals at Kongwa. The straight line method of calculating depreciation value with the assumption of 20% salvage value and useful life of 7 years the annual depreciation cost of 1 142 857 TSh. was used. This was then adjusted per animal per day assuming 20% empty time when the feedlot facilities are not in use. All costs were divided by the amount of extra meat produced for each period in order to derive the cost per extra kg meat produced.

The profit per kg of extra meat produced was obtained from the difference between price of meat and the total cost of producing that meat. Profit per carcass was obtained by multiplying the profit per kg with the amount of extra meat produced while profit per feedlot space was obtained by dividing profit per animal carcass with number of days in feedlot. Different scenarios were analysed based on different assumptions which have been made to mimic the beef market situation in Tanzania. The first scenario considered

market price of meat at the time of carrying out the experiment. It was assumed that when customers realize the difference between feedlot finished beef and ordinary beef they would be willing to pay a higher price for feedlot finished beef. The second scenario was taken as when the price of meat had increased by 10% due to feedlot finishing independent of time length. The third scenario was when the price of meat increases by 5 % for every 25 days increase in length of finishing.

Results and discussion

Biological values

The average daily gain increased with increasing levels of MEI. An increase of 444g/day (102%) was observed when the daily MEI increased from 55 to 85 MJ/day (Table 1). The daily gain was constant in different periods in feedlot but calculated total intake increased resulting into decreased efficiency with increased days in feedlot. With the aim of maximizing feed efficiency it is therefore not economical to keep steers in feedlot for periods longer than 100 days. The calculated final weight increased with MEI as well as days in feedlot. Long duration in feedlot with high daily MEI (85 MJ/day) resulted into higher final weight (278 kg) than short stay (212 kg). Low daily MEI showed slow growth rate and lower final weights than those with high MEI regardless of the time spent in feedlot. Short stay in feedlot (25 days) with lower daily MEI (55 MJ/day) gained only 11 kg compared to grazing (0 days), the value which was doubled (22 kg) for high daily MEI (85 MJ/day) in the same period. Furthermore, high MEI (85 MJ/day) required only 25 days to attain slaughter weight of 212 kg a value which required 50 days with low MEI (55 MJ/day). Thus feeding high energy diets was essential to allow higher MEI for rapid body weight gains (Fan et al 1995; Tangjitwattanachai and Sommart, 2012) which would result into higher final weights hence shortening the time spent in feedlot. The calculated carcass weight increased with increasing MEI and days in feedlot. Long stay in feedlot

(100 days) with high MEI resulted into increased (58%) carcass weight compared to low MEI which increased by only 25% as compared to grazing (0 days).

Table 1: Derived biological values

	Days in feedlot ¹								
	0	25		50		75		100	
Daily MEI (MJ/day) ²	0	55	85	55	85	55	85	55	85
Daily intake (kg DM/day) ³	0	5.3	7.4	5.3	7.4	5.3	7.4	5.3	7.4
Total intake (kg DM)	0	133	185	265	370	398	555	530	740
Initial weight (kg)	190	190	190	190	190	190	190	190	190
Daily gain (g) ⁴	0	432	879	432	879	432	879	432	879
Final weight (kg)	190	201	212	212	234	223	256	234	278
DP (%) ⁵	50	51	52	51	52	51	53	51	54
Carcass weight (kg)	95.0	102	110	108	122	113	136	119	150

¹Range of days required for TSZ cattle to stay in feedlot, estimated from Asimwe et al (2015b)

²Variations due to feed ration and feed levels, estimated from Asimwe et al (2015a, b)

³Average intake ranges to the categorized energy level, estimated from Asimwe et al (2015a, b)

⁴Derived from linear equation $y = 14.8x - 388$; y = daily gain g/day and x = daily MEI in MJ (Asimwe et al 2015a)

⁵DP ranges estimated from Asimwe et al (2015a, b)

Marginal meat production

Extra meat produced increased with increasing days in feedlot, higher values were calculated with higher MEI than lower MEI (Table 2). The amount of extra meat produced with high MEI in all periods of stay in feedlot was more than twice the amount produced with low MEI, showing the importance of energy concentration and intake of feedlot rations. The extra energy required to produce extra meat differed between the two energy levels chosen in the current study. For low MEI the extra energy needed to produce extra meat increased at a decreasing rate with increased days in feedlot which was 27, 11, and 6 MJ/kg for 50, 75 and 100 days in feedlot. For high MEI the extra energy required to produce extra meat increased in the 50 days period by 20 MJ/kg and then decreased by 3 MJ/kg with the longer periods of 75 and 100 days (Table 2). Feeding high energy diets to feedlot animals is more advantageous than feeding low energy diets because even at the same period of staying in feedlot more energy was needed to produce the same extra kg of meat for low MEI than high MEI. In the current study, it was

calculated that extra 46, 53, 67 and 76 MJ ME were required for extra kg of meat for low MEI in 25, 50, 75 and 100 days of stay respectively, when compared to high MEI. The cost of one MJ of feed was assumed to be the same because in practice it was found that feeds like hominy feed and rice polishing had the same price per MJ regardless of difference in energy content of these feeds. Hominy feed contain higher energy content than rice polishing (Urassa 2012; Asimwe et al 2015a and Laswai et al 2013).

Table 2: Derived marginal meat production and energy intake during feedlot finishing

	Days in feedlot								
	0	25		50		75		100	
Daily MEI (MJ/day)	0	55	85	55	85	55	85	55	85
Total MEI (MJ)	0	1375	2125	2750	4250	4125	6375	5500	8500
Extra meat (kg)	0	7.4	15.2	13.0	26.6	18.5	40.6	23.9	55.0
Extra MEI /extra meat (MJ/kg)	0	186	140	213	160	224	157	230	154
ME in total ration (MJ/kg DM) ¹	0	10	11.5	10	11.5	10	11.5	10	11.5
Cost for 1 MJ of feed ²	0	25.7	25.7	25.7	25.7	25.7	25.7	25.7	25.7

¹The ratio of ME intakes to total feed intake (Asimwe et al 2015a, b)

² Based on feed cost per kg (Asimwe et al 2015b)

Variable and fixed cost of production

Variable and fixed costs in production of quality beef for different periods in feedlot are presented in Table 3. Medication cost per animal increased with increased time the animal spent in feedlot regardless of their MEI levels. High values were calculated for long stay in feedlot (100 days) because with increased number of days more drugs were required for the control of both internal and external parasites. Labour cost similarly increased with advanced days in feedlot. Abattoir cost was the same for all periods because the abattoir charge for slaughtering an animal is the same regardless of its conditional status or its weight. Total non feed costs per animal were found to increase with increasing days in feedlot and was the same for all energy levels in a particular period of stay in feedlot.

When considering total non feed cost per kg of extra meat produced differences were observed between the two energy levels (Table 3). The observed non feed cost per kg extra meat was higher for low MEI than high MEI level and was found to decrease with advanced days in feedlot. The non feed cost per kg extra meat produced was very high (4500 and 2190 TSh.) in short stay (25 days) than (2630 and 1140) for long stay (100 days) for low and high MEI, respectively. This was attributed to the increase in amount of extra meat produced with longer period in feedlot.

The difference in feed cost per kg of extra meat observed in the current study resulted from different length of time in feedlot as well as the energy content of the diet used. The feed cost for kg of extra meat for low MEI increased with increased time in feedlot, while for high MEI the cost increased for the short stay (50 days) then decreased as time in feedlot was increased (75 and 100 days). This was attributed to the extra meat produced as periods in feedlot advanced. The difference in feed cost per extra kg of meat between low and high energy levels within the same period increased with days in feedlot. That was 1,180, 2,200, 2,590 and 2,730 TSh. for 25, 50, 75 and 100 days, respectively. This emphasizes the need to use high energy diets in feeding animals with high intake to increase weight gain and reduce cost of production. Feeding is known to be a major variable cost in any beef production project (Arthur and Herd 2008; Herd et al 2003). The item that contributed to the majority of operational cost in all treatment periods were the expense of feeding, which accounted for 52 – 78% of total cost. With the exclusion of cost of purchasing animals, non feed cost accounted for 22 – 49% of the total cost. The percentage of feed cost observed in the current study is lower than the 93% presented by Malope et al. (2007) with exclusion of animals. However, the two studies were carried out at two different places and times using different prices of items. Total cost per kg of extra

meat was observed to be high for low MEI (55 MJ/day) and increased as days in feedlot increased. For high MEI total cost decreased as days in feedlot advanced which was probably accounted by the increase in body weight. The difference in total cost per kg of extra meat between high and low MEI was found to increase with increasing period of stay in feedlot being 61, 68, 78 and 84 % for 25, 50, 75 and 100 days respectively. This implies that by using diet with high energy levels and animals with high intake for longer period in feedlots one can reduce the total cost per kg of extra meat by 84% compared to the one using diet with low energy content and animals with low intake. It has been found previously that profit depends to a large extent on production cost (Otouzburov 2004) thus use of high energy diets which minimizes cost can maximize profit.

Table 3: Variable and fixed cost (TSh.'000) incurred in finishing TSZ in feedlot

	Days in feedlot								
	0	25	50	75	100				
Daily MEI (MJ/day)	0	55	85	55	85	55	85	55	85
Medication cost/animal ¹	0	5.75	5.75	5.75	5.75	10.0	10.0	12.9	12.9
Labour cost/animal ²	0	7.50	7.50	15.0	15.0	22.5	22.5	30.0	30.0
Abattoir cost/animal	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Fixed cost/animal (depreciation) ³	0	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total non-feed cost/animal	0	33.3	33.3	40.8	40.8	52.5	52.5	62.9	62.9
Total non-feed cost/kg extra meat	0	4.50	2.19	3.16	1.53	2.85	1.29	2.63	1.14
Feed cost for kg of extra meat	0	4.77	3.59	6.30	4.10	6.62	4.03	6.80	3.97
Total cost/kg extra meat	0	9.27	5.77	9.46	5.63	9.48	5.33	9.43	5.11

¹ Assumed required medicines, vaccines and routine treatment
² Monthly wages per person adjusted to the cost for one animal per day
³ Annual depreciation cost adjusted per animal per day

Profitability analysis

Scenario 1: When meat prices do not change with feedlot finishing

When meat prices do not change with feedlot finishing, a loss was realized per kg of extra meat produced for low MEI contrary to high MEI where a profit was realized (Table 4). For high MEI levels the increase in profit per kg of extra meat was 61, 81 and 33% for increase in days from 25 to 50, 50 to 75, and 75 to 100 days respectively. The increase in

profit per carcass was 187, 177 and 79 % with increase in days from 25 to 50, 50 to 75 and 75 to 100 days respectively. The same trend was observed with regard to feedlot space, where profit increase was 43, 80 and 36 % with increase from 25-50, 50-75 and 75-100 days respectively. This implies that with high MEI profit maximization can be achieved between 50-75 days of stay in feedlot. Increase in the number of days in feedlot beyond 75 days results into a profit increase at a decreasing rate. Thus with high energy diets, the optimum period of keeping TSZ cattle in feedlot is 50-75 days.

Table 4: Profit (TSh.'000) estimated in finishing TSZ in feedlot (when meat price do not change by feedlot finishing)

	Days in feedlot								
	0	25		50		75		100	
Daily MEI (MJ/day)	0	55	85	55	85	55	85	55	85
Price per kg meat	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Profit/loss per kg extra meat	0	-3.27	0.23	-3.46	0.37	-3.48	0.67	-3.43	0.89
Profit /loss per animal carcass	0	-24.2	3.43	-44.6	9.84	-64.0	27.3	-82.0	48.8
Profit/loss per feedlot space per day	0	-0.97	0.14	-0.89	0.20	-0.85	0.36	-0.82	0.49

Scenario 2: Meat price is increased by 10% with feedlot finishing regardless of finishing length

Due to high levels of consumers' acceptance and willingness to pay for high quality beef (Nandonde et al 2013) the price of quality beef from feedlots will increase with time. When the price was increased by 10 % without considering length of finishing a profit was realized for all parameters analysed except for low MEI level (55 MJ/day) in 100 days of stay in feedlot (Table 5). The profit per kg meat decreased with advanced periods in feedlot, the highest value of 5,180 TSh. was obtained at the shortest period of stay (25 days) in feedlot with low MEI level (55 MJ/day). This implies that the increase in price for a kg of meat produced was not large enough to offset the cost incurred in producing that extra kg of meat in the advanced days in feedlot. Profit per carcass behaved

differently for the two levels of energy intake. With high MEI the profit increased while with low MEI it decreased with advanced days in feedlot, which was contributed by the increase in carcass weight gained from high MEI. Furthermore, it is the increased value per kg of the whole carcass during feedlot finishing that offset the production cost and gives rise to the profit obtained (Weisbjerg et al 2007). Tatum et al (2012) observed that revenue depends on the amount and value of weight added during the feeding period. Variation in profit observed between the two energy levels in the current study emphasizes the need to use high energy diets in finishing animals in feedlot for maximizing profit per carcass. For feedlot space profit decreased with increasing days in feedlot. Implying that profit per feedlot space can be maximized by keeping animals in feedlot for a shorter period, which allows quick flow of cash. This concurs with observations by Perdana (2003) that shorter time allows faster cash flow to farmers.

Table 5: Profit (TSh.'000) realized-when meat price increase by 10% due to feedlot finishing regardless of finishing length

	Days in feedlot								
	0	25		50		75		100	
Daily MEI (MJ/day)	0	55	85	55	85	55	85	55	85
Price per kg meat	6.0	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
Profit/kg extra meat	0	5.18	4.72	1.65	3.19	0.28	2.76	-0.40	2.61
Profit /animal carcass	0	38.4	71.8	21.2	85.1	5.16	112	-9.57	143
Profit/feedlot space per day	0	1.53	2.87	0.42	1.70	0.07	1.50	-0.10	1.43

Scenario 3: Meat price increased by increasing length of feedlot finishing

When meat price was increased by 5 % according to increased duration of 25 days in each finishing period the profit per kg extra meat also increased with increased days in feedlot for all energy levels but with varying magnitudes, highest profit being observed on 100 days (Table 6). As usual high MEI had higher values than low MEI in all periods of stay which might be attributed with the increased extra carcass weight produced with high energy diets (Figure 1).

Table 6: Profit (TSh.'000) realized-when meat price increase by increasing feedlot finishing length

	Days in feedlot									
	0	25		50		75		100		
Daily MEI (MJ/day)	0	55	85	55	85	55	85	55	85	
Price per kg meat	6.0	6.3	6.3	6.6	6.6	6.9	6.9	7.2	7.2	
Profit/kg extra meat	0	0.96	2.47	1.65	3.19	2.16	3.80	2.63	4.32	
Profit /animal carcass	0	7.08	37.6	21.2	85.1	39.8	155	62.9	238	
Profit/feedlot space per day	0	0.28	1.51	0.42	1.70	0.53	2.06	0.63	2.38	

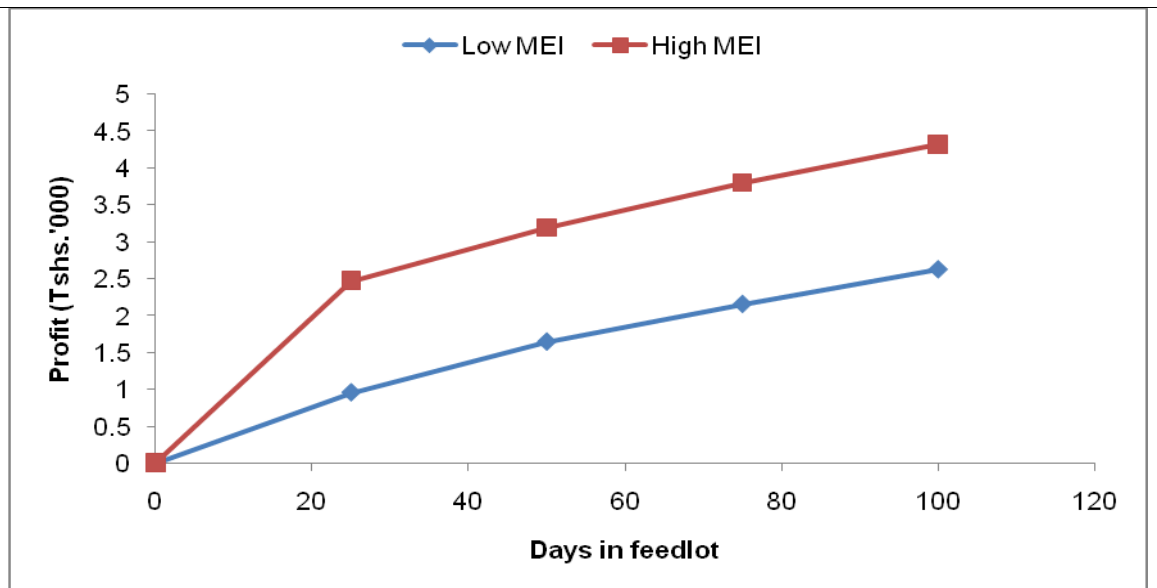


Figure 1: Profit per kg extra meat produced from TSZ cattle when meat price increase by increasing feedlot finishing length

The profit per animal carcass also increased with increasing time on feedlot, with higher profit on high MEI than low MEI level. The profit difference was observed to increase further with increased time on feedlot (Figure 2). With increase in price by considering length in feedlot finishing high profit was estimated when steers were kept in feedlot for longer time (100 days). It should be noted that not only the extra kg gain during feedlot that maximizes profit but also the increased whole carcass value which will cover the production cost and give profit (Weisbjerg et al 2007).

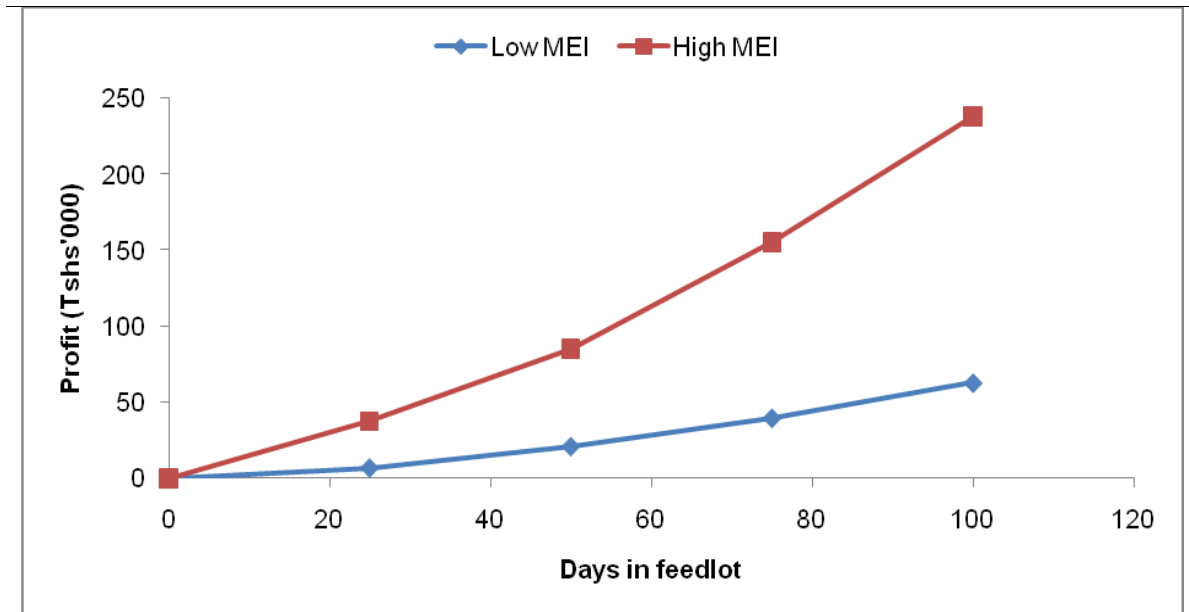


Figure 2: Profit per animal carcass produced from TSZ cattle when meat price increase by increasing feedlot finishing length

When profit per feedlot space was considered (Figure 3) the estimated profit was higher for high energy level than low energy level. Increase in profit seemed to be high for short stays (25 to 50 and 50 to 75) than advanced days in feedlot (75 to 100). The rate of profit increase for low MEI was 50 and 26 % for short stays and 19 % for advanced stays while for high MEI was 13 and 21 % for short stays and 15 % for advanced stays. Thus it is more beneficial to keep animals for short stays (50 to 75) in feedlot than long stays to maximize profit per feedlot space. This is because the frequency of keeping new batches of animals in feedlot will be high in short stays than in long stays.

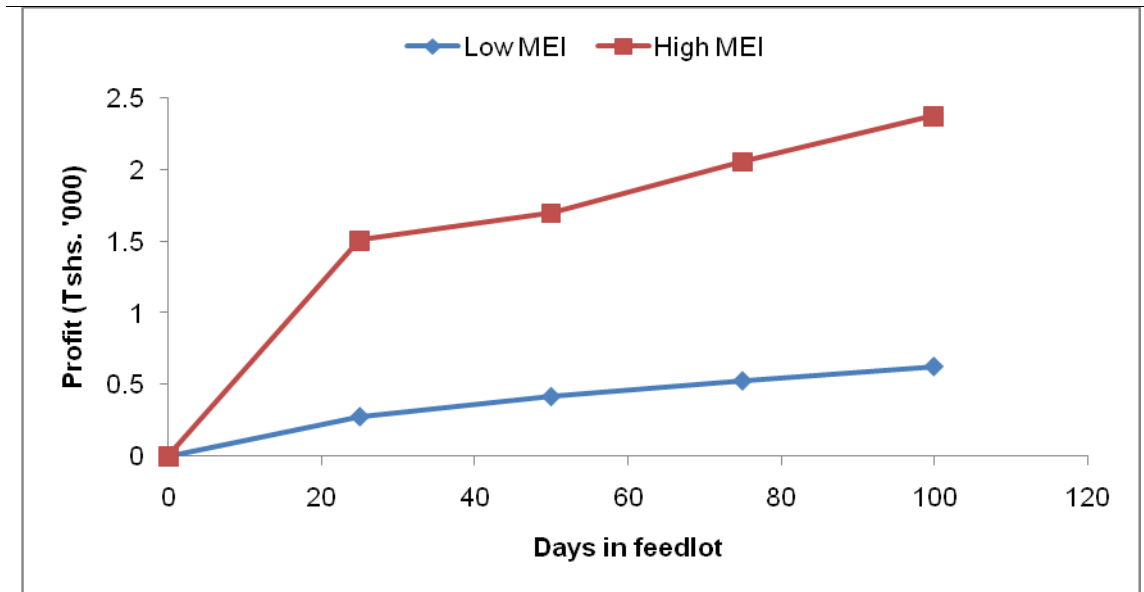


Figure 3: Profit per feedlot space from TSZ cattle when meat price increase by increasing feedlot finishing length

In general results from the current study agree with previous observations which found that high profit can be obtained when extra price is paid for high quality meat from feedlot (Weisbjerg et al 2007). Furthermore studies on customer willingness to pay for high quality beef have shown that customers in Tanzania prefer high quality beef (Nandonde et al 2013). What is needed is to give more education to customers and advertise further about feedlot finished beef.

Conclusions

Energy content and intake of feedlot finishing diet is very important in maximizing growth of finishing animals. The most economical feeding levels irrespectively of meat price and finishing length is always high feeding levels. High MEI was found to have low cost values than low MEI, feed cost per extra meat increased with low MEI while decreasing for high MEI in advanced days in feedlot, thus emphasizing the use of high energy diets with high intake in feedlot to reduce cost of production. Feed cost occupies

more than 50 % of total production cost and its percentage tends to increase while that of non-feed decreases with advanced days in feedlot, but the use of high energy diets with high intake for longer stays in feedlot can reduce total cost by 84 % compared to the use of low energy diets with low intake.

When meat prices do not change with feedlot finishing only high MEI is profitable, and high profit increments are on 50 to 75 days of stay in feedlot. When meat price increase by 10% due to feedlot finishing regardless of finishing length only profit per animal carcass increases with increasing days in feedlot for high MEI. When meat price increases by 5% with each increase in feedlot finishing length of 25 days, high profit per animal carcass will be realized with long stays (100 days) than short stays (25 days).

The optimum length of finishing is first of all depending on the consumer preferences and therefore the price they are willing to pay for the meat of different carcass composition. It is also to some extent determined by what is limiting for the production as for instance the number of animals or the feedlot capacity. If the feedlot capacity is limiting and consumers prefer less fat animals it may be economical to finish animals for 25–75 days, but for high final weights 50-75 days is the best, thus this appears to be the optimum period for keeping TSZ cattle in feedlot.

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CHAPTER EIGHT

8.0 CONCLUSIONS AND RECOMENDATIONS

8.1 Conclusions

- i. The study demonstrate that in feedlot finishing of beef cattle the diets based on molasses mixed with agro processing by products are better than maize meal based diets. A combination of molasses with hominy feed was superior in terms of ME intake, feed conversion efficiency, growth performance and carcass characteristics.
- ii. The use of diets based on agro processing by products in finishing TSZ cattle improved the quality of meat mainly tenderness and had no effects on proportions of different saleable cuts.
- iii. Both diet and post-mortem ageing improved meat tenderness of TSZ cattle. Thus hominy feed with molasses (HFMO) diet and ageing the meat for 9 – 12 days are the proper conditions for producing tender meat from TSZ cattle.
- iv. The performance of TSZ cattle in terms of growth, carcass characteristics and meat quality were improved as the number of days in feedlot increased. With this particular feeding system and animal conditions 75 days is the optimum period for TSZ cattle to stay in feedlot for good carcass characteristics and meat quality.
- v. Feeding diets with high energy content to animals with high intake resulted into high final weights at a lower cost. High MEI reduced the total cost by 84 % compared to low MEI.
- vi. It is economical to keep TSZ cattle in feedlot for 50-75 days for high final weight production when the price of feedlot finished meat is the same as unfinished meat. However, it is essential that the price per kg is higher after feedlot finishing than

before, but if the price does not increase by finishing, feedlotting will only be economical if the prices of concentrate feeds are very low compared to prices of carcass meat.

8.2 Recommendations

- i. Agro processing by products have been used in this study and have produced animals with high final weights and carcasses of high quality and tender. Thus the use of agro processing by-products in place of maize meal in finishing beef cattle is recommended to avoid competition with humans and other livestock species.
- ii. The current work has shown clearly that the use of agro processing by products increases growth rate and carcass quality of TSZ cattle, hence a comprehensive study is recommended to assess the acceptability and adoptability of this innovation to National ranches and other big companies.
- iii. The period for TSZ cattle to stay in feed in the feedlot had been found to be very important and from the present study, 75 days is the recommended time.
- iv. Further studies are recommended to assess different ages of TSZ cattle when placed in feedlot and fed on agro processing by products.