Sokoine University of Agriculture

MSc Dissertation

Feed Utilisation, Growth Performance and Carcass Characteristics of Tanzania Shorthorn Zebu Cattle Fed Rice Straws Under Traditional Finish Feeding System

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May 2024

FEED UTILISATION, GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF TANZANIA SHORTHORN ZEBU CATTLE FED RICE STRAWS UNDER TRADITIONAL FINISH FEEDING SYSTEM

Dissertation is Submitted to Sokoine University of Agriculture in Fulfilment of the Requirements for Master of Science Degree in Tropical Animal Production

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EXTENDED ABSTRACT

Tanzania has 36.6 million cattle and is one of the countries with the largest cattle population in Africa. Of the 36.6 million cattle, 96% are indigenous cattle and the majority of them belong to the Tanzania Shorthorn Zebu (TSHZ) breed. The TSHZ are kept under low input systems and grazed extensively in the communal rangelands. The low input management practices result into poor performance that has led to red meat production-demand imbalance in the country. The mismatch between supply and demand of beef is aggravated by the fast human population and economic growth. Some local cattle producers engage in feedlot practices as a means to increase beef production and capture the existing red meat market and hence, increase income generation to support their livelihoods. Most feedlot practitioners feed natural grasses including *Cenchrus ciliaris* hay to cattle as the basal diet and energy-based concentrates as supplement. However, hay usage is limited by its unavailability and high price, which necessitates farmers to look for alternative least cost basal diets such as cereal crop residues. Rice straw is among the cereal crop residues which are abundantly available and cheap in agro-pastoral communities of Tanzania. Despite the abundant availability of rice straws, these straws have high proportion of indigestible carbohydrate which limits their utilisation as a basal diet for fattening cattle. Treatment with urea can improve the nutritional value of rice straws and, hence, high performance of the fattened cattle. Therefore, the current study was conducted to evaluate the effects of partial or complete substitution of *C. ciliaris* hay with urea treated or untreated rice straws on feed utilisation, growth performance, carcass and meat characteristics of TSHZ. The current study was conducted at Mtanana village in Kongwa district, located about 82 km from Dodoma capital city in central Tanzania. Fifty (50) bulls with initial mean (± SD) weight of 132.4 ± 26.7 kg and age of 2.5 - 3 years were used in the experiment. The bulls were kept under total confinement and assigned randomly to five dietary treatments with 10 animals per treatment. The dietary treatments were used as basal diets and included *C. ciliaris* hay only (CCH), untreated rice straws (URS), urea treated rice straws (TRS), combination of untreated rice straws and hay (URH) and combination of urea treated rice straws and hay (TRH). In addition to the basal diet, all animals were fed the same supplementary diet comprised of maize bran (53%), molasses (25%), sunflower seed cake (20%), mineral premix (1.5%) and table salt (0.5%). The feeding trial took 84 days and at the end of the experiment, the experimental animals were evaluated for feed intake, weight gain, daily weight gain, percentage profit return, carcass characteristics and meat quality. Throughout the experimental period, clean water was provided *ad libitum* to all experimental animals. The results indicate differences ($p < 0.001$) in basal diet intake whereby animals under TRS had the highest value (1.6 ± 0.02 kg DM/day) and those on CCH had the lowest (1.3 ± 0.2 kg DM/day). Similarly, metabolisable energy intake was highest for animals fed TRS (86.0 ± 0.7 MJ/day) and lowest for those on CCH (72.0 ± 0.7 MJ/day). The animals fed TRH had the highest weight gain (64.7 ± 4.4 kg) and average daily gain (770 ± 0.1 g/day) while those on URS had the lowest weight gain (50.3 ± 4.4 kg) and average daily gain (599 ± 0.1 g/day). Also, feed conversion ratio varied ($p < 0.001$) among treatments and was lowest for animals on TRH (8.9 ± 0.1) and highest for animals on URS (11.9 ± 0.1), indicating that animals on TRH were more effective in converting feed to live weight. Animals fed URH had the highest hot carcass weight and some linear carcass measurements such as chest depth and hind limb circumference. The final meat pH was slightly higher in all animals subjected to different dietary treatments and was above the recommended value of 5.8. This resulted into dark red meat, probably due to the stress experienced by the animals at slaughter. Meat fat content was lower in animals fed TRS (10.6%) than in animals fed TRH (13.9%) and URS (11.9%). The animals on TRS had the highest proportion of lean (72.3%) compared to the animals on other treatments. The animals on TRH showed the least cost (TZS 5,244/=) for gaining one kilogram of live weight. However, the highest percentage profit return was observed in animals fed TRS (32.3%) while those fed CCH had the least (27.3%). Therefore, it is concluded that TRS is the best basal diet for fattening indigenous cattle because the animals fed this diet showed higher percentage profit margin, proportion of lean and lower fat and total lipid contents compared to those on other diets.

Keywords: Crop residues, Cattle fattening; Indigenous cattle; Feed conversion ration, Growth rate, Gross Margin, Traditional feedlot system; Lineal carcass measurements; Hot carcass weight; Meat tenderness,

IKISIRI KUU

Tanzania ina ng’ombe milioni 36.6 na ni miongoni mwa nchi zenye mifugo mingi barani Afrika. Kati ya ng’ombe milioni 36.6, asilimia 96.1 ni ng’ombe wa kienyeji na wengi wao ni wa aina ya Tanzania Shorthorn Zebu (TSHZ). TSHZ hufugwa kwa mfumo huria ambao hutumia mbinu kidogo na pembejeo kidogo katika uzalishaji na huchungiwa kwa wingi katika nyanda za malisho za Jumuiya. Matumizi ya mbinu ndogo za uzalishaji na pembejeo husababisha uzalishaji duni wa TSHZ ambao umesababisha upungufu wa nyama nyekundu nchini kutokana na kasi kubwa ya ukuaji wa Idadi ya watu na uchumi. Ili kutumia fursa hiyo, baadhi ya wafugaji wa ng'ombe hapa nchini hujihusisha na unenepeshaji ng’ombe kama njia ya kutumia fursa ya soko lililopo la nyama nyekundu na kujiongezea kipato. Wanenepeshaji walio wengi hutumia hei ya *Cenchrus ciliaris* kama chakula kikuu cha mifugo na kuwapa chakula cha ziada (mchanganyiko wa pumba, madini na virutubisho vingine muhimu). Matumizi ya hei katika unenepeshaji ina changamoto ya upatikanaji na bei yake ni kubwa. Changamoto hiyo imepelekea kuona namna ya kutafuta vyakula mbadala vya gharama nafuu na vinavyopatikana kirahisi kama vile mabaki ya mazao ya nafaka. Majani ya mpunga ni miongoni mwa mabaki ya mazao ya nafaka ambayo yanapatikana kwa wingi na kwa bei nafuu nchini Tanzania. Hata hivyo, majani ya mpunga yana kiwango kikubwa cha kabohaidreti isiyoweza kumeng’enywa na hivyo mnyama kula kidogo na virutubisho kidogo ambayo huzuia matumizi yake kama chakula muhimu cha kunenepesha ng’ombe. Majani ya Mpunga yakiboreshwa kwa kutumia urea yanaweza kuwa na viinilishe vingi, na kuboresha mmeng’enyo, hivyo, kuongeza uzalishaji wenye tija kwa mnyama. Kwa hiyo, utafiti huu ulifanyika ili kutathmini athari za kutumia kiasi kidogo au kutotumia kabisa hei ya *C. ciliaris* na kutumia majani ya Mpunga yaliyoboreshwa na Urea au ambayo hayajaboreshwa kama majani mbadala katika ufanisi wake ukuaji wa mnyama, uzalishaji wa nyama na ubora wa nyama baada ya kulisha TSHZ. Utafiti huo ulifanyika katika kijiji cha Mtanana

kilichopo katika Wilaya ya Kongwa, Mkoa wa Dodoma,Tanzania. Madume hamsini (50) yenye wastani wa awali (± SD) uzito wa kilo 132.4 ± 26.7 na umri wa miaka 2.5 - 3 walitumika katika jaribio hilo. Ng'ombe hao walihudumiwa wakiwa wamefungiwa ndani na waligawanywa bila upendeleo katika makundi matano yenye vyakula tofauti tofauti na kila kundi lilikuwa na ng'ombe 10. Vyakula vilivyotumika kama mlo kamili ni pamoja na hei ya *C. ciliaris* pekee (CCH), majani ya mpunga ambayo hayajaboreshwa na Urea (URS), majani ya mpunga yaliyoboreshwa na urea (TRS), mchanganyiko wa hei ya *C. ciliaris* na majani ya mpunga yasiyoboreshwa na Urea (URH) na mchanganyiko wa majani ya mpunga yaliyoboreshwa na urea na hei ya *C. ciliaris* (TRH). Mbali na lishe muhimu, wanyama wote walilishwa chakula kimoja cha ziada kilichojumuisha pumba za mahindi (53%), mabaki ya sukari (molasses) (25%), mashudu ya alizeti (20%), mchanganyiko wa madini (1.5%) na chumvi (0.5%). Jaribio la ulishaji lilichukua siku 84 na mwisho wa jaribio, wanyama walifanyiwa tathmini katika ulaji wa chakula, ukuaji, asilimia ya faida iliyopatikana, sifa za nyama na ubora wa nyama iliyopatikana. Matokeo yalionyesha tofauti ($p < 0.001$) katika ulaji wa mlo kamili ambapo wanyama waliokula majani ya mpunga yaliyoboreshwa na urea (TRS) walikuwa na ulaji wa juu zaidi (1.6 ± 0.02 kg DM/siku) na wale waliokula hei ya *C. ciliaris* pekee (CCH) walikuwa na ulaji kwa kiwango cha chini zaidi (1.3 ± 0.02 kg DM/siku). Vile vile, ulaji wa nishati ya metaboli ulikuwa wa juu zaidi kwa wanyama waliolishwa majani ya mpunga yaliyoboreshwa na urea (TRS) (86.0 ± 0.7 MJ/siku) na chini kabisa kwa wale waliolishwa hei ya *C. ciliaris* pekee (CCH) (72.0 ± 0.7 MJ/siku). Wanyama waliolishwa mchanganyiko wa majani ya mpunga yaliyoboreshwa na urea na hei ya *C. ciliaris* (TRH) walikuwa na uzito wa juu zaidi (kilo 64.7 ± 4.4) na wastani wa ongezeko la uzito kwa siku (770 ± 0.1 g/siku) wakati wale waliotumia URS walikuwa na uzito wa chini zaidi (50.3 ± 4.4 kg) na wastani wa ongezeko la uzito kwa siku (599 ± 0.1) g/siku). Pia, uwiano wa kiasi cha chakula kilichotumika kuzalisha kilo 1 ya uzito hai wa mnyama ulitofautiana ($p<0.001$) kati ya makundi ya vyakula na ulikuwa wa chini zaidi kwa wanyama waliokula TRH (8.9

± 0.1) na wa juu zaidi kwa wanyama waliokula URS (11.9 ± 0.1), ikionyesha kuwa wanyama walikula TRH walikuwa na ufanisi zaidi katika kubadilisha chakula na kuongeza uzito wa mnyama. Wanyama waliolishwa URH walikuwa na uzito wa juu zaidi wa mnyama baada ya kuchinjwa na kutoa viungo vya ndani na vipimo vingine vya mnyama huyo kama vile kina cha kifua na mduara wa mguu wa nyuma. pH ya mwisho ya nyama ilikuwa juu kidogo kwa wanyama wote waliofanyiwa utafiti kwa makundi yote ya vyakula na ilikuwa juu ya kiwango kinachopendekezwa cha 5.8. Hii ilisababisha kupatikana nyama nyekundu iliyokoza, ambayo labda ni kutokana na mshituko wa wanyama wakati wa kuchinjwa. Kiasi cha mafuta kwenye nyama (10.6%) kilikuwa cha chini kwa wanyama waliolishwa TRS kuliko wanyama waliolishwa TRH (13.9%) na URS (11.9%). Wanyama waliolishwa TRS walikuwa na kiasi kikubwa zaidi cha minofu (72.3%) ikilinganishwa na wanyama waliokuwa kwenye vyakula vingine. Wanyama waliolishwa TRH walitumia gharama ndogo zaidi (TZS 5,244/=) kutengeneza kilo moja ya uzito wa mnyama. Hata hivyo, asilimia ya juu zaidi ya faida ilionekana katika wanyama wanaolishwa TRS (32.3%) wakati wale wanaolishwa CCH walikuwa na angalau (27.3%). Kwa kuhitimisha, majani ya mpunga yaliyoboreshwa na urea (TRS) ndio lishe bora zaidi ya kunenepesha ng'ombe wa asili (TSHZ) kwa sababu wanyama waliokula majani haya walionyesha asilimia kubwa ya faida, uwiano mzuri wa minofu na mafuta na hivyo kuzalisha nyama bora ikilinganishwa na wale waliokuwa kwenye makundi mengine ya vyakula.

Maneno muhimu: Mabaki ya mazao, Unenepeshaji wa ng'ombe; Ng'ombe wa kiasili;Kiwango cha ubadilishaji wa chakula kuwa uzito hai, Kiwango cha Ukuaji, Pato la Jumla, Vipimo vya mnyama baada ya kuchinjwa; Uzito wa mnyama baada ya kuchinjwa; ulaini wa nyama,

DECLARATION

I, **Edson Henry Kilyenyi**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration, and it has neither been nor concurrently been submitted for a higher degree award in any other institution.

………………………….　　　　　　　　　　…………………………
Edson Henry Kilyenyi　　　　　　　　　　Date
(MSc. Candidate)

The above declaration is confirmed by;

………………………….　　　　　　　　　　…………………………
Prof. Sebastian W. Chenyambuga　　　　　　　　　　Date
(Supervisor)

………………………….　　　　　　　　　　…………………………
Prof. Daniel E. Mushi　　　　　　　　　　Date
(Supervisor)

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LIST OF PUBLISHED PAPERS/MANUSCIPTS

i. Edson Henry Kilyenyi[1], Daniel Elius Mushi[1] and Sebastian Wilson Chenyambuga (2023). Feed Utilization and Growth Performance of Tanzania Shorthorn Zebu Fed Untreated or Urea Treated Rice Straws as Hay Replacement in Traditional Feedlot System. *International Journal of Animal Science and Technology*. Vol. 7, No. 2, 2023, pp. 11-18. *doi: 10.11648/j.ijast.20230702.11*

ii. Edson Henry Kilyenyi[1], Daniel Elius Mushi[1] and Sebastian Wilson Chenyambuga (2023). Carcass measurements and meat quality of Tanzania Shorthorn Zebu finished on untreated or urea-treated rice straws as a hay replacement. *East African Journal of Science, Technology and Innovation* (Accepted).

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DEDICATION

This disseration is dedicated to my father, the late Henry Paul Kilyenyi and my lovely mother Augusta Ernest Ngili who laid the foundation of my education. Also, this work is dedicated to my lovely wife, Madam Neema Aizack Ngakonda and my children Catherine, Prince, Junior and Noreen for their profound love, care and encouragements throughout my studies. Your in-depth love, moral support, patience, understanding and encouragement have helped to make this learning process a bit easier for me. I salute and love you all!

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LIST OF ABBREVIATIONS, ACRONYMS ABD SYMBOL

ADF	Acid Detergent Fiber
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CCH	*Cenchrus ciliaris* Hay
COSTECH	Tanzania Commission for Science and Technology
CP	Crude Protein
DAARS	Department of Animal, Aquaculture, and Range Sciences
DM	Dry Matter
et al.,	and others
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
g/kg	gram per kilogram
GIT	Gastrointestinal Tract
LD	*Longissimus dorsi*
MEI	Metabolizable Energy Intake
NBS	National Bureau of Statistics
NDF	Neutral Detergent Fiber
SD	Standard Daviation
TRH	Treated Rice Straws and Hay
TRS	Treated Rice Straws
TSHZ	Tanzania Shorthorn Zebu
TZS	Tanzania Shillings
URH	Urea-treated Rice and Hay
URS	Untreated Rice Straws
&	and
~	Approximation

CHAPTER ONE

1.0 General Introduction

There are 1.5 billion cattle worldwide, of which one-quarter are found in Africa and 2.2% are in Tanzania (FAO, 2021; NBS, 2021). Cattle have different economic values, their meat is a highly preferred animal source food, and possess cultural significance among traditional livestock keepers (Ruvuga *et al.*, 2020). In Tanzania the population of cattle is 36.6 million and of these 96% are indigenous cattle, predominantly the Tanzania Shorthorn Zebu (TSHZ). The TSHZ is a small-sized *Bos indicus* breed (mature live weight <250 kg) and is characterised by a hump on the back, long dewlap, various colour patterns, shiny hair coat and long legs (Mwacharo & Rege, 2002). There are many strains of TSHZ, such as Gogo, Iringa red, Chagga White, Mbulu, Maasai and Singida White (Mushi & Baruani, 2021). These cattle strains are essential for achieving sustainable development goals in the country (Godber & Wall, 2014). The TSHZ are kept under traditional livestock production systems, mainly pastoralism and agro-pastoralism, which are the least cost or low input systems. In these systems livestock keepers depend on natural pastures for feeding their ruminal livestock over a large area of communal grazing land as dictated by pasture availability (Mccabe *et al*., 2014; Truebswasser & Flintan, 2018).

The TSHZ thrives under extensive systems because of its drought resilience and tolerance to diseases like East Coast Fever and Trypanosomiasis (Hansen, 2004; Yaro *et al*., 2016). Also, the small body sizes mean that the TSHZ are early-maturing cattle, unlike *Bos taurus* cattle breeds which have large body sizes (Nogueira, 2004). It is estimated that the TSHZ accounts for 98% of all beef produced in Tanzania (URT, 2022). The higher contribution to beef production is primarily due to their large number in the country, and not due to production capacity of the individual animals (Mushi, 2020; NBS, 2021). Consequently, there is a red-meat deficit in Tanzania as the current beef production can only meet 83% of the local demands

(Michael *et al*., 2018). The beef demand-production imbalance is attributed to the country's human population and economic growth, meaning that more people can afford to buy beef and its products (Kadigi *et al*., 2013; Kibona *et al.*, 2022). Another reason for beef demand-production imbalance is low annual off-take rate (10%) due to the long period taken for an animal to attain mature live weight under extensive systems (Asimwe, 2015; Michael *et al.,* 2018; Mushi & Baruani, 2021).

The TSHZ takes longer time (5-7 years) to attain mature weight because of poor nutrition, and grazing land management challenges (Woodhouse & Mccabe, 2018; Mccabe *et al*., 2021). The grazing lands are owned collectively by the pastoralists and agro-pastoralists living in the respective villages. Under this system, all livestock keepers have equal chance for access to the available forages and water resources in the grazing area (Ruvuga *et al*., 2020; Mccabe *et al.*, 2021;). The collective ownership of the grazing lands can lead to a concept of "*tragedy of the commons*" because of lack of agreement on the proper management of the resources in the grazing areas. This is driven by immigrants from other places who utilise the available resources unfairly (Solomon *et al*., 2007; Moritz *et al.*, 2015). The "tragedy of commons" causes degradation of grazing lands, which is characterised by the loss of palatable grass species, an increase in noxious plants (weeds) and bush distribution, loss of biodiversity and soil erosion (Dunne *et al*., 2011; Sangeda & Maleko, 2018; Pfeiffer *et al*., 2019). Grazing land degradation affects the ability of the foraged area to support high cattle performance and beef production, as is the case in most parts of Tanzania. Grazing lands degradation has led to increased pastoral mobility in search of pastures and water, which, in turn, has resulted into regular conflicts between herders and farmers (Ripkey *et al*., 2021; Wainaina *et al*., 2021). Grazing land reallocation for other uses and increased frequency of extended droughts due to climate change, affect forage regeneration and lead to poor livestock performance due to overstocking and overgrazing (Godde *et al*., 2018a; Ondier *et al*., 2019).

Poor cattle performance in the extensive production systems is exacerbated by seasonal forage fluctuations in the semi-arid areas, which accounts for 80% of total grazing land in Tanzania (Selemani, 2020; Mccabe *et al*., 2021). Semi-arid areas are characterized by erratic and insufficient rainfall (400 - 600 mm annually) which cannot support high forage production for livestock (Liwenga, 2008; Ruvuga *et al*., 2021). Forage biomass varies over the year, with abundancy during the rainy season and scarcity during the dry periods (Safari *et al.*, 2011; Selemani *et al.*, 2013; Ruvuga *et al.*, 2021). Consequently, cattle grazed in the communal rangelands change their bodyweight and body condition score seasonally (Selemani *et al.*, 2013). Cattle can gain weight during the rainy season, but loose the weight during the dry and the produced meat is of lower quality and quantity than in more intensive cut-and-carry systems (Mushi, 2020). The reason for lower cattle weight gain under extensive system is associated with high energy expenditure due to long distances walks while looking for pasture and water (Jung *et al.*, 2002). The poor performance of cattle during the dry season is also caused by poor nutritive values of the native grass species available in the semi-arid areas with low protein content ranging from 71.4 to 73.3 g/kg DM and energy value of 3.5 - 5.9 MJ/kg DM. The values are lower than the crude protein of 87.5 -117.8 g/kg DM and energy value of 7.3 - 9.2 MJ/kg DM found in improved grasses like *Cenchrus ciliaris* (Bwire *et al.*, 2003; Safari *et al.*, 2011; Hamid *et al.*, 2020; Ruvuga et *al*., 2021).

1.1 Pastoral Migration, Feed Shortage Alleviation and Traditional Feedlot System

Pastoralists employ various strategies to ensure optimum livestock performance and sustain their livelihoods in semi-arid. Pastoralists rely on migration to alleviate feed shortages during the dry seasons (Mccabe *et al.*, 2014; Treydte *et al.*, 2017). The pastoralists would move from their native land during the dry period when forage resources are depleted to another area where forage is abundant. These seasonal migrations are usually over a very long distance of up to 80 km and last until forage is regenerated in the immagrant pastoralists' native land (Adriansen & Nielsen, 2005). Ecologically, these migrations are considered necessary for grazing land regeneration and reducing the risk of converting open rangelands into desert while maintaining different ecosystem services (Teague & Barnes, 2017; Wainaina *et al*., 2021). Socially, various challenges associated with migration are experienced, including conflicts among different pastoral groups and other land users (Benjaminsen *et al*., 2006; Ripkey *et al.,* 2021). These conflicts can sometimes turn deadly and affect meat production and social order over a long term (Benjaminsen *et al.*, 2009). Furthermore, pastoral migration is becoming difficult in Tanzania due to human population growth, which causes previously grazed areas to be used for other purposes, such as crop cultivation, settlements and infrastructure developments to meet different needs (Selemani, 2020). The outcome of pastoral movements has now inculcated some pastoralists to change their mind set into intensification of grazing land to ensure its effective utilisation for sustainable ruminant production.

Forage reserves or enclosure establishment is an example of the intensification in the collectively owned rangelands. These enclosures are tradionally known as "*Olalili* or *Ngitiri"* among the Maasai pastoralists and Sukuma agro-pastoralists, respectively, in Tanzania (Safari *et al*., 2019; Selemani, 2020). The forage reserves are established and managed by traditional institutions, which in this case refers to the informal livestock organisation with the intention to address the recurring problem of forage shortage (Glowacki, 2020). The traditional institutions rely on social contracts whereby individuals make a collective decision on what part of rangeland not to be grazed during the rainy season to ensure forage accumulation, which would then be foraged during the dry period (Nyberg *et al*., 2019; Safari *et al.*, 2019). The arrangement provides feed supply for livestock during the dry period while supporting biodiversity and soil conservation (Tefera *et al.,* 2007; Verdoodt *et al.*, 2010). The system is similar to rotational grazing under the ranch system since it employs adaptive grazing management; however, it is done over a large area, and decisions are usually made by experienced elders and implemented by youths (Sangeda & Maleko, 2018; Wainaina *et al.*, 2021). Although enclosures are usually collectively owned, private enclosures with a size ranging from 1.6 to 8.5 ha are not uncommon among agro-pastoralists in areas with flexible grazing land tenure systems (Safari *et al*., 2019).

Unfortunately, forage reserves are dominated by native pasture species which have poor nutritive value, which limits their utilisation for adequate livestock feeding and improved cattle performance under pastoral production systems in Tanzania (Safari *et al*., 2011; Ruvuga *et al.*, 2021). Also, resting duration and type of forage reserve management (private or communal) do not necessarily result in high biomass yield of the palatable grass species in semi-arid areas (Tefera *et al.*, 2007; Seymour *et al*., 2010; Verdoodt *et al.*, 2010; Safari *et al*., 2019). The lack of quality and palatable grass species has led to the recommendation for cultivation of improved forage species, e.g. *Cenchrus ciliaris*, in the traditional established reserves to ensure feed availability throughout the year (Ngenzi *et al*., 2023). It is expected that adoption of improved forage species cultivation by livestock keepers would maintain forage supply all year around. This will ensure high meat yields in terms of carcass weight while maintaining other meat attributes such as colour and tenderness (Mushi, 2020; Kimirei *et al.*, 2022). Improved forage establishments in African semi-arid areas is limited by collective ownership of grazed rangelands, availability of planting materials and technical know-how, especially among the pastoralists who do not have relevant experience (Leweri *et al.*, 2021; Mekonnen *et al.*, 2022; Ngenzi *et al.,* 2023).

It well known that pasture grazing alone can not provide sufficient nutrients to fulfill the requirements of most beef cattle breeds, even under the best conditions and management (Greenwood, 2021). It is recommended that beef cattle should be fattened before slaughter in order to improve beef production (Wendimu *et al.,* 2023). Beef cattle can be fattened during the dry season, which entails feeding animals with high nutritive value feedstuffs to increase their weight, improve body conformation, carcass yield and quality. This feeding practice is known as feedlotting and intends to increase economic return and negate body weight loss experience during the dry season, which can lead to poor meat quality attributes (Ruvuga *et al.*, 2020; Kibona *et al.*, 2022). Recently, traditional feedlot system has been established in the Lake zone of Tanzania, mainly because of the need to offset the red meat deficit and get high return from fattening enterprises (Kimirei *et al.*, 2022). Livestock keepers and other feedlot practitioners feed nutritious diets to the already matured but underweight cattle to ensure that they attain the required market weight within a relatively short period of less than 100 days (Asimwe *et al*., 2015; Mushi, 2020). Through this approach, the fattened cattle are kept indoor in the barn, fed *ad libitum* hay as basal diet and supplemented with high energy concentrates obtained from agricultural by-products such as cereal brans, seed cakes and molasses together with minerals/vitamins to meet their nutritional requirements (Mushi, 2020; Kimirei *et al.*, 2022; Ruvuga *et al*., 2022).

These agricultural by-products are rich in essential macro-nutrients, namely, protein and energy and can promote fast growth rate of 639 - 952 g/day in TSHZ (Asimwe *et al.,* 2015; Mushi, 2020). The fast growth rate means high carcass weight and meat yield, which can reduce the red meat production-demand imbalance in Tanzania (Michael *et al.,* 2018). Hay is commonly used as the basal diet during fattening, however, nowadays it is becoming scarce and sold at high price during the dry periods and hence,its use increases operational cost. Therefore, there is a need to find alternative cheap feed resources such as cereal crop-residues that can be used as basal diet. Crop residues such as maize stovers, rice straws and sorghum stovers obtained after cereal crop harvesting are potential feed resources for animals under the feedlot (Mushi, 2020; Subudhi *et al.,* 2020). Cereal crop residues can be co-fed with- or replace improved grass hay as the basal diet in traditional feedlotting system as they are abundantly available (Njie & Reed, 1995; Mushi, 2020; Sarkar *et al.*, 2020). Livestock keepers usually purchase crop residues on-farms shortly after harvesting (Treydte *et al.*, 2017; Ngenzi *et al.,* 2023). Nazli *et al.* (2018) and Mushi (2020) reported daily weight gain of 133 - 618 g/day for beef cattle fed different crop residues. Rice straws are among the most abundant crop residues in Tanzania, but have poor feeding value because of their low nutritional values as they contain high neutral detergent fibre (NDF) of up to 849 g/kg DM (Wanapat *et al.,* 2009; Nazli *et al.,* 2018). Moreover, high NDF contents means that cattle fed rice straws would not be able to attain the required market weight on time. This could prolong the fattening period, affect meat quality, national food security and overall profitability of the feedlot practice (Mushi & Baruani, 2021; Ripkey *et al.,* 2021). Nevertheless, rice straw nutritional value improvement for more profitable feedlotting system is possible.

1.2 Problem Statement and Justification

Rice straws can be used as a basal diet for cattle under feedlot conditions. However, rice straws have high NDF and ADF contents, lignification and silicification levels and low crude protein content that lead to low palatability, intake and digestibility. The rice straws can be treated using different means and methods to improve their feeding value. Urea and strong alkalis like calcium hydroxide are used to treat and enhance the utilisation of rice straws (Vadiveloo & Fadel, 2009; Wanapat *et al.,* 2009; Lunsin *et al.,* 2018). Calcium hydroxide can react and break down structural carbohydrates, thus improving feed intake, digestibility and performance of cattle fed rice straws based diet (Wanapat *et al.,* 2009). However, the use of strong alkali for straw treatment is limited by their availability, high price and handling difficulties, especially under traditional feedlot systems. Moreover, alkali does not increase crude protein content in the treated straws that is needed to support optimum growth (Wei *et al.,* 2018). On the other hand, urea treatment improves forage digestion and adds nitrogen to the treated forage, which is then converted into microbial protein in the rumen (Wanapat *et al.,* 2009; Lunsin *et al.,* 2018). Increasing nitrogen content and easy handling compared to strong alkali make urea treatment a suitable method for improving rice straws utilisation in traditional feedlot system in Tanzania. Also, urea is readily available in many parts in Tanzania, and it is sold as a subsidised industrial fertiliser for crop cultivation (Cedrez *et al.,* 2020). This means traditional livestock keepers can acquire urea at a lower price, thus making feedlot practices profitable. Therefore, urea treatment is the most suitable method to improve the straws quality under traditional feedlot system.

Urea treated rice straws can replace conventional basal diets, e.g. grass hay under the traditional feedlotting system in Tanzania. However, there are no studies that have evaluated the effects of replacing grass hay with urea treated rice straws as basal diet for fattened TSHZ under traditional feedlot system. The previous studies on TSHZ feedlotting focused on the use of agro-industrial by-products as supplementary diet and maize stovers and treated wheat straws as the basal diet, and their use resulted in positive live weight gain (Asimwe *et al.,* 2015; Mushi, 2020). However, these studies showed lower economic returns due to the higher feeding cost associated with the use of agricultural by-products (Asimwe *et al.,* 2016). On the other hand, feeding ruminants with rice straws results into good animal performance. For instance, Mafriwal cattle fed rice straws based diet gained 133 - 383 g per day (Nazli *et al.*, 2018). Similarly, a study by Wanapat *et al.* (2009) reported improved milk yield and composition in Thailand's dairy cow fed urea treated rice straws. However, none of the studies assessed the economic analysis of treating and feeding rice straws to fattened cattle under tropical conditions. Also, there are limited studies on the effects of co-feeding grass hay and rice straws as basal diet. Therefore, this study was undertaken to evaluate the effects of replacing grass hay as the basal diet with untreated or urea treated rice straws on growth performance and feed utilisation of zebu cattle under the traditional feedlot system. Moreover, the study investigated the economic return of using untreated and urea treated rice straws basal diet to facilitate easy adoption of the technology by different feedlot practitioners. In this study *Cenchrus ciliaris* hay was used as the control basal diet since most feedlot practitioners in Tanzania use it as the basal diet for cattle fattening. It was expected that the results obtained from the current study would contribute to improving the feeding practices and profitability of the traditional feedlot system in Tanzania.

1.4 Study Objective

1.4.1 General objective

To increase production of quality beef and profitability of cattle finishing operations through improved utilisation of rice straws as the least cost basal diet under the traditional feedlot system in Tanzania.

1.4.2 Specific objectives

i. To evaluate growth performance and nutrients utilisation of TSHZ cattle fed either untreated or urea treated rice straws in place of *C. ciliaris* hay as basal diet in traditional feedlot system.
ii. To assess the effects of replacing *C. ciliaris* hay with untreated and urea treated rice straws on carcass and meat qualities of TSHZ cattle finished under traditional feedlot system.
iii. To analyse economic return and profitability of using untreated or urea treated rice straws in place of *C. ciliaris* hay as basal diet for fattening cattle under traditional feedlot system.

1.5 Null Hypothesis

There are no significant differences in growth performance, feed utilisation, carcass characteristics, meat quality and profitability between TSHZ fed rice straws and those fed *C. ciliaris* hay as basal diet under traditional feedlot system.

1.6 Methodology Overview

A complete randomized feeding trial was conducted for 84 days at a cattle fattening unit located at Mtanana B village in Kongwa district, Dodoma region, central Tanzania (Paper I). A total of 50 TSHZ bulls with initial mean weight of 132 kg were obtained from the local farmers at Mtanana A and Mtanana B villages. Upon arrival at the fattening unit, all animals were dewormed and sprayed with acaricides to control endoparasites and ectoparasites, respectively. The bulls were randomly divided into five groups of 10 animals for each group. The animals in each group were housed together, and group-fed with their respective dietary treatment. The dietary treatments were *Cenchrus ciliaris* hay (CCH), untreated rice straws (URS), urea-treated rice straws (TRS), combination of untreated rice straws and hay (URH) and combination of urea-treated rice straws and hay (TRH). These dietary treatments were fed as the basal diets and all animals were supplemented with the same concentrate diet comprised of maize bran, molasses, sunflower seed cake, mineral premix and table salt. The basal and concentrate diets were measured before and after feeding to determine feed intake. Animal body weights were measured at the start of the feeding experiment and then biweekly up to the end of the experiment. The following parameters were computed:- average daily feed intake, metabolizable energy intake, weight gain, daily weight gain, feed conversion ratio and profitability of the fattened cattle. At the end of the feeding trial, the fattened cattle were taken to the abattoir for slaughter, whereby five out of the ten animals from each treatment were sampled randomly for carcass and meat quality assessment (Paper II). The carcass characteristics and meat qualities evaluated were slaughter weight, linear carcass measurements, non-carcass components, tissue composition, meat temperature and pH, meat chemical composition and tenderness.

1.7 The organisation of the Dissertation

The dissertation is organised into five chapters, and the first chapter provides background information on livestock production systems in semi-arid areas, feed shortage alleviation strategy and feedlotting practices, justification for undertaking the current study, research objectives and methodology overview. The published paper and accepted manuscript are presented in Chapter two and Chapter three, respectively. Chapter four presents a general discussion in detail whereby key results are interpreted and compared with other findings. The chapter also addresses the knowledge gap, which was not answered by the current study, and raises new research questions. Finally, Chapter five provides conclusions and recommendations to different stakeholders for effective utilisation of rice straws based diets and improving traditional feedlot system in Tanzania.

CHAPTER TWO

2.0 Effects of Replacing *Cenchrus ciliaris* Hay with Untreated or Urea Treated Rice Straws on Feed Utilization and Growth Performance of Tanzania Shorthorn Zebu in Traditional Feedlot System

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Feed Utilization and Growth Performance of Tanzania Shorthorn Zebu Fed Untreated or Urea Treated Rice Straws as Hay Replacement in Traditional Feedlot System

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Abstract: This study evaluated the effects of complete or partial replacement of *Cenchrus ciliaris* hay with untreated or urea treated rice straws on feed intake, growth performance, feed conversion ratio (FCR) and gross margin of Tanzania Shorthorn Zebu (TSHZ) cattle under feedlot condition. A total of 50 bulls with age of 2.5 - 3.0 years and mean initial weight of 132.4 ± 26.7 kg were assigned randomly to five treatments *i.e.* 100% *Cenchrus ciliaris* hay (CCH), 100% untreated rice straws (URS), 100% urea treated rice straws (TRS), 50% untreated rice straw + 50% *C. ciliaris* hay (URH) and 50% treated rice straw + 50% *C. ciliaris* (TRH). All animals were supplemented with a diet comprised of 53% maize bran, 25% molasses, 20% sunflower seed cake, 1.5% mineral premix and 0.5% table salt. The results show that average daily gain and weight gain did not differ ($p > 0.05$) among the treatments. However, animals on TRH showed the highest growth rate (770.0 ± 0.1 g/day) and weight gain (64.7 ± 4.4 kg), followed by those on TRS (growth rate = 725.0 ± 0.1 g/day, weight gain = 60.9 ± 4.4 kg) while those on URS had the lowest growth rate (599.0 ± 0.1 g/day) and weight gain (50.3 ± 4.4 kg). Animals fed TRS (9.8 ± 0.1) and TRH (8.9 ± 0.1) had lower ($p \leq 0.001$) FCR than those fed CCH (10.3 ± 0.1), URS (11.9 ± 0.1) and URH (10.4 ± 0.1). The highest gross margin was obtained on animals under TRS (TZS 154,293.00) while the lowest was found on animals under CCH (TZS 120,450.00). Partial or complete replacement of hay with treated or untreated rice straws resulted into higher growth performance than feeding hay alone. Feeding animals with urea treated rice straws resulted into higher growth performance and better feed utilization compared to feeding hay or untreated rice straws. It is concluded that complete replacement of hay with urea treated rice straws resulted into high growth rate, lower FCR and high gross margin, hence, it is recommended as the best basal diet for fattening of TSHZ under traditional feedlot system.

Keywords: Crop Residues, Cattle Fattening, Feed Conversion Ratio, Gross Margin, Growth Rate

1. Introduction

Tanzania has 35.3 million cattle, of which 96.5% are indigenous breeds that produce 98% of beef and 67.7% of milk in the country [1, 2]. Tanzania Shorthorn Zebu (TSHZ) is the predominant indigenous breeds and constitutes about 95% of cattle kept in the country. The breed is kept in semi-arid areas under pastoralism (14%) and agro-pastoralism (80%) production systems due to their good drought, heat and disease tolerance [3, 4]. These agro-pastoralists and pastoralists practice extensive production systems, whereby TSHZ are herded continuously on natural pastures available on communal grazing lands throughout the year. Cattle production under these systems is faced with challenge of inadequate quantity and unavailability of quality feeds, especially during the dry periods. The native grass species, upon which cattle depend, have low nutritional values characterised by low protein and energy contents, and poor digestibility [5, 6].

Therefore, TSHZ reared on these natural pastures have very low beef production with mature weight of 200 - 350 kg, carcass weight of 100 - 175 kg and attain slaughter weight after 5 - 7 years [2]. The slow growth and small mature body size increase greenhouse gases emission per unit of livestock product and affect farmers' livelihoods [7-9]. This, in turn, leads to deficit in red meat supply and failure to meet the increased demand as the result of economic and population growth in Tanzania. According to Michael et al. [10], Tanzania had red-meat deficit of 17% (~125,000 tonnes) in the year 2022. This deficit necessitates a need for efficient cattle production system so as to meet high red-meat demand, improve farmers' livelihoods and protect environment.

Feedlot finish feeding is commonly used as the means to enable mature cattle to attain acceptable market weight within a short time and improve meat quality before slaughter. Cattle under feedlot system are fed nutrient dense diets for a period of up to 90 days under zero grazing system to enable fast weight gain [11-14]. In addition to concentrates, animals under feedlot are given roughage (hay) as basal diet which serves as the source of structural material for proper rumen functioning [14, 15]. However, in recent years hay has become expensive and availability of quality hay is limited by low level of pasture production [16, 17]. Therefore, there is a need to look for cheaper alternative roughage that can be fed as basal diet during feedlot finish feeding. Cereal crop residues such as rice straws can be used as an alternative to hay due to their abundance and easy accessibility [18]. Rice straws have low production cost among cereal crop residues, thus, they can serve as a practical source of fodder for ruminants. However, rice straw can barely support cattle nutritional requirements for maintenance because of their poor digestibility and lower protein content [19, 20].

Urea treatment can improve rice straws digestibility and thus, increase their intake and consequently cattle production performance [21, 22]. In addition, urea treatment increases nitrogen content of the treated straws and this nitrogen can be converted into protein by rumen microbes [23, 24]. There are limited studies on the use of urea treated rice straws as basal diet for TSHZ cattle under feedlot system. Most studies focused on the use of hay or maize stovers as basal diet for cattle under feedlot or substitution of maize meal and molasses with maize bran and rice polishing [12, 20, 21]. Therefore, this study was conducted to evaluate the effects of complete or partial replacement of *Cenchrus ciliaris* hay with untreated or urea-treated rice straws on intake, *in vitro* digestibility, growth performance and profitability of TSHZ finished under traditional feedlot system. It was hypothesized that replacing *C. ciliaris* hay with treated rice straws would result to similar or higher TSHZ growth performance at a reduced cost.

2. Materials and Methods

2.1. Location of the Study Area

Feeding trial was conducted at Mtanana village which is found in Kongwa district (6°- 6°6'S, 26°22'-36°30'E), about 82 km from Dodoma city in central Tanzania. The district has altitude of 1067 m above sea level with annual rainfall of 254 - 660 mm and average daily temperature of 23 - 32°C [25]. Kongwa district has semi-arid climate and open grassland vegetation dominated by *Cynodon* spp, *Aristida* spp., *Chloris gayana* and *Urochloa mosambicensis* grass species [11]. Livestock production is the major economic activity in the district and it is characterised by continuous herding in the communal grazing lands. This warranted selection of the study area for the current feeding experiment.

2.2. Experimental Animals

A total of fifty TSHZ bulls were obtained from the livestock farmers and used in the feedlot experiment. The bulls had the age of 2.5 - 3 years (age was estimated based on dentition) and mean weight of 132.4 ± 26.7 kg (mean ± SD). All animals were dewormed by administering 15 - 20 ml of Albendazole 10% W/V (Bimeda-Oral suspension) according to live weight at the beginning of the study and deworming was repeated after 45 days during the experimental period. External parasites were also controlled by using Albadip Super 100EC (Alphacypermethrin 100%) whereby 1 ml was mixed with 2 litres of water and sprayed on the animal using knapsack sprayer. The experimental animals were assigned randomly to five dietary treatments, with 10 animals per treatment.

2.3. Experimental Feed Preparation

Five dietary treatments were formulated, treatment one consisted of 100% *C. ciliaris* hay (CCH). Treatment two, three, four and five were made up of 100% untreated rice straw (URS), 100% treated rice straw (TRS), 50% untreated rice straw + 50% *C. ciliaris* hay (URH) and 50% treated rice straw + 50% *C. ciliaris* hay (TRH), respectively. Hay used in this study was purchased at Tanzania Livestock Research Institute - Mpwapwa. The hay was cut as standing hay after *C. ciliaris* seed harvesting. Rice straws were collected from Msowero, Kilosa district where SARO 5 (TXD 306) rice variety is cultivated in the lowlands [26]. Some rice straws were treated with 3% urea which was prepared by dissolving 3 kg of urea into 20 litres of water that was used to treat 100 kg of rice straw. Treatment of rice straws was done by spraying the straw with urea solution using knapsack sprayer. The straws sprayed with urea solution were ensiled into a ground silo covered by airproof polythene sheet and allowed to ferment for 21 days. Straws and hay were chopped manually into small pieces of ~3 cm before being fed to the animals. The TRH and URH diets were made by mixing equal weight of hay and treated or untreated rice straws in the trough during feeding.

2.4. Experimental Animal Management and Feeding

The animals were housed in a barn which had five pens with each pen having a size of 20 m x 20 m and a group of 10 animals was allocated into each pen. The treatments were randomly allocated to the five groups of animals, a total of 10 animals per treatment. The treatment for each group formed the basal diet. The experimental animals were given their respective dietary treatment *ad-libitum* early in the morning at 0600 h. The experimental animals were also given concentrate diet as supplementary feed. They were fed concentrate diet at 80% of their daily feed intake (estimated as 3% of their live weight). The concentrate was given into two equal portions at 0800 h and 1400 h. The amount of concentrate diet given daily was determined from the mean live weight of the animals in the respective group. The concentrate diet used in this experiment was formulated to contain 12.7 MJ ME/kg DM and 12 g/kg DM CP. These metabolisable energy (ME) and crude protein (CP) are required for maintenance and daily weight gain of about 1 kg for small sized cattle breeds (~200 kg) as recommended by NRC [27]. The concentrate diet consisted of 53% maize bran, 25% molasses, 20% sunflower seed cakes, 1.5% mineral premix and 0.5% table salt. These ingredients were purchased from the local agro-processing mills and agro-veterinary store at Kibaigwa town, Kongwa district and were mixed thoroughly before were given to the animals. Samples of concentrate diets, individual ingredients and dietary treatments were taken for laboratory chemical analysis to determine the proximate composition. All animals had free access to clean drinking water during the experimental period.

2.4.1. Determination of Feed Intake, Feed Conversion Ratio and Growth Performance

The experimental period was 84 days after the adaptation period of 10 days. The adaptation period aimed at acclimatizing the animals to their respective dietary treatments. The experimental animals were weighed individually before the start of the experiment using a weighing scale and then assigned randomly to the five dietary treatments. Each animal was weighed individually after every 14 days during the experimental period so as to determine average daily gain. Weight gain per animal was calculated as final live weight minus the initial live weight in kg. Average daily gain (ADG) per animal was calculated as weight gain in kg divided by experimental period in days.

The animals were zero grazed and fed their respective dietary treatment in group of 10 bulls per treatment. The amounts of basal diet (hay and rice straws) and concentrate provided to each group were measured before feeding on each day and the feed refusals were collected daily in the morning (prior to next feeding) and weighed so as to determine feed intake for each group. The intake recorded for each group was divided by the number of animals in the group in order to estimate individual animal feed (in dry-matter, DM) intake and metabolisable energy intake (MEI). In addition, feed conversion ratio (FCR) was computed as the ratio of feed intake to weight gained per animal during the study period.

2.4.2. Chemical Analysis of Feed Ingredients and Formulated Diets

Concentrate diet, feed ingredients and dietary treatment samples were analysed for their chemical composition and digestibility at the Animal nutrition laboratory of Sokoine University of Agriculture. The DM, ash, crude protein (CP), ether extract (EE) and crude fibre (CF) were determined according to the standard methods of Association of Official Analytical Chemists [28]. Nitrogen free extract was calculated by subtracting ash, CP, EE and CF from the DM of feed. Van Soest [29] method was used to determine neutral detergent fiber (NDF) and acid detergent fiber (ADF). *In vitro* dry matter digestibility (IVDMD) was analyzed according to Tilley and Terry [30] two-stage procedure. The equation 0.012CP + 0.031EE + 0.005CF + 0.014NFE was used to calculate ME of the concentrates. The ME in hay and rice straws (dietary treatments) was calculated using the equation; 0.15 (0.98*IVDMD-4.8) [31, 32].

2.4.3. Gross Margin Analysis

Gross margin analysis was used to assess the profitability of cattle fattening under different dietary treatments. Gross margin was computed as the difference between total revenue earned and total variable cost incurred. Bull selling was the only revenue source in this study and the value of each bull was calculated as final live weight of an animal multiplied by wholesale price of 1 kg of live weight. Variable cost included costs of purchasing bulls, feeds, and payment for veterinary services and labour. Bulls purchasing price was obtained by multiplying the initial weight of each animal by price of 1 kg of live weight basing on a prevailing market price of such animals at the start of the experiment. Feed cost was calculated by multiplying the total amount of feed consumed by each animal and the market price of one kilogram of feed during the study period. Also, the cost per kg live weight gain was calculated based on FCR and retail price per kilogram of the respective feed. Veterinary services included all the costs incurred during deworming and control of external parasites while labour cost included monthly salary paid to animal attendants. The labour cost was divided by the number of animals to obtain cost per animal.

2.5. Statistical Analysis

Statistical program R (version 4.0.1) was used to analyse data on DMI, MEI, weight gain, growth rate, FCR, feed cost, total variable cost, revenue and gross margin. One-way ANOVA model under completely randomized design was applied during data analysis. The model was defined as Y (feed intake, growth performance, revenue, variable cost and gross margins) = Dietary treatment + Residual error. Tukey's test was used to determine the differences between a pair of treatment means and was declared significant at $p \leq 0.05$.

3. Results

3.1. Chemical Composition of Feed Ingredients and Formulated Diets

The results in Table 1 show that the ME and IVDMD values of *C. ciliaris* hay were lower than those of both untreated and urea treated rice straws. On the other hand, 16

urea treated rice straws had slightly higher ME and IVDMD than untreated rice straws. The NDF and ADF values were relatively higher in *C. ciliaris* hay and untreated rice straws than in urea treated rice straws. Urea treated rice straws had relatively higher CP than untreated ones and *C. ciliaris* hay. Among the feedstuffs used in the experiment, sunflower seed cake had the highest CP (223.7 g/kg DM) and EE (140.3 g/kg DM) while the untreated rice straws (54.2 g/kg DM) and *C. ciliaris* hay (56.9 g/kg DM) had the lowest CP contents. Furthermore, *C. ciliaris* hay had the highest NDF (743.5 g/kg DM) and lowest IVDMD (31.6%) among the feedstuffs used in the experiment.

***Table 1.** Chemical composition of feed ingredients and concentrate diet.*

Feedstuff	DM (g/kg)	Ash (g/kg DM)	CP (g/kg DM)	EE (g/kg DM)	NDF (g/kg DM)	ADF (g/kg DM)	IVDMD (%)	ME MJ/kg DM
Concentrate diet	815.1	82.0	112.4	94.9	314.1	131.1	55.6	12.7
Sunflower seed cake	954.6	49.5	223.7	140.3	564.7	393.8	-	-
Maize bran	905.9	46.6	103.5	73.6	497.8	72.6	59.6	13.2
Cenchrus ciliaris hay	855.0	103.9	56.9	-	743.5	413.4	31.6	5.5
Untreated rice straw	872.8	216.0	54.2	-	631.0	405.0	31.9	9.0
Urea treated rice straw	860.5	268.3	72.6	-	543.9	321.8	53.1	9.3

DM = dry matter; CP = crude protein; EE = Ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; IVDMD = *In-vitro* dry matter digestibility; ME = metabolisable energy

3.2. Feed Intake, Feed Conversion Ratio and Growth Performance

The dry matter feed intake, ME intake, weight gain, daily weight gains and FCR are shown in Table 2. There were statistical differences ($p < 0.001$) in feed and ME intake among dietary treatments. Animals on URH had higher concentrate intake (5.9 kg DM/day) and total feed intake (7.4 kg DM/day) than the animals on CCH (5.1 kg DM/day for concentrate and 6.4 kg DM/day for total feed). Animals on CCH had the lowest roughage intake (1.3 kg DM/day) while those on TRS had the highest (1.6 kg DM/day). Similarly, total ME intakes were lowest in CCH and highest in TRS.

***Table 2.** Feed intake and growth performance (mean ± SE) of Tanzania Shorthorn Zebu cattle subjected to five different dietary treatments.*

Parameters	Dietary treatment CCH	URS	TRS	URH	TRH	p-value
Feed intake (kg DM/day)						
Concentrate	5.1 ± 0.02^a	5.6 ± 0.02^b	5.6 ± 0.02^b	5.9 ± 0.02^c	5.5 ± 0.02^d	<0.001
Roughage	1.3 ± 0.02^a	1.5 ± 0.02^b	1.6 ± 0.02^c	1.5 ± 0.02^b	1.4 ± 0.02^d	<0.001
Total	6.4 ± 0.02^a	7.1 ± 0.02^b	7.2 ± 0.02^b	7.4 ± 0.02^c	6.8 ± 0.02^e	<0.001
Metabolizable energy intake (MJ/day)						
Concentrate	64.8 ± 0.6^a	71.1 ± 0.6^b	$71.1 \pm 0.6^{b,d}$	74.9 ± 0.6^c	69.9 ± 0.6^d	<0.001
Roughage	7.2 ± 0.2^a	13.5 ± 0.2^b	14.9 ± 0.2^b	10.9 ± 0.2^c	10.4 ± 0.2^d	<0.001
Total	72.0 ± 0.7^a	84.6 ± 0.7^b	86.0 ± 0.7^b	85.8 ± 0.7^b	80.3 ± 0.7^c	<0.001
Growth performance						
Initial live weight (kg)	123.6 ± 8.0	146.9 ± 8.0	128.8 ± 8.0	143.8 ± 8.3	120.1 ± 8.0	0.083
Final live weight (kg)	175.4 ± 6.4^c	$197.2 \pm 6.4^{a,b}$	$197.3 \pm 6.7^{a,b}$	203.9 ± 6.7^a	$184.8 \pm 6.4^{b,c}$	0.025
Weight gain (kg)	51.8 ± 4.4	50.3 ± 4.4	60.9 ± 4.4	60.1 ± 4.7	64.7 ± 4.4	0.116
Average daily gain (g/day)	617.0 ± 0.1	599.0 ± 0.1	725.0 ± 0.1	716.0 ± 0.1	770.0 ± 0.1	0.118
Feed Conversion Ratio (FCR)	10.3 ± 0.1^b	11.9 ± 0.1^a	9.8 ± 0.1^c	10.4 ± 0.1^b	8.9 ± 0.1^d	<0.001

Means in the same row with different superscript letters are significant different (P≤0.05)
CCH = Cenchrus ciliaris hay, URS = 100% untreated rice straw, TRS = 100% treated rice straw, URH = 50% untreated rice straw + 50% Cenchrus ciliaris hay, TRH = 50% treated rice straw + 50% Cenchrus ciliaris hay

Growth performance results showed that, there were no statistical differences ($p > 0.05$) in initial live weight, weight gained and average daily weight gain of animals subjected to different dietary treatments. However, treatment had significant effect on final body weight and FCR. Final live weight was highest in animals under URH (203.9 ± 6.7 kg) and lowest in animals under CCH (175.4 ± 6.4 kg). On the other hand, FCR was highest in URS and lowest in TRH.

3.3. Gross Margin Analysis

Results on gross margin analysis are shown in Table 3 whereby the revenue obtained did not differ among dietary treatments ($p = 0.08$). However, it was lower in CCH by TZS 91,164/= compared to URH which had the highest revenue. Total variable cost differed ($p = 0.01$) among the treatments and was 15% higher in URH compared to CCH which had the lowest. The highest cost (TZS 253,109/=) for concentrates was found in URH whereas CCH treatment had the least concentrate cost (TZS 221,470/=). On the other hand, roughage cost was highest in TRS (TZS 35,272/=) and lowest in URS (TZS 22,562/=). The costs of producing 1 kg of live weight comparison showed that it costed more to produce mentioned live weight for the animals fed URS compared to those on TRH. Gross margin did not differ (p =

0.88) among dietary treatments. However, animals on TRS had relatively higher gross return (32.3%) compared to the animals on other treatments.

Table 3. Economic analysis (in Tanzanian Shillings, TZS) of Zebu cattle subjected to various dietary treatments under traditional feedlot system.

Parameters	Dietary treatment					
	CCH	URS	TRS	URH	TRH	p-value
Revenue per animal						
Bulls selling price	561,280 ± 21,608	631,040 ± 21,608	631,467 ± 21,608	652,444 ± 22,777	591,360 ± 21,608	0.06
Variable cost per animal						
Bulls purchasing price	170,000 ± 13,417	203,000 ± 13,417	184,000 ± 13,417	206,666 ± 14,143	182,000 ± 13,417	0.30
Concentrate cost	221,470[b]	242,563[a]	242,563[a]	233,109[a]	233,532[c]	<0.001
Roughage cost	34,020[a]	22,562[a]	35,272[a]	38,559[a]	32,995[c]	<0.001
Veterinary cost	3,340	3,340	3,340	3,340	3,340	-
Labour cost	120,000	120,000	120,000	120,000	120,000	-
Total variable cost	440,830 ± 13,417[c]	483,465 ± 13,417[ab]	477,174 ± 13,417[ab]	505,674 ± 14,143[a]	465,867 ± 13,417[bc]	0.01
Cost per kg weight gain	7,594	8,293	5,912	5,978	5,244	-
Gross margin	120,450 ± 13,122	147,575 ± 13,122	154,293 ± 13,122	146,770 ± 13,122	125,493 ± 13,122	0.87
Percentage profit margin	27.3	30.5	32.3	29.0	26.9	-

1 USD = TZS 2,356

[a,b,c] Means in the same row with different letters are statistically different ($p<0.05$)

CCH = 100% Cenchrus ciliaris hay; URS = 100% untreated rice straw; TRS = 100% treated rice straw; URH = 50% untreated rice straw + 50% Cenchrus ciliaris hay; TRH = 50% treated rice straw + 50% Cenchrus ciliaris hay

4. Discussion

4.1. Chemical Composition of Formulated Diets

The CCH had ME content which was lower than 7.3 - 9.2 MJ ME/kg DM obtained in *C. ciliaris* hay from other studies [31, 32], probably due to differences in growth stage at harvesting. Similarly, *C. ciliaris* had ME lower than untreated and treated rice straw in this study which is contrary to Wei *et al.* [33]. The differences in ME content between *C. ciliaris* and rice straw based diets are due to their variations in IVDMD which was lower than 51 - 68% for *C. ciliaris* based diets [32, 34]. The ME values for untreated and treated rice straws in this study are higher than 6.4 - 8.5 MJ/kg DM obtained by Nazli et al. in rice straw based diets [20]. The ME differences in rice straws could be due to the differences of level of inclusion in the diet and rice variety used. Urea treated rice straws had slightly higher CP and ME contents, and digestibility value compared to untreated rice straws in the present study. This observation is in agreement with the findings by Wanapat et al. [21]. It has been shown that treatment of poor quality forage with urea breaks structural carbohydrate, which enhances digestibility and this, in return, increases forage nutritional values including CP and ME contents [22].

The NDF values were higher in CCH than in URS contrary to the findings obtained by Wei *et al.* [33] who observed lower NDF in corn silage compared to straw based diets. The variation may be because the *C. ciliaris* hay used in this study was harvested at advanced growth stage *i.e.* post seed harvesting. Also, rice straws used in this study belonged to SARO 5 (TXD 306) variety which is a lowland rice and its NDF value in this study is closer to 655 - 676 g/kg DM reported in other lowland rice varieties [34]. Nonetheless, CCH had NDF content within the values of 725 - 898 g/kg DM reported for *C. ciliaris* in other studies [35-37]. The NDF contents affect not only feed intake, but also growth performance of the experimental animals.

4.2. Feed Intake and Growth Performance

The animals on CCH had relatively lower total feed intake compared to those on other dietary treatments due to lower intake of both roughage and concentrate. The *C. ciliaris* hay contributed to lower intake in this study because of its low digestibility as a results of higher NDF content which increases satiety in the animals [38, 39]. Additionally, CCH poor taste could have affected feed intake and palatability in TSHZ as it has been observed before in horses due to extended storage time [40, 41]. Moreover, low total feed intake observed in animals on TRH compared to URH is attributed to additive effects of including *C. ciliaris* hay in treated rice straw. Also, it seems that inclusion of *C. ciliaris* lowered roughage ME intake in URH and TRH treatments compared to URS and TRS which had only untreated rice straws and urea treated rice straws, respectively. This is due to the fact that CCH had low digestibility and poor palatability due to high NDF content as described above.

Experimental animals in this study had total MEI which is in line with the amount of energy required (72.1 MJ/day) for 1 kg daily weight gain in cattle [27]. The total ME intake observed in the present study are closer or within the range of 69.4 - 86.4 MJ ME/day values reported for TSHZ cattle in other studies [11, 12]. It can, therefore, be said that energy levels in the dietary treatments were sufficient to meet TSHZ nutrient requirement for growth. This indicates that any of the dietary treatments could support fast growth of fattened cattle under the traditional feedlot system. However, animals in the present study did not achieve 1 kg daily gain in any of the dietary treatment, despite being supplied with the required energy. This could be due to low genetic potential of the animals for growth or advanced animal age and nutritional background of the animals used in this study.

Moreover, NRC [27] estimation for growth rate is based on European cattle breeds which have larger body size and grow faster than the TSHZ.

Nonetheless, growth rates of cattle under TRS, URH, and TRH treatments were closer to 1 kg/day which showed suitability of these diets for feedlot finishing of TSHZ. Also, animals on CCH had lower weight gain than those on TRS, URH and TRH, mainly due to low CP content and digestibility of *C. ciliaris* hay which resulted into lower roughage and concentrate intakes of animals under CCH. This shows that urea treated rice straws can replace *C. ciliaris* hay in feedlot finish feeding of TSHZ and this can result into even better growth performance. The superior weight gain observed in URH fed animals over those on CCH and URS or TRH over TRS indicate synergistic effects of co-feeding hay and rice straw on enhancing efficiency of rumen ecosystem. This is likely because of an increase in rumen fibrolytic bacteria at the expense of fungal predatory species [42, 43].

The results in this study have shown that complete or partial replacement of *C. ciliaris* hay with treated rice straws led to higher body weight gain and growth rate due to better FCR. The FCR values for animals on treatments in which hay was partially replaced by treated rice straw were slightly lower than those with hay, untreated rice straw or combination of the two. Higher FCR values are indicative of production inefficiencies that may lead to increased contribution of livestock to greenhouse gas emissions and farm economic losses [8, 9]. In this study partial replacement of hay with rice straws increased feed utilization efficiency. On the other hand, urea treatment of rice straws resulted into increased weight gain, growth rate and lower FCR values due to the higher ME intakes. The FCR values for TSHZ observed in this study are within the range of 8.1 - 11.5 reported by Asimwe *et al.* [11], but higher than the FCR of 6.1 - 8.0 reported by Asimwe *et al.* [25] and Kimirei *et al.* [44]. The differences could be due to the differences in plane of nutrition, number of days in the feedlot and physiological condition of fattened bulls. The choice of fattening diet should be substantiated by not only its influence on growth performance but also the economic return.

4.3. Gross Margin Analysis

The three types of rice straw-based treatments (URS, TRS and URH) had higher total variable cost than CCH. This can be attributed to higher roughage and concentrates intake of animals subjected to these treatments, which, in turn, led to higher feed cost in the former. Also, it was observed that URS and URH had lower roughage cost compared to CCH, TRS and TRH. This is because of high price of hay while additional treatment of rice straws with urea increased the cost [17, 23]. Although, there were no significant differences in gross margin among the treatments, animals on TRS showed relatively higher gross margin value compared to those on the other treatments. This is due to relatively fast growth and high weight gain of animals under TRS compared to those on CCH and URS, indicating that treatment of rice straw with urea improved growth performance of the animals and, hence, profit. Although animals on TRH had the highest growth rate and weight gain, the inclusion of hay which has high cost resulted into low profit. Moreover, the percentage profit margin in URS, TRS, URH and TRH were higher or similar to that of CCH. This indicates that replacing hay with rice straws resulted into almost similar profit as it was also noted by Asimwe *et al.* [11] and Njie and Reed [18].

Economically, it costed more to produce 1 kg of live weight in animals under CCH and URS compared to TRS, URH or TRH. This indicates that feeding sole untreated rice straw to fatten TSHZ is uneconomical and inefficient over a long term. Furthermore, the cost per 1 kg gain among all dietary treatments in this study were higher than the cost of TZS 2,374-3,244 obtained by Kimirei et al. [44], but the costs for TRS, URH and TRH are within the value of TZS 3,590 - 6,800 reported by Asimwe et al. [45]. These variations in feed cost can be attributed to differences in dietary feed materials and dry matter intake, inclusion level of ingredients, cost per kilogram of feed and growth rate of experimental animals. Nonetheless, this study has shown that feeding treated rice straws alone or in combination with hay reduced feed cost per kilo gained. Moreover, TRS was found to be better since it resulted into higher gross margin compared to TRH, despite the fact that animals on TRH had higher weight gain and almost similar feed cost per kg gain.

5. Conclusions

It is concluded that complete replacement of *C. ciliaris* hay with urea treated rice straws results into higher growth performance, gross margin and low cost per 1 kg weight gain, but complete replacement of hay with untreated rice straw increases FCR and cost per kg gain under feedlot conditions. Moreover, urea treatment of rice straws resulted into increased nutritive value, higher growth performance and better (lower) FCR than both untreated rice straws and hay. Feeding animals with urea treated rice straws alone or in combinations with 50% hay promotes fast growth, higher weight gains and lower feed requirement per weight gain. The TRS is, therefore, recommended for feeding TSHZ under traditional feedlot system as it results into higher profit than TRH and URS.

Conflict of Interest Statement

The authors declare that they have no competing interests.

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References

[1] URT, "Minister budget speech 2022/2023," Dodoma, Tanzania, 2022.

[2] URT, "Minister budget speech 2020/2021," Dodoma, Tanzania, 2021.

[3] P. J. Hansen, "Physiological and cellular adaptations of zebu cattle to thermal stress," *Anim. Reprod. Sci.*, vol. 82–83, pp. 349–360, Jul. 2004.

[4] S. W. Chenyambuga, S. M. Nalaila, and S. H. Mbaga, "Assessment of uses, special qualities and management aspects of Iringa Red *Zebu* cattle in Tanzania," *Livest. Res. Rural Dev.*, vol. 20, no. 2, p. 17, 2000.

[5] P. R. Ruvuga *et al.*, "Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements," *J. Environ. Manage.*, vol. 290, p. 112635, Jul. 2021.

[6] I. Selemani, L. O. Eik, Ø. Holand, T. Ådnøy, E. Mtengeti, and D. Mushi, "Variation in quantity and quality of native forages and grazing behavior of cattle and goats in Tanzania," *Livest. Sci.*, vol. 157, no. 1, pp. 173–183, Oct. 2013.

[7] C. M. Godde *et al.*, "Global rangeland production systems and livelihoods at threat under climate change and variability," *Environ. Res. Lett.*, vol. 15, no. 4, p. 044021, Apr. 2020.

[8] E. M. Kihoro, G. C. Schoneveld, and T. A. Crane, "Pathways toward inclusive low-emission dairy development in Tanzania: Producer heterogeneity and implications for intervention design," *Agric. Syst.*, vol. 190, p. 103073, May 2021.

[9] J. Hawkins, G. Yesuf, M. Zijlstra, G. C. Schoneveld, and M. C. Rufino, "Feeding efficiency gains can increase the greenhouse gas mitigation potential of the Tanzanian dairy sector," *Sci. Rep.*, vol. 11, no. 1, pp. 1-15, 2021.

[10] S. Michael *et al.*, "Tanzania livestock master plan," Nairobi, Kenya, 2018.

[11] L. Asimwe *et al.*, "Growth performance and carcass characteristics of Tanzania Shorthorn *Zebu* cattle finished on molasses or maize grain with rice or maize by-products," *Livest. Sci.*, vol. 182, pp. 112–117, Dec. 2015.

[12] D. E. Mushi, "Feedlot performance of Tanzanian Shorthorn *Zebu* finished on local feed resources," *Trop. Anim. Health Prod.*, vol. 52, no. 6, pp. 3207–3216, 2020.

[13] D. S. Shija *et al.*, "Chemical composition and meat quality attributes of indigenous sheep and goats from traditional production system in Tanzania," *Asian-Australasian J. Anim. Sci.*, vol. 26, no. 2, pp. 295–302, 2013.

[14] J. Safari, D. E. Mushi, L. A. Mtenga, G. C. Kifaro, and L. O. Eik, "Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished Small East African goats," *Livest. Sci.*, vol. 125, pp. 266–274, 2009.

[15] D. E. Mushi, J. Safari, L. A. Mtenga, G. C. Kifaro, and L. O. Eik, "Effects of concentrate levels on fattening performance, carcass and meat quality attributes of Small East African × Norwegian crossbred goats fed low quality grass hay," *Livest. Sci.*, vol. 124, no. 1–3, pp. 148–155, Sep. 2009.

[16] W. Rangi, D. D. Ngaruko, and A. A. Gimbi, "Socioeconomic Benefits of Traditional Beef Cattle Feedlots in The Lake Zone Regions of Tanzania," *Huria J.*, vol. 25, no. 2, pp. 118–130, 2018.

[17] S. M. Sala, D. J. Otieno, J. Nzuma, and S. M. Mureithi, "Determinants of pastoralists' participation in commercial fodder markets for livelihood resilience in drylands of northern Kenya: Case of Isiolo," *Pastoralism*, vol. 10, no. 1, p. 18, Dec. 2020.

[18] M. Njie and J. D. Reed, "Potential of crop residues and agricultural by-products for feeding sheep in a Gambian village," *Anim. Feed Sci. Technol.*, vol. 52, no. 3–4, pp. 313–323, Apr. 1995.

[19] D. Kiran and U. Krishnamoorthy, "Rumen fermentation and microbial biomass synthesis indices of tropical feedstuffs determined by the in vitro gas production technique," *Anim. Feed Sci. Technol.*, vol. 134, no. 1–2, pp. 170–179, 2007.

[20] M. H. Nazli, R. A. Halim, A. M. Abdullah, G. Hussin, and A. A. Samsudin, "Potential of feeding beef cattle with whole corn crop silage and rice straw in Malaysia," *Trop. Anim. Health Prod.*, vol. 50, no. 5, pp. 1119-1124, Jun. 2018.

[21] M. Wanapat, S. Polyorach, K. Boonnop, C. Mapato, and A. Cherdthong, "Effects of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows," *Livest. Sci.*, vol. 125, no. 2–3, pp. 238–243, 2009.

[22] J. Vadiveloo and J. G. Fadel, "The response of rice straw varieties to urea treatment," *Anim. Feed Sci. Technol.*, vol. 151, pp. 291–298, 2009.

[23] R. Lunsin, S. Duanyai, R. Pilajun, S. Duanyai, and P. Sombatsri, "Effect of urea- and molasses-treated sugarcane bagasse on nutrient composition and in vitro rumen fermentation in dairy cows," *Agric. Nat. Resour.*, vol. 52, no. 6, pp. 622-627, Dec. 2018.

[24] D. Yulistiani, Z. A. Jelan, J. B. Liang, H. Yaakub, and N. Abdullah, "Effects of Supplementation of Mulberry (Morus alba) Foliage and Urea-rice Bran as Fermentable Energy and Protein Sources in Sheep Fed Urea-treated Rice Straw Based Diet," *Asian-Australasian J. Anim. Sci.*, vol. 28, no. 4, pp. 494–501, 2015.

[25] L. Asimwe, A. E. Kimambo, G. H. Laswai, L. A. Mtenga, M. R. Weisbjerg, and J. Madsen, "Effect of days in feedlot on growth performance, carcass and meat quality attributes of Tanzania shorthorn zebu steers," *Trop. Anim. Health Prod.*, vol. 47, no. 5, pp. 867–876, 2015.

[26] G. E. Gewele, H. F. Mahoo, and F. C. Kahimba, "Comparison of Silicon Status in Rice Grown Under the System of Rice Intensification and Flooding Regime in Mkindo Irrigation Scheme, Morogoro, Tanzania * 1," *Tanzania J. Agric. Sci.*, vol. 19, no. 2, pp. 216–226, 2020.

[27] NRC, *Nutrient requirements of Beef Cattle: Eigth Revised Edition.* Washington, DC, US: The National Academies Press, 2001.

[28] AOAC, "Official methods of analysis of AOAC international (16th ed.. Arlington, Virginia, USA: AOAC International.," *Assoc. Off. Agric. Chem.*, vol. 1, no. Volume 1, 1990.

[29] P. J. Van Soest, J. B. Robertson, and B. A. Lewis, "Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition," *J. Dairy Sci.*, vol. 74, no. 10, pp. 3583–3597, Oct. 1991.

[30] J. M. A. Tilley and R. A. Terry, "A TWO-STAGE TECHNIQUE FOR THE IN VITRO DIGESTION OF FORAGE CROPS," *Grass Forage Sci.*, vol. 18, no. 2, pp. 104–111, Jun. 1963.

[31] J. M. N. Bwire, H. Wiktorsson, and A. J. Mwilawa, "A feeding strategy of combining tropical grass species for stall-fed dairy cows," *Trop. Grasslands*, vol. 37, no. 2, pp. 94–100, 2003.

[32] P. R. Ruvuga *et al.*, "Dry matter intake, dry matter digestibility and growth performance in goats fed grass-based diet (Brachiaria or Cenchrus) compared with a concentrate-based diet," *African J. Agric. Res.*, vol. 18, no. 1, pp. 52–57, 2022.

[33] M. Wei, L. Chen, X. M. Lian, Z. Q. Chen, and P. S. Yan, "Energy and protein requirements for maintenance of Southern Yellow cattle fed a corn silage or straw-based diet," *Livest. Sci.*, vol. 207, pp. 75–82, 2018.

[34] H. N. Subudhi *et al.*, "Genetic variation for grain yield, straw yield and straw quality traits in 132 diverse rice varieties released for different ecologies such as upland, lowland, irrigated and salinity prone areas in India," *F. Crop. Res.*, vol. 245, p. 107626, 2020.

[35] H. T. Kebe, I. C. Madakadze, A. Angassa, and A. Hassen, "Nutritive Value of Grasses in Semi-arid Rangelands of Ethiopia: Local Experience Based Herbage Preference Evaluation versus Laboratory Analysis," *Asian-Australasian J. Anim. Sci.*, vol. 26, no. 3, pp. 366–377, Mar. 2013.

[36] J. B. Kizima, E. J. Mtengeti, and S. Nchimbi-Msolla, "Seed yield and vegetation characteristics of Cenchrus Ciliaris as influenced by fertilizer levels, row spacing, cutting height and season," *Livest. Res. Rural Dev.*, vol. 26, no. 8, p. 148, 2014.

[37] K. Z. Mganga *et al.*, "Forage value of vegetative leaf and stem biomass fractions of selected grasses indigenous to African rangelands," *Anim. Prod. Sci.*, vol. 61, pp. 1476–1485, 2021.

[38] I. J. Salfer, M. C. Morelli, Y. Ying, M. S. Allen, and K. J. Harvatine, "The effects of source and concentration of dietary fiber, starch, and fatty acids on the daily patterns of feed intake, rumination, and rumen pH in dairy cows," *J. Dairy Sci.*, vol. 101, no. 12, p. 10911, Dec. 2018.

[39] B. A. Loureiro *et al.*, "Insoluble fibres, satiety and food intake in cats fed kibble diets," *J. Anim. Physiol. Anim. Nutr. (Berl).*, vol. 101, no. 5, pp. 824–834, Oct. 2017.

[40] R. Baumont, "Palatability and feeding behaviour in ruminants," *Ann. Zootech.*, vol. 45, pp. 385–400, 1996.

[41] M. Blackman and M. J. S. Moore-Colyer, "Hay for horses: the effects of three different wetting treatments on dust and nutrient content," *Anim. Sci.*, vol. 66, no. 3, pp. 745–750, 1998.

[42] C. L. Williams, B. J. Thomas, N. R. Mcewan, P. R. Stevens, C. J. Creevey, and S. A. Huws, "Rumen Protozoa Play a Significant Role in Fungal Predation and Plant Carbohydrate Breakdown," *Front. Microbiol.*, vol. 11, no. April, pp. 1–14, 2020.

[43] X. Han, B. Li, X. Wang, Y. Chen, and Y. Yang, "Effect of dietary concentrate to forage ratios on ruminal bacterial and anaerobic fungal populations of cashmere goats," *Anaerobe*, vol. 59, pp. 118–125, Oct. 2019.

[44] G. Kimirei, S. W. Chenyambuga, D. E. Mushi, G. M. Msalya, and Z. Mpenda, "Feedlot Performance and Profitability of Tanzania Shorthorn Zebu Finished on Local Feed Resources in Kongwa District, Tanzania," *Int. J. Anim. Sci. Technol.*, vol. 6, no. 4, pp. 78–85, 2022.

[45] L. Asimwe, A. E. Kimambo, G. H. Laswai, L. A. Mtenga, M. R. Weisbjerg, and J. Madsen, "Economics of finishing Tanzania Shorthorn Zebu cattle in feedlot and optimum finishing period," *Livest. Res. Rural Dev.*, vol. 28, no. 11, p. 201, 2016.

CHAPTER THREE

3.0 Carcass Measurements and Meat Quality of Tanzania Shorthorn Zebu Finished on Untreated or Urea-Treated Rice Straws as a Hay Replacement

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Abstract

A study was conducted to evaluate the effects of complete and partial replacement of *Cenchrus ciliaris* hay as a basal diet with urea-treated or untreated rice straws on carcass measurements and meat quality of Tanzania shorthorn Zebu (TSHZ) under a traditional feedlot system. The dietary treatments were *C. ciliaris* hay (CCH), untreated rice straw (URS), treated rice straw (TRS), untreated rice straws plus *C. ciliaris* hay (URH) and treated rice straws plus *C. ciliaris* hay (TRH). Ten 2.5 - 3-year-old TSHZ bulls were randomly allocated and fed the respective diets for 84 days. The animals on URH had the highest slaughter weight (203.9 kg), empty body weight (182.7 kg) and hot carcass weight (115.5 kg), while those on CCH had the lowest slaughter weight (175.4kg) and empty body weight (146.4kg). There were no variations ($p > 0.05$) among

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animals on different treatments regarding lean, fat and bone proportions, changes in pH and cooking loss. The shear force after ageing for one and seven days was lowest ($p < 0.05$) for the meat from animals on TRS (52.1 N/cm^2) compared to those on other treatments. Similarly, animals on TRS had a higher lean meat proportion (72.3%) compared to 69.8-71.5% for the animals on other treatments. The meat was dark red, and the final pH was 5.9 - 6.1 post-slaughter for all treatments, above the 5.8 recommended in quality meat. It is concluded that TRS can be used as a basal diet due to high lean meat proportion and tenderness, while URH can be selected due to high carcass weight for TSHZ fattening in the traditional feedlot system.

Keywords: Cattle fattening; Indigenous cattle; Crop residues; Traditional feedlot system; Lineal carcass measurements; Hot carcass weight; Meat tenderness

3.1 Introduction

Tanzania has a population of 36.6 million cattle, dominated by Tanzania Shorthorn Zebu, TSHZ cattle (*Bos indicus*) breeds (Michael *et al*., 2018; National Bureau of Statistics, NBS, 2021). The TSHZ are kept in arid and semi-arid areas, under agro-pastoral and pastoral systems, where they are fed natural pastures and migrate seasonally over a large area in search of forage and water. Agro-pastoral and pastoral livestock production systems are faced with a decline in the size of available grazing land. The decline is attributed to rangeland reallocation for crop cultivation and settlement due to human population growth and increased drought frequency and intensity caused by climate change (Chimwamurombe & Mataranyika, 2021; Ruvuga *et al.,* 2021). Also, there are seasonal changes in natural pasture availability, both in quantity and quality, during the dry season (J. Safari et al., 2011). Moreover, overgrazing and lack of pasture species that are better adapted to biotic (pests and diseases) and abiotic (drought and poor soil fertility) stress reduce rangeland productivity (Godde *et al.,* 2018b).

Poor rangeland productivity leads to animal weight loss during the dry season, causing a delay in attaining the desired market weight (Safari *et al.*, 2011). Also, fluctuations in animal growth lead to low beef production in agro-pastoral and pastoral systems. The weight loss and animal delay in attaining market weight affect meat quality, farmers' income, food security and livelihoods (Mushi, 2020). Otherwise, human population growth, increased urbanisation, and middle-income earners have increased red meat demand in Tanzania. Currently, it is estimated that the red meat deficit in the country is about 17%; thus, there is a need to optimise livestock performance (Komarek *et al.,* 2021; Michael *et al.,* 2018). Livestock keepers make different efforts to increase meat production, such as feedlot practices, where matured animals are finished using nutrient-rich diets, e.g. concentrates for 90 days. The concentrate diet enables animals to attain the market weight earlier and enhances meat quality attributes (Mushi, 2020; Safari *et al*., 2009; Shija *et al.,* 2013).

Adoption of feedlot practice by traditional livestock farmers is limited by the availability and high cost of concentrates such as maize grain, maize bran and molasses, which are needed to formulate energy-dense diets (Asimwe *et al.,* 2016; Ekpa *et al.,* 2019). Under the traditional feedlot system, animals are fed grass hay, e.g. (*Cenchrus ciliaris*) as a basal diet and supplemented with concentrates (Mushi et al., 2009; J. Safari et al., 2009). Hay is fed to reduce operational costs and ensure normal rumen functioning by supplying dietary fibres (González *et al*., 2012). The number of feedlot practitioners has increased rapidly in recent years because of the profitable nature of the enterprise (Michael *et al.,* 2018). The high number of practitioners has triggered an increase in hay demand, while unreliable rainfall and prolonged dry season have reduced hay production and raised its price consequently (Sala *et al.,* 2020). There is a need to find an alternative cheap fodder that can be used as the basal diet in traditional feedlot operations to reduce feeding costs while maintaining meat quality.

Rice straw is among the most readily available and cheaper fodder materials in the tropics, with the production of up to 3.2 million tonnes (t) in Tanzania in 2018/2019 (Kamel, 2022). Extensive rice cultivation produces straws as a crop residual, which can be fed as a basal diet to animals under a traditional fattening system. However, rice straws have low energy, protein, and digestibility due to high lignin content, limiting their feed value and utilization (Nazli *et al*., 2018). Urea treatment of rice straw can improve intake, digestibility and protein levels (Vadiveloo & Fadel, 2009; Wanapat et al., 2009). There are limited studies done on the effects of feeding urea-treated rice straws on carcass characteristics and/or meat quality of TSHZ, with most studies focused on the effects of urea-treated rice straw on cattle growth performance (Nazli *et al*., 2018; Wei *et al*., 2018). The current study evaluated the effects of partial or complete replacement of *C. ciliaris* hay with untreated or urea-treated rice straws on carcass characteristics and meat quality attributes.

3.2 Materials and Methods

3.2.1 Study area description

The study was conducted at Mtanana village, Kongwa district (6^{o}-6^{o}6’S, 26^{o}22’- 36^{o}30’E), 82 km from Dodoma capital city in central Tanzania. The district is located 1067 m above sea level and experiences 254 - 660 mm and 23 - 32^{o}C annual rainfall and daily temperature, respectively (Asimwe *et al.,* 2015a). The district experiences a semi-arid climate with vegetation dominated by natural pastures such as *Aristida* spp., *Chloris gayana*, *Cynodon* spp and *Urochloa mosambicensis* grass species (Asimwe *et al.,* 2015b). Agriculture (crop cultivation and livestock production) is the major economic activity in the district. The district had ~1.5 million TSHZ cattle in 2021 (per district records) grazed continuously in the communal rangelands. Similarly, feedlot practices are standard in the district, thus the site selection for this study.

3.2.2 Experimental animals

Fifty TSHZ bulls with an initial live weight of 132.4 ± 26.7 kg (mean ± SD) and 2.5 - 3 years old (age determined based on dentition) were obtained from farmers and fattened under traditional feedlot system. The experimental animals were randomly divided into five groups of 10 animals, and each group was housed in a ban of 20 m x 20 m. There were no significant differences ($p = 0.085$) in the initial live weight of the animals in different groups. All animals were dewormed using Albendazole 10% W/V (Bimeda-Oral suspension) at the beginning of the fattening period and after 45 days. Also, the animals were sprayed with Albadip Super 100EC (Alphacypermethrin 100%) at the start of the experiment and then every 14 days to control external parasites.

3.2.3 Experimental treatments and management of the animals

Five dietary treatments were formulated, which included *C. ciliaris* hay (CCH), untreated rice straws (URS) and urea-treated rice straws (TRS). Others were untreated rice straws plus *C. ciliaris* hay (URH) and urea-treated rice straws plus *C. ciliaris* hay (TRH). The dietary treatments were analysed for crude protein (CP), neutral detergent fibre (NDF), dry matter digestibility (IVDMD) and metabolisable energy (ME) (Table 1) as described in detail in Kilyenyi *et al.* (2023). These treatments were used as the basal diets where CCH was a control, while rice straw-based diets (URS, TRS, URH and TRH) were the evaluated treatments. The *C. ciliaris* hay was obtained from the Tanzania Livestock Research Institute, Mpwapwa, where it was harvested after seed production. Rice straws (SARO 5/TXD 306 variety) were purchased and collected from farmers in the Kilosa district. The rice straws were treated with urea, prepared by mixing 3 kg with 20 litres of water and then spraying on 100 kg of straws. The rice straws were fermented with urea for 21 days following Vadiveloo and Fadel (2009) techniques. Rice straws and hay were chopped manually into 3 cm long pieces before feeding. Untreated (URS) or urea-treated (TRS) rice straws were mixed in equal proportions with

C. ciliaris hay in the feeding trough for URH and TRH treatments, respectively.

In addition, a concentrate diet was formulated using maize bran (53%), molasses (25%), sunflower seed cake (20%), mineral premix (1.5%) and table salt (0.5%). The concentrate diet was laboratory analysed for ME and CP, 12.7 MJ ME /kg DM and 112.4 g CP /kg DM. The concentrate diet was fed as a supplementary diet to all experimental animals. It was provided at 80% of the animals' dry matter intake (DMI), estimated at 3% of the respective group's average body weight. The forage and concentrates DMI were used to calculate the individual animals' total metabolisable energy intake (TMEI) (Kilyenyi *et al.,* 2023). All animals had free access to drinking water during the entire feeding period. The animals were given an adaptation period of 10 days to acclimatise to the experimental settings and then fed their respective dietary treatment for 84 days. Each experimental animal was weighed individually before the start of the experiment to obtain the initial live weight and then at the end of the experiment for the final live weight.

3.2.4 Carcass measurements

Five animals were sampled randomly from 10 animals for each dietary treatment, resulting in a sample size of 25 animals used to evaluate different carcass measurements and meat quality. Carcass measurements included slaughter weight, empty body weight, carcass weight, linear measurements and non-carcass components. The experimental animals were transported to Kongwa Ranch abattoir, 22 km from the fattening location. Upon arrival, the animals were inspected and allowed to rest for 13 hours before slaughter. Each animal was weighed before slaughter to determine slaughter weight. The animals were stunned during slaughter and suspended immediately, which was followed by the severing of the neck with a sharp knife as per Halal slaughter protocols. The suspended body was left to bleed completely, then skinned and eviscerated.

Non-carcass components, namely heart, kidneys, liver, lungs, spleen, and internal fats (heart, ruminal, renal, and inguinal), were removed from the carcass and weighed individually. The rumen, reticulum, omasum, abomasum, small intestine and large intestine were weighed, first with their respective contents and then without the contents after being washed thoroughly. This was done to determine the weight of the full and empty gastrointestinal tract (GIT), respectively, and their difference was used to estimate the weight of GIT contents. The GIT contents' weight was subtracted from the slaughter weight to determine the empty body weight. Offal such as head, hide, feet, tail, anus, scrotum and penis were collected and weighed together. The percentage of each organ was calculated as the weight of the respective organ to empty body weight.

Hot carcass weight was determined by weighing the unchilled carcass after removing the head, hide and internal organs. Dressing percentage was calculated as the ratio of hot carcass weight to slaughter weight times 100. The left half carcass was used to determine linear measurements (see Figure 1) using a 5 m tape measure. Carcass length was measured from the cranial side of the ischio-pubis symphysis to the middle of the 1st rib. Chest depth was measured from the downside of the medulla channel at the 5th to 6th thoracic vertebra to the intersection down the side of the external bone with a line through the middle of the internal face of the tarso-metatarsal joint and parallel to the caudal side of 5th rib. Hind limb-length and circumference were measured from the tibia distal end to the cut edge of subcutaneous fat and around a line joining anterior pubic symphysis, respectively.

3.2.5 Meat quality assessment

Meat quality was determined by measuring meat temperature and pH, lean, fat and bone proportion in the carcass, meat colour, shear force and cooking loss. Digital meat thermometer and pH meter (Mettle Toledo) were used to measure carcass temperature and pH.

The temperature and pH were taken directly from the left half of the carcass on the 10^{th} rib in the *Longissimus dorsi* (LD) muscle. The temperature and pH were measured 45 minutes and 24 hours post-slaughter at room temperature and in the chill room, respectively. Carcass composition was determined using the 10^{th} rib joint of the left half carcass following the Robelin and Geay (1984) method. The total joint weight was measured before dissection into fat, lean and bone tissues. Individual tissues were weighed separately and expressed as a percentage of the total joint weight.

About 500 g of LD muscle was sampled from the right half of the carcass from the 7^{th} - 13^{th} ribs 45 minutes post-mortem, packed and taken to the laboratory for analysis. The muscle was split into three pieces, each 5 cm in length. These pieces were aged one, seven, and fourteen days by being placed in a cold room set at 4°C. After the respective ageing time, the meat sample was sealed in PVC bags and stored at -20^{0}C. The meat samples aged for one day were used for colour determination using a colorimeter (CR-410, Minolta Co. LTD, Japan). The colour measurements were taken thrice per sample and averaged. The colours were measured in L* (lightness), a* (redness), and b* (yellowness).

A 2 cm thick aged meat sample weighing 120 g was thawed and cooked to determine cooking loss. The sample was cooked in the thermometric-controlled water bath set at 75^{0}C for one hour and then cooled at room temperature for two hours. The cooked sample was removed from the PVC bag, dried with clean paper towels and weighed. Cooking loss was calculated in percentage based on a weight difference before and after cooking. The cooked sample was then cut along the fibre direction into 1 cm x 1 cm cubes 5 cm long to determine shear force using the Warner-Bratzler shear force instrument (WBSF, Z2.5, Germany). The instrument was set at a 1 kN load cell with a 100 mm/min crosshead speed. The force required to shear through the cube at a right angle to the muscle fibre direction was recorded.

Meat chemical composition was determined using LD muscle aged for one day, following the methods of the Association of Official Analytical Chemists (AOAC, 1990). Moisture content was determined by oven-drying 3 g of minced meat at 105^{o}C for 48 h. The dried meat was burnt at 600^{0}C in a muffle furnace for 6 h to determine ash content. Kjeldahl method was used to determine CP in a 1 g meat sample. A 5 g meat sample was used to estimate the total lipid content extracted using petroleum ether in a Soxhlet apparatus.

3.2.6 Statistical analysis

Data on carcass measurements and meat quality attributes were analysed using the R-Statistical program version 4.2.3. The data were analysed using a one-way ANOVA model: Y (carcass measurements and meat quality traits) = Dietary treatment + Residual error. Ageing effects on meat tenderness were analysed by another ANOVA model: Y (cooking loss or shear force) = Aging duration + Dietary treatment + Aging duration*Dietary treatment + Residual error. Tukey's test was used to determine the significance of the differences between means of independent variables, and the difference was declared statistically significant at $p \leq 0.05$.

3.3 Results

3.3.1 Carcass measurements and non-carcass components

Table 2 shows carcass measurements and non-carcass components; the treatments' slaughter and empty body weights differed ($p \leq 0.05$). The animals on CCH had lower slaughter weight and empty body weight by 28.5 kg and 36.4 kg, respectively than animals on URH, which had the highest slaughter weight (203.9 kg) and empty body weight (182.7 kg). There were no statistical differences ($p > 0.05$) in hot carcass weight, dressing percentage, carcass length and non-carcass components among the treatments.

The treatment influenced chest depth, hind-limb circumference, and length ($p < 0.05$). They were the lowest in the animals fed on the

CCH diet and highest in the URH diet. The chest depth, hind-limb circumference and length values for the animals on CCH were lower by 9%, 13% and 8%, respectively, compared to those on URH. Moreover, chest depth and hind-limb circumference did not differ ($p > 0.05$) among the animals on URS, TRS, URH and TRH diets. Hind-limb length varied between URS and TRH, with a difference of 4.2 cm between the diets.

3.3.2 Meat quality

Table 3 shows the different meat quality attributes of TSHZ under different dietary treatments. The lean, fat and bone proportion on the 10th rib joint and their ratio did not differ ($p > 0.05$) among the treatments. Treatments significantly affected shear force but not meat colour and cooking loss. Shear force varied significantly among the treatments on day 1 and day 7 but not on day 14 after ageing. On day 1, meat from animals on URS had the highest shear force, while animals on TRS had the lowest value. Also, the meat from animals on CCH had a shear force that was lower by 11.23 and 2.12 N/cm^2 compared to the URS and URH, respectively, but it exceeded TRS and TRH by 12.94 and 0.69 N/cm^2, respectively. On day 7, the meat from animals subjected to the CCH diet had higher shear force by 10.96, 7.21, 6.71 and 0.01 N/cm^2 than TRH, TRS, URS and URH, respectively.

Ageing duration had effects ($p \leq 0.001$) on both cooking loss and shear force, where mean shear force was significantly higher on day 1 (67.4 N/cm^2) than on day 7 (41.2 N/cm^2), which, in turn, was higher than that on day 14 (36.8 N/cm^2). The cooking loss followed a similar trend: day 1 (22.8%), day 7 (21.3%) and day 14 (19.9%). There were no variations ($p > 0.05$) in the pH and temperature of the meat samples from animals subjected to different dietary treatments. Figures 2 and 3 show that meat temperature and pH declined with time. The pH values were 6.5 - 6.6 after 45 minutes post-slaughter and 5.9 - 6.1 after 24 hours, while temperatures were 34.7 - 35.7^{o}C and 9.8 - 11.0°C, 45 minutes and 24 hours post-slaughter, respectively.

3.4 Discussion

3.4.1 Carcass measurements

The variations in carcass measurements between the animals fed the control diet (CCH) and those on other treatments (URS, TRS and URH) were attributed to the differences in TMEI, which was lower by 10-16% in the control compared to other treatments. The animals on CCH and TRH had a slaughter weight lower than 200.5 - 292.9 kg for TSHZ, while those on URH, URS and TRS were closer or within the mentioned range (Mushi, 2020). The lower slaughter weight in the animals on CCH and TRH indicates that these treatments could not produce heavier carcasses due to insufficient nutrient supply. However, hot carcass weight did not vary among treatments in this study but was lower than 119 – 151 kg (Asimwe *et al.*, 2015b, 2015a; Mushi, 2020), with the variations attributed to differences in fattening period, slaughter age, feeding strategy and Zebu cattle strains.

The animals on all treatments had lower hind limb length and chest depth than 65.5 - 69.5 cm and 48.2 - 60.0 cm, respectively, for Zebu cattle (Ojong *et al*., 2017). Hind limb circumference was within 81.8 - 91.3 cm (Asimwe *et al*., 2015a) in all treatments in this study except for CCH. The chest depth, hind-limb length, and circumference differences between the current and previous studies may be due to the plane of nutrition, diet composition and/or feed intake variations. Similarly, these factors contributed to the differences in empty body weight observed in this study, which was lower than 190-268 kg for TSHZ (Asimwe *et al*., 2015a, 2015b). The higher slaughter, empty body, and carcass weights showed that hay replacement with untreated rice straws (partial or complete) and urea-treated rice straws (complete) resulted in better outcomes.

Slaughter and empty body weights did not vary between the bulls fed urea-treated rice straws (TRS) and untreated rice straws (URS), attributed to similar TMEI in the two treatments. Also, CP variations between URS and TRS were small and did not influence weight gain (results not reported here) and slaughter weight. Consequently, URS, TRS or URH can be used as a basal diet for TSHZ fattening in place of hay with poor nutritional values. There were no variations in dressing percentage among animals on different treatments in the present study, which was attributed to a lack of differences in the non-carcass components, *i.e.* GIT and internal fat, as was also noted by Simões *et al*. (2005) in cattle. The dressing percentage values observed in this study were within 49-52% obtained by Shirima *et al*. (2016) in extensively grazed TSHZ. However, the values in the present study are higher than 47.3 – 51.9% obtained by Mushi and Baruani (2021) in free-ranging TSHZ strains.

3.4.2 Meat quality characteristics

The lean, fat, and bone proportions and lean-to-fat ratios did not differ significantly in all dietary treatments, which indicated the experimental animals were in a similar plane of nutrition. However, the meat of the animals on TRS had a higher lean proportion than those on other treatments; thus, urea-treated rice straws are ideal for producing premium meat. Nonetheless, the lean proportion in this study is higher than 57.0-68.9%, while the fat proportion is higher than 2.8 - 3.9% but within 13.7 - 27.1% in Zebu cattle (Asimwe *et al.*, 2015b, 2015a; Ojong *et al.,* 2017). The variations in lean and fat contents are attributed to the differences in the rib sample, type of diet used, and fattening duration. The lean-to-fat ratio observed in this study is higher than the 2.0 - 4.8 ratio (Asimwe *et al.*, 2015a, 2015b) but lower than the 7.0 - 8.8 ratio (Mushi & Baruani, 2021), this shows that the experimental animals were fed moderately.

The low total lipid content in LD muscle obtained in this study meant the fattening period, and diets were sufficient for lean muscle deposition. They did not cause excessive fat deposition. Excessive fat is unhealthy in meat due to the risk of coronary heart disease; thus, consumers do not prefer it, which lowers the market value (Fayet-Moore *et al.*, 2014; Park *et al.*, 2018; Shahrai *et al.*, 2020). It is also expensive to produce meat with a high fat content as more energy is required for fat deposition than muscle development. Meat temperature and pH declined post-slaughter for all treatments, as was expected. Still, they did not vary among bulls on different treatments because of similar fatness levels, as described by Mushi (2020). Also, slow carcass cooling was due to large hot carcass weight in this study because smaller carcasses cool fast (Shija *et al*., 2013). Fast carcass cooling and slow pH decline can lead to cold shortening, affecting meat tenderness and increasing the ageing duration (Álvarez *et al.*, 2022).

The final or ultimatum pH (pHu) post-slaughter for all treatments exceeded 5.8 recommended for quality meat (Li *et al.*, 2014). The pHu is influenced by muscle glycogen reserves, with insufficient reserves leading to higher pHu, which alters meat taste and colour (Barrasso *et al.*, 2022). Meat colour was darker red in all treatments, similar or close to L^* = 32.1-37.3 and a^* = 13.3-17.4 in cattle with high pHu (Li *et al.*, 2014). Also, meat colour was darker in this study than in the previous studies, where cattle were fattened with straws/hay or fattened after being extensively grazed (Guerrero *et al.,* 2013; Soulat *et al.*, 2022). Overall, experimental animals had sufficient TMEI, and it can be argued that animals had adequate glycogen reserves. Therefore, it can be concluded that the high pHu in this study was due to the stress of experimental animals at the abattoir and during slaughtering (Guerrero *et al.,* 2013). Dark red meat has a lower shelf-life (Viljoen *et al.*, 2002); hence, improving the slaughtering environment for quality meat production in Tanzania is essential.

The cooking loss in this study is higher than 17.1 - 18.8% reported in French cattle (Guerrero *et al*., 2013) but closer or within 21.1-23.0% in TSHZ (Mushi & Baruani, 2021). The variations between the studies are attributed to the differences in the ageing period, carcass fat content, breeds and prior management of fattened cattle. This study's shear force values on day 1 and day 7 are within 44.0 - 110.4 N/cm^2 for TSHZ (Asimwe *et al.*, 2015a; Mushi and Baruani, 2021). The meat of the TRS and TRH animals had lower shear and produced more tender meat than that of other treatments. The TRS and TRH can be suggested as better diets; however, animals fed these diets had lower hot carcass weights than those on the URH. Shear force and cooking loss declined with ageing time in this study; thus, the meat from URH should be aged longer than 7 days, improving meat tenderness, as Cho *et al.* (2016) noted.

3.5 Conclusions

Replacing *C. ciliaris* hay with untreated- (partial, *i.e.* URH or complete, *i.e.* URS) and treated rice (complete, TRS) straws resulted in higher slaughter weight, empty body weight and carcass weight. Linear carcass measurements, meat colour, changes in pH and temperature, shear force and cooking loss were similar or even better in URS, URH, TRS and TRH compared to CCH. Moreover, the proportions of lean, fat, bone, and chemical composition in meat were similar in all dietary treatments. Therefore, the study has shown that replacing *C. ciliaris* hay with rice straws results in superior carcass characteristics and meat quality attributes in TSHZ under a traditional feedlot system. The TRS is recommended as an ideal diet among the five basal diets used for TSHZ fattening. It leads to tender meat with a relatively higher proportion of lean, suitable for premium beef production.

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Conflict of interest

None

References

Adriansen, H. K., & Nielsen, T. T. (2005). The geography of pastoral mobility: A spatio-temporal analysis of GPS data from Sahelian Senegal. *GeoJournal*, *64*, 177–188. https://doi.org/10.1007/s10708-005-5646-y

Álvarez, C., Koolman, L., Whelan, M., & Moloney, A. (2022). Effect of Pre-Slaughter Practises and Early Post-Mortem Interventions on Sheep Meat Tenderness and Its Impact on Microbial Status. *Foods*, *11*(2), 181. https://doi.org/10.3390/FOODS11020181

AOAC. (1990). Official methods of analysis of the Association of Official Analytical Chemists. In K. Helrich (Ed.), *Association of Official Analytical Chemists* (15th ed., Vol. 1). AOAC International. https://doi.org/10.1371/journal.pone.0013135

Asimwe, L., Kimambo, A. E., Laswai, G. H., Mtenga, L. A., Weisbjerg, M. R., & Madsen, J. (2015). Effect of days in feedlot on growth performance, carcass and meat quality attributes of Tanzania shorthorn zebu steers. *Tropical Animal Health and Production*, *47*(5), 867–876. https://doi.org/10.1007/s11250-015-0801-z

Asimwe, L., Kimambo, A. E., Laswai, G. H., Mtenga, L. A., Weisbjerg, M. R., & Madsen, J. (2016). Economics of finishing Tanzania Shorthorn Zebu cattle in feedlot and optimum finishing period. *Livestock Research for Rural Development*, *28*(11), 201. http://www.lrrd.org/lrrd28/11/asim28201.html

Asimwe, L., Kimambo, A. E., Laswai, G. H., Mtenga, L. A., Weisbjerg, M. R., Madsen, J., & Mushi, D. E. (2015). Growth performance and carcass characteristics of Tanzania Shorthorn Zebu cattle finished on molasses or maize grain with rice or maize by-products. *Livestock Science*, *182*, 112–117. https://doi.org/10.1016/j.livsci.2015.11.001

Barrasso, R., Ceci, E., Tufarelli, V., Casalino, G., Luposella, F., Fustinoni, F., Dimuccio, M. M., & Bozzo, G. (2022). Religious slaughtering: Implications on pH and temperature of bovine carcasses. *Saudi Journal of Biological Sciences*, *29*(4), 2396–2401. https://doi.org/10.1016/J.SJBS.2021.12.002

Benjaminsen, T. A., Maganga, F. P., & Abdallah, J. M. (2009). The Kilosa Killings: Political Ecology of a Farmer-Herder Conflict in Tanzania. *Development and Change*, *40*(3), 423–445. https://doi.org/10.1111/j.1467-7660.2009.01558.x

Benjaminsen, T. A., Rohde, R., Sjaastad, E., Wisborg, P., & Lebert, T. (2006). Land Reform, Range Ecology, and Carrying Capacities in Namaqualand, South Africa. *Annals of the Association of American Geographers*, *96*(3), 524–540. https://doi.org/10.1111/j.1467-8306.2006.00704.x

Bwire, J. M. N., Wiktorsson, H., & Mwilawa, A. J. (2003). A feeding strategy of combining tropical grass species for stall-fed dairy cows. *Tropical Grasslands*, *37*(2), 94–100.

Cedrez, C. B., Chamberlin, J., Guo, Z., & Hijmans, R. J. (2020). Spatial variation in fertilizer prices in Sub-Saharan Africa. *PLOS ONE*, *15*(1), e0227764. https://doi.org/10.1371/JOURNAL.PONE.0227764

Chimwamurombe, P. M., & Mataranyika, P. N. (2021). Factors influencing dryland agricultural productivity. *Journal of Arid Environments*, *189*, 104489. https://doi.org/10.1016/J.JARIDENV.2021.104489

Cho, S., Kang, S. M., Seong, P., Kang, G., Kim, Y., Kim, J., Lee, S., & Kim, S. (2016). Effect of Aging Time on Physicochemical Meat Quality and Sensory Property of Hanwoo Bull Beef. *Korean Journal for Food Science of Animal Resources*, *36*(1), 68. https://doi.org/10.5851/KOSFA.2016.36.1.68

Dunne, T., Western, D., & Dietrich, W. E. (2011). Effects of cattle trampling on vegetation, infiltration, and erosion in a tropical rangeland. *Journal of Arid Environments*, *75*(1), 58–69. https://doi.org/10.1016/j.jaridenv.2010.09.001

Ekpa, O., Palacios-rojas, N., Kruseman, G., Fogliano, V., & Linnemann, A. R. (2019). Sub-Saharan African Maize-Based Foods - Processing Practices , Challenges and Opportunities Sub-Saharan African Maize-Based Foods - Processing Practices ,. *Food Reviews International*, *35*(7), 609–639. https://doi.org/10.1080/87559129.2019.1588290

FAO. (2021). *FAOSTAT Statistical Database*. https://www.fao.org/faostat/en/#data/QCL

Fayet-Moore, F., Cunningham, J., Stobaus, T., & Droulez, V. (2014). Fat Content and Composition in Retail Samples of Australian Beef Mince. *Nutrients*, *6*(6), 2217–2228. https://doi.org/10.3390/NU6062217

Firson, N. E., & Wahyono, T. (2020). Effect of different level of urea addition for rice straw fermentation application : in vitro evaluation. *IOP Conference Series: Earth and Environmental Science*, *465*, 012016. https://doi.org/10.1088/1755-

1315/465/1/012016

Galina, M. A., Guerrero, M., Puga, C., & Haenlein, G. F. W. (2004). Effect of a slow-intake urea supplementation on growing kids fed corn stubble or alfalfa with a balanced concentrate. *Small Ruminant Research*, *53*(1–2), 29–38. https://doi.org/10.1016/j.smallrumres.2003.08.009

Glowacki, L. (2020). The emergence of locally adaptive institutions: Insights from traditional social structures of East African pastoralists. *BioSystems*, *198*, 104257. https://doi.org/10.1016/j.biosystems.2020.104257

Godber, O. F., & Wall, R. (2014). Livestock and food security: vulnerability to population growth and climate change. *Global Change Biology*, *20*(10), 3092. https://doi.org/ 10.1111/GCB.12589

Godde, C. M., Garnett, T., Thornton, P. K., Ash, A. J., & Herrero, M. (2018a). Grazing systems expansion and intensification: Drivers, dynamics, and trade-offs. *Global Food Security*, *16*, 93–105. https://doi.org/10.1016/j.gfs.2017.11.003

Godde, C. M., Garnett, T., Thornton, P. K., Ash, A. J., & Herrero, M. (2018b). Grazing systems expansion and intensification: Drivers, dynamics, and trade-offs. *Global Food Security*, *16*, 93–105. https://doi.org/10.1016/j.gfs.2017.11.003

González, L. A., Manteca, X., Calsamiglia, S., Schwartzkopf-Genswein, K. S., & Ferret, A. (2012). Ruminal acidosis in feedlot cattle: Interplay between feed ingredients, rumen function and feeding behavior (a review). *Animal Feed Science and Technology*, *172*(1–2), 66–79. https://doi.org/10.1016/j.anifeedsci.2011.12.009

Guerrero, A., Sañudo, C., Albertí, P., Ripoll, G., Campo, M. M., Olleta, J. L., Panea, B., Khliji, S., & Santolaria, P. (2013). Effect of production system before the finishing period on carcass , meat and fat qualities of beef. *Animal*, *7*(12), 2063–2072. https://doi.org/10.1017/S1751731113001729

Hamid, A., Singh, S., Agrawal, M., & Agrawal, S. B. (2020). Effects of plant age on performance of the tropical perennial fodder grass, Cenchrus ciliaris L. subjected to elevated ultraviolet-B radiation. *Plant Biology*, *22*(5), 805–812. https://doi.org/10.1111/PLB.13116

Hansen, P. J. (2004). Physiological and cellular adaptations of zebu cattle to thermal stress. *Animal Reproduction Science*, *82–83*, 349–360. https://doi.org/10.1016/J.ANIREPROSCI.2004.04.011

Hawkins, J., Yesuf, G., Zijlstra, M., Schoneveld, G. C., & Rufino, M. C. (2021). Feeding efficiency gains can increase the greenhouse gas mitigation potential of the Tanzanian dairy sector. *Scientific Reports*, *11*(1), 1–15. https://doi.org/10.1038/s41598-021-83475-8

Hwang, K., Claus, J. R., Jeong, J. Y., & Hwang, Y. (2022). Physical and Biochemical Mechanisms Associated with Beef Carcass Vascular Rinsing Effects on Meat Quality : A Review. *Food Science of Animal Resources*, *42*(3), 389–397.

Jung, J., Yngvesson, J., & Jensen, P. (2002). Effects of reduced time on pasture caused by prolonged walking on behaviour and production of Mpwapwa Zebu cattle. *Grass and Forage Science*, *57*(2), 105–112. https://doi.org/10.1046/j.1365-2494.2002.00307.x

Kadigi, R. M. J., Kadigi, I. L., Laswai, G. H., & Kashaigili, J. J. (2013). Value chain of indigenous cattle and beef products in Mwanza region, Tanzania: Market access, linkage and opportunities for upgrading. *Academia Journal of Agricultural Research*, *1*(8), 145–155. http://www.academia.edu/8037416/Value_chain_of_indigenous_cattle_and_beef_products_in_Mwanza_region_Tanzania_Market_access_linkages_and_opportunities_for_upgrading

Kamel, L. (2022). *Production volume of rice in Tanzania from seasons 2010/11 to 2018/19 (Chart)*. https://www.statista.com/statistics/1168387/production-volume-of-rice-in-tanzania/

Kibona, C. A., Yuejie, Z., & Tian, L. (2022). Factors that influence beef meat production in Tanzania. A Cobb-Douglas production function estimation approach. *PLOS ONE*, *17*(8), e0272812. https://doi.org/10.1371/JOURNAL.PONE.0272812

Kilyenyi, E. H., Mushi, D. E., & Chenyambuga, S. W. (2023). Feed Utilization and Growth Performance of Tanzania Shorthorn Zebu Fed Untreated or Urea Treated Rice Straws as Hay Replacement in Traditional Feedlot System. *International Journal of Animal Science and Technology*, *7*(2), 11–18. https://doi.org/10.11648/j.ijast.20230702.11

Kimirei, G., Chenyambuga, S. W., Mushi, D. E., Msalya, G. M., & Mpenda, Z. (2022). Feedlot Performance and Profitability of Tanzania Shorthorn Zebu Finished on Local Feed Resources in Kongwa District , Tanzania. *International Journal of Animal Science and Technology*, *6*(4), 78–85. https://doi.org/10.11648/j.ijast.20220604.11

Komarek, A. M., Dunston, S., Enahoro, D., Godfray, H. C. J., Herrero, M., Mason-D'Croz, D., Rich, K. M., Scarborough, P., Springmann, M., Sulser, T. B., Wiebe, K., & Willenbockel, D. (2021). Income, consumer preferences, and the future of livestock-derived food demand. *Global Environmental Change*, *70*, 102343. https://doi.org/10.1016/J.GLOENVCHA.2021.102343

Kongphitee, K., Sommart, K., Phonbumrung, T., Gunha, T., & Suzuki, T. (2018). Feed intake , digestibility and energy partitioning in beef cattle fed diets with cassava pulp instead of rice straw. *Asian-Australasian Journal of Animal Sciences*, *31*(9), 1431–1441. https://doi.org/https://doi.org/10.5713/ajas.17.0759

Leweri, C. M., Msuha, M. J., & Treydte, A. C. (2021). Rainfall variability and socio-economic constraints on livestock production in the Ngorongoro Conservation Area, Tanzania. *SN Applied Sciences*, *3*(1), 1–10. https://doi.org/10.1007/S42452-020-04111-0/TABLES/2

Li, P., Wang, T., Mao, Y., Zhang, Y., Niu, L., Liang, R., Zhu, L., & Luo, X. (2014). Effect of Ultimate pH on Postmortem Myofibrillar Protein Degradation and Meat Quality Characteristics of Chinese Yellow Crossbreed Cattle. *The Scientific World Journal*, 174253.

Liwenga, E. T. (2008). Adaptive livelihood strategies for coping with water scarcity in the drylands of central Tanzania. *Physics and Chemistry of the Earth*, *33*, 775–779. https://doi.org/10.1016/j.pce.2008.06.031

Lunsin, R., Duanyai, S., Pilajun, R., Duanyai, S., & Sombatsri, P. (2018). Effect of urea- and molasses-treated sugarcane bagasse on nutrient composition and in vitro rumen fermentation in dairy cows. *Agriculture and Natural Resources*, *52*(6), 622–627. https://doi.org/10.1016/J.ANRES.2018.11.010

Mccabe, J. T., Leslie, P. W., & Davis, A. (2021). The Emergence of the Village and the Transformation of Traditional Institutions: A Case Study from Northern Tanzania. *Human Organisation*, *79*(2), 150–160. https://doi.org/10.17730/1938-3525.79.2.150.The

Mccabe, J. T., Smith, N. M., Leslie, P. W., & Telligman, A. L. (2014). Livelihood Diversification through Migration among a Pastoral People: Contrasting Case Studies of Maasai in Northern Tanzania. *Human Organisation*, *73*(4), 389–400.

https://doi.org/10.17730/humo.73.4.vkr10nhr65g18400

Mekonnen, K., Bezabih, M., Thorne, P., Gebreyes, M. G., Hammond, J., & Adie, A. (2022). Feed and forage development in mixed crop–livestock systems of the Ethiopian highlands: Africa RISING project research experience. *Agronomy Journal*, *114*(1), 46–62. https://doi.org/10.1002/AGJ2.20853

Mganga, K. Z., Ndathi, A. J. N., Wambua, S. M., Bosma, L., Kaindi, E. M., Kioko, T., Kadenyi, N., Musyoki, G. K., Van Steenbergen, F., & Musimba, N. K. R. (2021). Forage value of vegetative leaf and stem biomass fractions of selected grasses indigenous to African rangelands. *Animal Production Science*, *61*, 1476–1483. https://doi.org/10.1071/AN19597

Michael, S., Mbwambo, N., Mruttu, H., Dotto, M. M., Ndomba, C., Da Silva, M., Makusaro, F., Nandonde, S., Crispin, J., Shapiro, B., Desta, S., Nigussie, K., Negassa, A., & Gebru, G. (2018). *Tanzania livestock master plan*.

Moritz, M., Hamilton, I. M., Yoak, A. J., Scholte, P., Cronley, J., Maddock, P., & Pi, H. (2015). Simple movement rules result in ideal free distribution of mobile pastoralists. *Ecological Modelling*, *305*, 54–63. https://doi.org/10.1016/j.ecolmodel.2015.03.010

Mushi, D. E. (2020). Feedlot performance of Tanzanian Shorthorn Zebu finished on local feed resources. *Tropical Animal Health and Production*, *52*(6), 3207–3216. https://doi.org/10.1007/s11250-020-02346-y

Mushi, D. E., & Baruani, J. M. (2021). Preliminary Study on Slaughter and Meat Quality Characteristics of Selected Strains of Tanzania Shorthorn Zebu. *Tanzania Journal of Agricultural Sciences*, *20*(2), 278–294.

Mushi, D. E., Safari, J., Mtenga, L. A., Kifaro, G. C., & Eik, L. O. (2009). Effects of concentrate levels on fattening performance, carcass and meat quality attributes of Small East African × Norwegian crossbred goats fed low quality grass hay. *Livestock Science*, *124*(1–3), 148–155. https://doi.org/10.1016/j.livsci.2009.01.012

Mwacharo, J. M., & Rege, J. E. O. (2002). On-farm characterization of the indigenous small East African Shorthorn Zebu cattle (SEAZ) in the Southeast rangelands of Kenya. *Animal Genetic Resources Information*, *32*, 73–86. https://doi.org/10.1017/s1014233900001577

Nantongo, Z., Kiggundu, M., Moorby, J., Kigozi, A., Walusimbi, H.

K., & Mugerwa, S. (2021). The influence of supplemental feed protein concentration on growth and carcass characteristics of Short Horn Zebu bulls grazing natural pastures. *Scientific African*, *13*, e00856. https://doi.org/10.1016/J.SCIAF.2021.E00856

Nazli, M. H., Halim, R. A., Abdullah, A. M., Hussin, G., & Samsudin, A. A. (2018). Potential of feeding beef cattle with whole corn crop silage and rice straw in Malaysia. *Tropical Animal Health and Production*, *50*(5), 1119–1124. https://doi.org/10.1007/s11250-018-1538-2

NBS. (2021). National Sample Census of Agriculture 2019/20. In *The United Republic of Tanzania*.

Ngenzi, O. D., Msalya, G. M., & Maleko, D. D. (2023). Influence of seedbed type and cattle manure level on herbage characteristics and forage nutritive value of Cenchrus ciliaris in a semi-arid area. *Tropical Agriculture*, *100*(3), 191–205.

Ngenzi, O. D., Ruvuga, P. R., Msalya, G. M., & Maleko, D. D. (2024). Participatory establishment of Cenchrus ciliaris forage grass among pastoralists in a semi-arid rangeland area of eastern Tanzania. *African Journal of Range and Forage Science*, *41*(1), 29–38. https://doi.org/10.2989/10220119.2023.2219700

Nguyen, D. V., Tran, N. B. T., Vang, M. A., Le, H. T. T., Nguyen, G. T. T., Nguyen, Q. H., Blanchard, M., Bailey, A., & Ives, S. (2021). Live Weight and Body Conformation Responses of Culled Local Yellow Cows Fed Maize Silage and Urea-Treated Rice Straw in an Intensive Feedlot System in Northwest Vietnam. *Advances in Animal and Veterinary Sciences*, *9*(8), 1283–1291. https://doi.org/http://dx.doi.org/10.17582/journal.aavs/2021/9.8.1283.1291

Nhiem, D. Van, Berg, J., & Kjos, N. P. (2013). Effects of replacing fish meal with soy cake in a diet based on urea-treated rice straw on performance of growing Laisind beef cattle. *Tropical Animal Health and Production*, *45*, 901–909. https://doi.org/10.1007/s11250-012-0304-0

Njie, M., & Reed, J. D. (1995). Potential of crop residues and agricultural by-products for feeding sheep in a Gambian village. *Animal Feed Science and Technology*, *52*(3–4), 313–323. https://doi.org/10.1016/0377-8401(94)00710-Q

Nogueira, G. P. (2004). Puberty in South American Bos indicus (Zebu) cattle. *Animal Reproduction Science*, *82–83*, 361–372. https://doi.org/10.1016/j.anireprosci.2004.04.007

Nyberg, G., Mureithi, S. M., Muricho, D. N., & Ostwald, M. (2019). Enclosures as a land management tool for food security in African drylands. *Journal of Land Use Science*, *14*(1), 110–121. https://doi.org/10.1080/1747423X.2019.1636147

Ojong, W. B., Saccà, E., Corazzin, M., Sepulcri, A., & Piasentier, E. (2017). Body and meat characteristics of young bulls from Zebu Goudali of Cameroon and its crosses with the Italian Simmental. *Italian Journal of Animal Science*, *17*(1), 240–249. https://doi.org/10.1080/1828051X.2017.1326855

Ondier, J. O., Okach, D. O., Onyango, J. C., & Otieno, D. O. (2019). Interactive influence of rainfall manipulation and livestock grazing on species diversity of the herbaceous layer community in a humid savannah in Kenya. *Plant Diversity*, *41*(3), 198–205. https://doi.org/10.1016/j.pld.2019.04.005

Park, S. J., Beak, S. H., Jung, D. J. S., Kim, S. Y., Jeong, I. H., Piao, M. Y., Kang, H. J., Fassah, D. M., Na, S. W., Yoo, S. P., & Baik, M. (2018). Genetic, management, and nutritional factors affecting intramuscular fat deposition in beef cattle — A review. *Asian-Australasian Journal of Animal Sciences*, *31*(7), 1043–1061. https://doi.org/10.5713/AJAS.18.0310

Pfeiffer, M., Langan, L., Linstädter, A., Martens, C., Gaillard, C., Ruppert, J. C., Higgins, S. I., Mudongo, E. I., & Scheiter, S. (2019). Grazing and aridity reduce perennial grass abundance in semi-arid rangelands – Insights from a trait-based dynamic vegetation model. *Ecological Modelling*, *395*, 11–22. https://doi.org/10.1016/j.ecolmodel.2018.12.013

Prado, I. N., Prado, R. M., Rotta, P. P., Visantainer, J. V, Moletta, J. L., & Perotto, D. (2008). Carcass characteristics and chemical composition of the Longissimus muscle of crossbred bulls (Bos taurus indicus vs Bos taurus taurus) fi nished in feedlot. *Journal of Animal and Feed Sciences*, *17*, 295–306. https://doi.org/https://doi.org/10.22358/jafs/66609/2008

Rangi, W., Ngaruko, D. D., & Gimbi, A. A. (2018). Socioeconomic Benefits of Traditional Beef Cattle Feedlots in The Lake Zone Regions of Tanzania. *Huria Journal*, *25*(2), 118–130.

Ripkey, C., Little, P. D., Dominguez-Salas, P., Kinabo, J., Mwanri, A., & Girard, A. W. (2021). Increased climate variability and sedentarization in Tanzania: Health and nutrition implications on pastoral communities of Mvomero and Handeni districts, Tanzania. *Global Food Security*, *29*, 100516. https://doi.org/10.1016/J.GFS.2021.100516

Robelin, J., & Geay, Y. (1984). Body composition of cattle as affected by physiological status, breed, sex and diet. In F. M. C. Gilchrist & R. I. Mackie (Eds.), *Herbivore Nutrition in the Subtropics and Tropics.* (pp. 525–548). Science Press.

Ruvuga, P. R., Wredle, E., Fupi, G. F., Augustino, C., Kasiba, B. R., Selemani, I. S., & Kronqvist, C. (2022). Dry matter intake , dry matter digestibility and growth performance in goats fed grass-based diet (Brachiaria or Cenchrus) compared with a concentrate-based diet. *African Journal of Agricultural Research*, *18*(1), 52–57. https://doi.org/10.5897/AJAR2021.15785

Ruvuga, P. R., Wredle, E., Mwakaje, A., Selemani, I. S., Sangeda, A. Z., Nyberg, G., & Kronqvist, C. (2020). Indigenous Rangeland and Livestock Management Among Pastoralists and Agro-pastoralists in Miombo Woodlands, Eastern Tanzania. *Rangeland Ecology and Management*, *73*(2), 313–320. https://doi.org/10.1016/j.rama.2019.11.005

Ruvuga, P. R., Wredle, E., Nyberg, G., Hussein, R. A., Masao, C. A., Selemani, I. S., Sangeda, A. Z., & Kronqvist, C. (2021). Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements. *Journal of Environmental Management*, *290*, 112635. https://doi.org/10.1016/j.jenvman.2021.112635

Saeed, O. A., Sazili, A. Q., Akit, H., Alimon, A. R., & Samsudin, A. A. B. (2018). Effect of corn supplementation on purine derivatives and rumen fermentation in sheep fed PKC and urea-treated rice straw. *Tropical Animal Health and Production*, *50*, 1859–1864. https://doi.org/https://doi.org/10.1007/s11250-018-1636-1

Safari, J. G., Mushi, D. E., Mtenga, L. A., Kifaro, G. C., & Eik, L. O. (2011). Growth, carcass yield and meat quality attributes of Red Maasai sheep fed wheat straw-based diets. *Tropical Animal Health and Production*, *43*, 89–97. https://doi.org/10.1007/s11250-010-9658-3

Safari, J., Mushi, D. E., Kifaro, G. C., Mtenga, L. A., & Eik, L. O. (2011). Seasonal variation in chemical composition of native forages, grazing behaviour and some blood metabolites of Small East African goats in a semi-arid area of Tanzania. *Animal Feed Science and Technology*, *164*(1–2), 62–70.

https://doi.org/10.1016/j.anifeedsci.2010.12.004

Safari, J., Mushi, D. E., Mtenga, L. A., Kifaro, G. C., & Eik, L. O. (2009). Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished Small East African goats. *Livestock Science*, *125*, 266–274. https://doi.org/10.1016/j.livsci.2009.05.007

Safari, J., Singu, I., Masanyiwa, Z., & Hyandye, C. (2019). Social perception and determinants of Ngitili system adoption for forage and land conservation in Maswa district, Tanzania. *Journal of Environmental Management*, *250*, 109498. https://doi.org/10.1016/j.jenvman.2019.109498

Sala, S. M., Otieno, D. J., Nzuma, J., & Mureithi, S. M. (2020). Determinants of pastoralists' participation in commercial fodder markets for livelihood resilience in drylands of northern Kenya: Case of Isiolo. *Pastoralism*, *10*(1), 18. https://doi.org/10.1186/s13570-020-00166-1

Sangeda, A. Z., & Maleko, D. D. (2018). Rangeland condition and livestock carrying capacity under the traditional rotational grazing system in northern Tanzania. *Livestock Research for Rural Development*, *30*(5), 79. http://www.lrrd.org/lrrd30/5/sange30079.html

Sarkar, S., Skalicky, M., Hossain, A., Brestic, M., Saha, S., Garai, S., Ray, K., & Brahmachari, K. (2020). Management of crop residues for improving input use efficiency and agricultural sustainability. *Sustainability (Switzerland)*, *12*(23), 1–24. https://doi.org/10.3390/su12239808

Selemani, I., Eik, L. O., Holand, Ø., Ådnøy, T., Mtengeti, E., & Mushi, D. (2013). Variation in quantity and quality of native forages and grazing behavior of cattle and goats in Tanzania. *Livestock Science*, *157*(1), 173–183. https://doi.org/10.1016/j.livsci.2013.08.002

Selemani, I. S. (2020). Indigenous knowledge and rangelands' biodiversity conservation in Tanzania: success and failure. *Biodiversity and Conservation*, *29*, 3863–3876. https://doi.org/10.1007/s10531-020-02060-z

Seymour, C. L., Milton, S. J., Joseph, G. S., Dean, W. R. J., Ditlhobolo, T., & Cumming, G. S. (2010). Twenty years of rest returns grazing potential, but not palatable plant diversity, to Karoo rangeland, South Africa. *Journal of Applied Ecology*, *47*(4), 859–867. https://doi.org/10.1111/j.1365-2664.2010.01833.x

Shahrai, N. N., Babji, A. S., Maskat, M. Y., Razali, A. F., & Yusop, S. M. (2020). Effects of marbling on physical and sensory characteristics of ribeye steaks from four different cattle breeds. *Animal Bioscience*, *34*(5), 904–913. https://doi.org/ 10.5713/AJAS.20.0201

Shija, D. S., Mtenga, L. A., Kimambo, A. E., Laswai, G. H., Mushi, D. E., Mgheni, D. M., Mwilawa, A. J., Shirima, E. J. M., & Safari, J. G. (2013). Chemical composition and meat quality attributes of indigenous sheep and goats from traditional production system in Tanzania. *Asian-Australasian Journal of Animal Sciences*, *26*(2), 295–302. https://doi.org/10.5713/ajas.2012.12432

Shirima, E. J. M., Nsiima, L. M. P., Mwilawa, A. J., Temu, J., Michael, S., Silva Mlau, D. D., & Polidori, P. (2016). Evaluation of Slaughter and Carcass Characteristics from Indigenous Beef Cattle in Six Abattoirs of Tanzania. *Journal of Scientific Research and Reports*, *10*(2), 1–8. https://doi.org/10.9734/JSRR/2016/22397

Simões, J. A., Mira, J. F. F., Lemos, J. P. C., & Mendes, I. A. (2005). Dressing percentage and its relationship with some components of the fifth quarter in Portuguese cattle breeds. *Livestock Production Science*, *96*(2–3), 157–163. https://doi.org/10.1016/j.livprodsci.2005.01.016

Solomon, T. B., Snyman, H. A., & Smit, G. N. (2007). Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management*, *82*(4), 481–494. https://doi.org/10.1016/ J.JENVMAN.2006.01.008

Soulat, J., Monteils, V., & Picard, B. (2022). Effects of Rearing Management Applied throughout the Charolais Young Bulls' Life on Carcass and Meat Quality. *Foods*, *11*, 2878. https://doi.org/10.3390/FOODS11182878

Stergiadis, S., Zou, C., Chen, X., Allen, M., Wills, D., & Yan, T. (2016). Equations to predict methane emissions from cows fed at maintenance energy level in pasture-based systems. *Agriculture, Ecosystems & Environment*, *220*, 8–20. https://doi.org/10.1016/J.AGEE.2015.12.023

Subudhi, H. N., Prasad, K. V. S. V, Ch, R., Rameswar, P. S., Pathak, H., Ravi, D., Khan, A. A., Padmakumar, V., Blümmel, M., & Rice, N. (2020). Genetic variation for grain yield , straw yield and straw quality traits in 132 diverse rice varieties released for different ecologies such as upland , lowland , irrigated and salinity prone areas in India. *Field Crops Research*, *245*, 107626. https://doi.org/10.1016/j.fcr.2019.107626

Teague, R., & Barnes, M. (2017). Grazing management that regenerates ecosystem function and grazingland livelihoods. *African Journal of Range & Forage Science*, *34*(2), 77–86. https://doi.org/10.2989/10220119.2017.1334706

Tefera, S., Snyman, H. A., & Smit, G. N. (2007). Rangeland dynamics in southern Ethiopia: (1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management*, *85*(2), 429–442. https://doi.org/10.1016/j.jenvman.2006.10.007

Treydte, A. C., Schmiedgen, A., Berhane, G., & Tarekegn, K. D. (2017). Rangeland forage availability and management in times of drought – A case study of pastoralists in Afar, Ethiopia. *Journal of Arid Environments*, *139*, 67–75. https://doi.org/10.1016/J.JARIDENV.2016.12.014

Truebswasser, U., & Flintan, F. (2018). Extensive (pastoralist) cattle contributions to food and nutrition security. In *Encyclopedia of Food Security and Sustainability* (pp. 310–316). https://doi.org/10.1016/B978-0-08-100596-5.21529-1

Trujillo, A. I., Marichal, M. D. J., & Carriquiry, M. (2010). Comparison of dry matter and neutral detergent fibre degradation of fibrous feedstuffs as determined with in situ and in vitro gravimetric procedures. *Animal Feed Science and Technology*, *161*(1–2), 49–57. https://doi.org/10.1016/j.anifeedsci.2010.08.001

URT. (2022). *Minister budget speech 2022/2023*.

Vadiveloo, J., & Fadel, J. G. (2009). The response of rice straw varieties to urea treatment. *Animal Feed Science and Technology*, *151*, 291–298. https://doi.org/10.1016/j.anifeedsci.2009.03.003

Verdoodt, A., Mureithi, S. M., & Van Ranst, E. (2010). Impacts of management and enclosure age on recovery of the herbaceous rangeland vegetation in semi-arid Kenya. *Journal of Arid Environments*, *74*(9), 1066–1073. https://doi.org/10.1016/j.jaridenv.2010.03.007

Viljoen, H. F., De Kock, H. L., & Webb, E. C. (2002). Consumer acceptability of dark, firm and dry (DFD) and normal pH beef steaks. *Meat Science*, *61*(2), 181–185. https://doi.org/10.1016/

S0309-1740(01)00183-8
Wainaina, P., Minang, P. A., Nzyoka, J., Duguma, L., Temu, E., & Manda, L. (2021). Incentives for landscape restoration: Lessons from Shinyanga, Tanzania. *Journal of Environmental Management*, *280*, 111831. https://doi.org/10.1016/j.jenvman.2020.111831
Wanapat, M., Polyorach, S., Boonnop, K., Mapato, C., & Cherdthong, A. (2009). Effects of treating rice straw with urea or urea and calcium hydroxide upon intake , digestibility, rumen fermentation and milk yield of dairy cows. *Livestock Science*, *125*(2–3), 238–243. https://doi.org/10.1016/j.livsci.2009.05.001
Watanabe, G., Motoyama, M., Nakajima, I., & Sasaki, K. (2018). Relationship between water-holding capacity and intramuscular fat content in Japanese commercial pork loin. *Asian-Australas J Anim Sci*, *31*(6), 914–918.
Wei, M., Chen, L., Lian, X. M., Chen, Z. Q., & Yan, P. S. (2018). Energy and protein requirements for maintenance of Southern Yellow cattle fed a corn silage or straw-based diet. *Livestock Science*, *207*, 75–82. https://doi.org/10.1016/j.livsci.2017.09.002
Wendimu, A., Tekalign, W., Bojago, E., & Zemarku, Z. (2023). Beef cattle fattening practices and marketing system in tropical highlands of Ethiopia. *Journal of Agriculture and Food Research*, 14, 100806.
Woodhouse, E., & Mccabe, J. T. (2018). Well-being and conservation : diversity and change in visions of a good life among the Maasai of northern Tanzania. *Ecology and Society*, *23*(1), 43. https://doi.org/https://doi.org/10.5751/ES-09986-230143
Yaro, M., Munyard, K. A., Stear, M. J., & Groth, D. M. (2016). Combatting African Animal Trypanosomiasis (AAT) in livestock: The potential role of trypanotolerance. *Veterinary Parasitology*, *225*, 43–52. https://doi.org/10.1016/J.VETPAR.2016.05.003

Table 1: Dietary treatments (basal diet) and their chemical composition

Dietary treatments	**CCH**	**URS**	**TRS**	**URH**	**TRH**
Cenchrus ciliaris hay (%)	100	-	-	50	50
Untreated rice straws (%)	-	100	-	50	-
Treated rice straws (%)	-	-	100	-	50
ME (MJ/kg DM)	5.5	9.0	9.3	7.3	7.4
CP (g/kg DM)	56.9	54.2	72.6	55.6	64.8
NDF (g/kg DM)	743.5	651.0	543.9	697.3	643.7
IVDMD (%)	31.6	51.9	53.1	41.8	42.4
TMEI (MJ/day)	72.0	84.6	86.0	85.8	80.3

CCH = Cenchrus ciliaris hay, URS = Untreated rice straw, TRS = Treated rice straw, URH = Untreated rice straw with hay, TRH = Treated rice straw with hay

ME = Metabolisable energy, CP = Crude Protein, EE = Ether extract, NDF = Neutral Detergent Fibre, IVDMD = In-vitro dry-matter digestibility, TMEI = Total metabolisable energy intake (dietary treatment and supplement)

Table 2: Carcass quality of Tanzania short-horned Zebu bulls fed different dietary treatments

Parameters	Dietary treatments CCH	URS	TRS	URH	TRH	SEM	p-value
Carcass characteristics							
Slaughter weight (kg)	175.4[c]	197.2[a,b]	197.3[a,b]	203.9[a]	184.8[b,c]	6.5	0.025
Empty body weight (kg)	146.4[c]	174.5[a,b]	174.8[a,b]	182.7[a]	161.9[b,c]	6.1	0.017
Hot carcass weight (kg)	96.3	106.5	106.1	115.5	95.3	5.8	0.125
Dressing percentage (%)	52.2	53.3	51.6	53.9	51.3	1.4	0.673
Linear carcass measurements (cm)							
Carcass length	92.6	98.4	97.8	98.3	88.6	1.2	0.07
Chest depth	35.6[b]	38.0[a]	37.4[a]	39.2[a]	38.6[a]	0.7	0.02
circumference	80.4[b]	89.2[a,b]	88.8[a,b]	92.8[a]	85.2[a,b]	2.5	0.02
Hind limb length	59.4[c]	64.4[a]	62.4[a,b,c]	63.2[a,b]	60.2[b,c]	1.2	0.04
Non-carcass components							
Head, hide, feet, tail, anus, scrotum and penis (%)	25.4	25.8	24.3	24.6	24.3	1.0	0.756
Heart (%)	0.6	0.6	0.6	0.6	0.6	0.1	0.780
Spleen (%)	0.6	0.6	0.6	0.6	0.7	0.1	0.838
Kidney (%)	0.4	0.5	0.5	0.5	0.4	0.1	0.554
Internal fat (%)	1.5	2.0	1.7	2.0	1.6	0.3	0.636
Liver (%)	2.0	1.9	2.0	1.9	1.9	0.1	0.960
Pluck (%)	2.1	2.2	2.1	2.2	2.0	0.1	0.796
Gastrointestinal tract (GIT) – full (%)	22.8	22.6	24.7	22.5	22.2	1.6	0.789
Gastrointestinal tract (GIT) – empty (%)	8.4	8.0	7.6	7.7	7.5	0.3	0.370
Gastrointestinal tract (GIT) – content (%)	14.4	14.6	17.1	14.8	14.6	1.5	0.714

[a, b, c] Means in the same row with different letters are statistically different (p<0.05)

CCH = Cenchrus ciliaris hay, URS = Untreated rice straw, TRS = Treated rice straw, URH = Untreated rice straw with hay, TRH = Treated rice straw with hay

Table 3: Meat quality attributes of the Tanzania short-horned Zebu bulls fed different dietary treatments

Parameters	Dietary Treatments CCH	URS	TRS	URH	TRH	SEM	p-value
Tissue composition of 10th rib joint (%)							
Lean	69.8	71.5	72.3	71.0	69.8	2.0	0.9
Fat	10.1	11.9	10.6	10.9	13.9	2.1	0.7
Bone	19.3	15.6	15.5	17.4	15.4	2.0	0.7
The ratio of lean, fat and bone on the 10th rib joint							
Lean:Bone	3.6	4.6	4.7	4.1	4.5	0.8	0.8
Lean:Fat	6.9	6.0	6.8	6.5	5.0	2.0	0.6
(Lean + Fat): Bone	4.1	5.3	5.4	4.7	5.4	1.0	0.9
Chemical composition of *Longissimus dorsi* muscle							
Moisture (%)	71.0	69.7	74.2	73.0	73.1	2.1	0.546
Ash (%)	4.0	4.6	4.8	4.7	4.7	0.5	0.795
Crude Protein (CP) (%)	23.4	23.2	24.1	22.7	23.0	5.6	0.914
Total lipid (%)	0.6	2.5	0.8	1.8	1.2	0.1	0.668
Meat colour							
*L**	33.1	31.3	32.3	32.1	33.9	2.3	0.925
*a**	10.8	10.7	10.8	11.9	10.9	1.0	0.900
*b**	5.4	5.1	5.2	5.7	5.7	0.8	0.966
Shear force after ageing							
Day 1 (N/cm^2)	65.1^b	76.3^a	52.1^c	$67.2^{a,b}$	64.4^b	2.9	<0.001
Day 7 (N/cm^2)	46.0^a	$39.3^{a,b}$	$38.8^{a,b}$	46.0^a	35.1^b	2.6	0.012
Day 14 (N/cm^2)	39.8	36.9	34.8	37.0	35.3	2.9	0.763
Cooking loss after ageing							
Day 1 (%)	21.6	23.4	23.2	22.7	23.2	0.9	0.564
Day 7 (%)	20.8	21.9	21.3	21.5	20.7	0.7	0.741
Day 14 (%)	20.1	20.1	19.7	19.7	19.6	0.6	0.970

$^{a, b, c}$ Means in the same row with different letters are statistically different ($p<0.05$)

CCH = Cenchrus ciliaris hay, URS = Untreated rice straw, TRS = Treated rice straw, URH = Untreated rice straw with hay, TRH = Treated rice straw with hay

L = lightness; a* = redness; b* = yellowness*

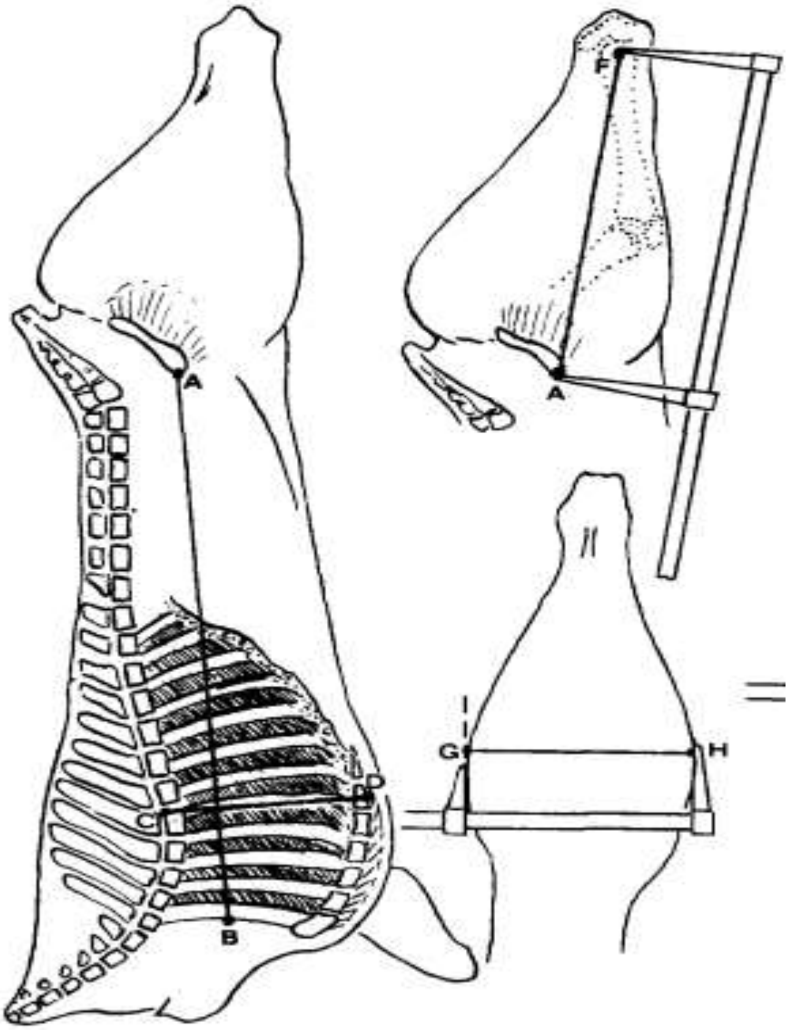

Figure 1: Lineal carcass measurements, as adopted from *Navajas et al., 2010*

Keynote: Carcass length (A-B), Chest depth (C-D), Hind limb length (A-F), Hind limb circumference (G-H)

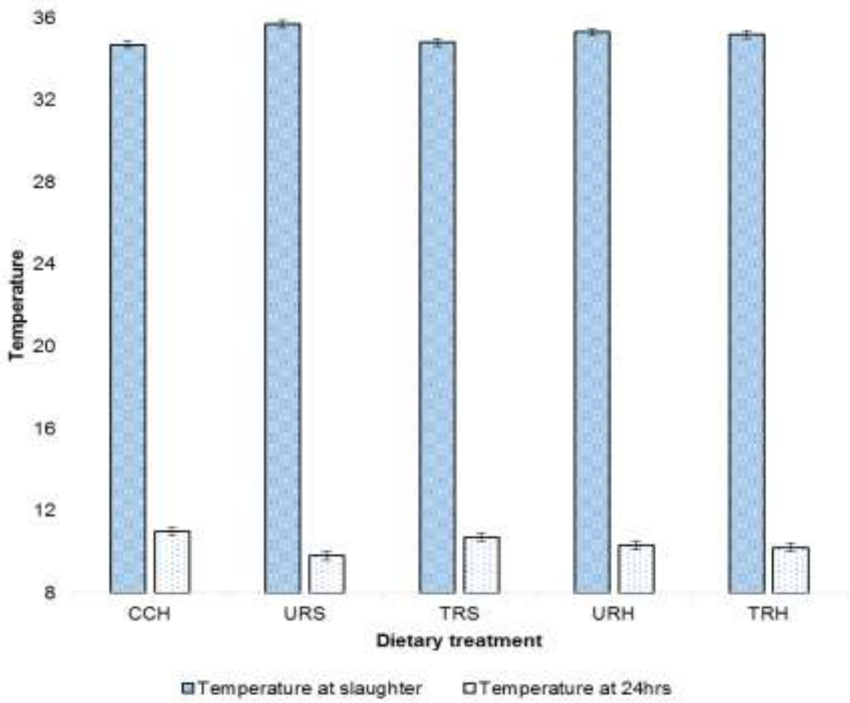

Figure 2: Temperature change for the meat from the Tanzania Shorthorn Zebu subjected to different dietary treatments

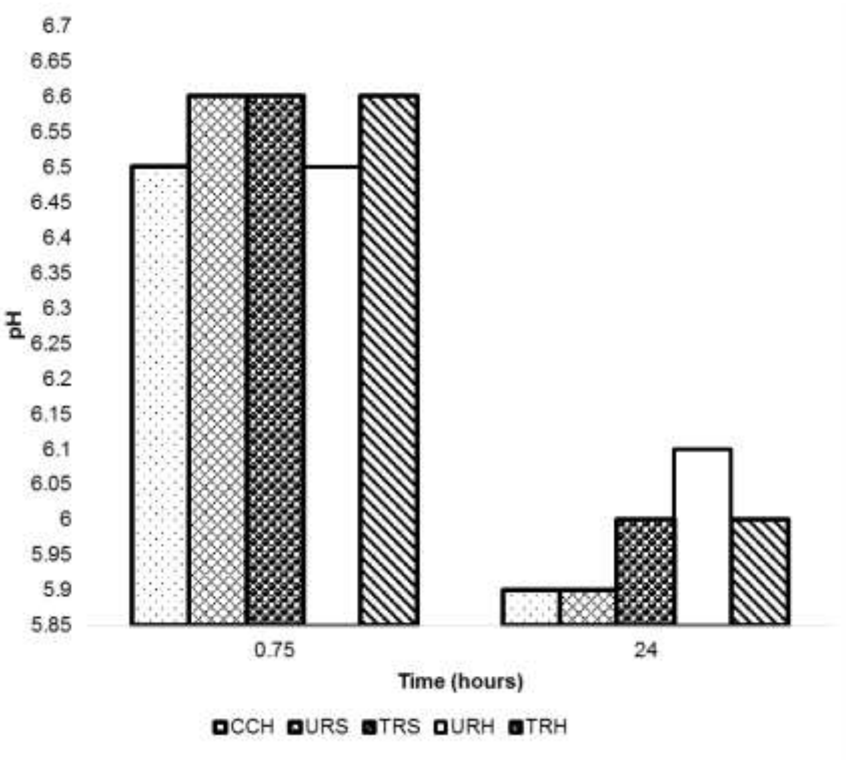

Figure 3: pH change for the meat from the Tanzania Shorthorn Zebu subjected to different dietary treatments

CHAPTER FOUR

4.0 General Discussion

4.1 Nutritive Values and Feed Intake

Chemical composition of the *Cenchrus ciliaris* hay (CCH), untreated rice straw (URS) and urea treated rice straw (TRS) showed that neutral detergent fibre (NDF) content was relatively higher in untreated rice straws (URS) than in urea treated rice straws (TRS). The results implies that urea treatment improved feed quality by reducing the amount of structural carbohydrate as it has been reported by Vadiveloo and Fadel (2009). The rice straws in this study had lower NDF than the value of 713 - 808 g/kg DM and 553 - 722 g/kg DM reported by Nazli *et al.* (2018) and Subudhi *et al.* (2020), respectively. The differences in NDF values between the current and previous studies may be due to the difference in the rice variety used and amount of urea used during treatments. *Cenchrus ciliaris* hay (CCH) in this study had NDF content at the upper limit and higher than the value of 685 - 710 g/kg DM reported in *C*. *ciliaris* in semi-arid areas (Mganga *et al.,* 2021; Ngenzi et al., 2023). The NDF variations could be due to the differences in *C. ciliaris* variety and growth stage during harvest. Also, CCH had higher NDF than URS, similar to the findings reported by Nazli *et al.* (2018) on rice straws and maize silage, but it is in contrast to the belief that forage grasses have lower structural carbohydrates than cereal crop residues (Galina *et al.,* 2004; Safari *et al.*, 2011; Wei *et al.,* 2018). The *C. ciliaris* hay had higher NDF content in this study because it was prepared after seed harvesting, hence, the grasses were harvested at advanced growth stage and of poor quality. Rice straws were also collected after harvesting of the rice grains in the current study. The higher NDF content in *C. ciliaris* than URS in this study could be due to morphological differences whereby *C. ciliaris* contain higher stem to leaf proportion than rice straws (Mganga et al., 2021; Ngenzi *et al.,* 2023). Lowland rice tends to have straws with lower NDF content (Subudhi *et al*., 2020) as it was observed in this study.

The NDF varied between CCH and rice straws diets (URS and TRS) which meant either URS or TRS could be better basal diet than CCH for cattle fattening in traditional feedlot system. This claim is substiated by the observed differences in IVDMD and ME between CCH and the rice straws and the differences is attributed to high NDF value in CCH which influences nutrient digestibility (Trujillo *et al.*, 2010). Nonetheless, the IVDMD and ME found in the CCH were within the range of 21 - 61% and 2.6 - 9.2 MJ/kg DM, respectively (Mganga *et al.*, 2021; Ruvuga *et al.*, 2022; Ngenzi *et al.*, 2023). On the other hand, the URS and TRS had IVDMD within the range of 37 - 62% and 50 - 70%, respectively, while their ME were higher than the value of 4.8 - 6.4 MJ/kg DM reported for untreated rice straws and 5.4 - 8.9 MJ/kg DM for treated rice straws (Vadiveloo & Fadel, 2009; Nhiem *et al*., 2013; Nazli *et al*., 2018; Saeed *et al.,* 2018; Firson & Wahyono, 2020). The variations in IVDMD and ME of rice straws between the current and previous studies are due to differences in rice varieties, digestibility and ME estimation methods, and urea concentration used for rice straw treatment. Moreover, the IVDMD and ME differences between URS and TRS were very small and this has been observed in other studies on urea treated rice straws (Vadiveloo & Fadel, 2009). The reasons behind this little differences between URS and TRS was the lower urea concentration (3%) used and the treatment duration. However, CP content was higher in TRS than in URS and CCH due to additional nitrogen from urea. This demonstrates the importance of treatment of rice straws with urea as it was recommended by Wanapat *et al.* (2009). Generally, there is a need for additional studies to evaluate the effects of higher urea concentration on IVDMD, ME and CP of rice straws and the low quality *C. ciliaris* hay.

Forage nutritional values influence feed intake which, in turn, contributes to animal growth performance. The hay DM intake for animals on CCH treatment is the same as the DM intake of 1.2 - 1.3 kg DM/day (Asimwe *et al.,* 2015), but lower than the value of 3.5 kg DM/day (Asimwe *et al.,* 2015; Mushi, 2020) observed among fattened TSHZ fed hay based diets. The variations in hay intake between the current and the previous studies are due to diiferences in forage species, feed management, animal condition and hay quality. On the other hand, animals on URS and URH treatments had hay DM intake lower than 2.7 - 3.0 kg DM/day that has been observed in animals fed untreated rice straws based diet (Kongphitee *et al.,* 2018) while those on TRS and TRH had hay DM intake that is lower than 3.1 - 3.7 kg DM/day obtained for zebu cattle fed urea treated rice straws based diets (Nguyen *et al.*, 2021). The animals fed rice straws based diets had lower roughage intake in the current study compared to the previous studies due to the differences in the inclusion levels of rice straws in the diet, zebu cattle strains and age of cattle used. Overall, animals on CCH had lower roughage intake compared to those on rice straw based diets because *C. ciliaris* hay had higher NDF content which causes satiety due to its high retention period and slow digesta movement in the gut (Trujillo *et al.*, 2010). Also, high NDF content was the reason why animals on CCH had the lowest concentrate and total feed intake compared to those on other diets. Similarly, the higher roughage intake in animals on TRS compared to those on URS was due to the differences in their NDF values as described above. Unexpectedly, the roughage intake was higher for animals on URH than those on TRH, which could be a result of synergestic effects of combining *C. ciliaris* and untreated rice straws that caused increased feed intake due to high palatability, despite their higher NDF.

Also, the differences in metabolisable energy (ME) intake among animals subjected to different dietary treatments in this study was the direct results of differences in total feed intake and nutritive values of the diets. The ME intake of animals fed rice straw based diets is higher than the ME intake of 57.7 - 65.2 MJ/day obtained in animals fed rice straws based diet while the ME intake of animals on CCH is within the ME intake of 56.9 - 80.7 MJ/day observed in animals fed hay based diets by Asimwe *et al.* (2015), Mushi (2020) and Nguyen *et al.* (2021). The observed ME intake of animals under different dietary treatments in the current study were sufficient to meet maintainance and growth requirements of TSHZ under the traditional feedlot system.

4.2 Growth Performance, Feed Conversion Ratio and Economic Analysis

The weight gain and average daily weight gain obtained in this study were within the value of 58 - 95 kg and 280 - 960 g/day, respectively, observed in TSHZ (Asimwe *et al.,* 2015; Mushi, 2020; Kimirei *et al.,* 2022). The animals on CCH and URS treatments showed lower weight gain and average daily weight gain compared to those on URH, TRS and TRH treatments. These results meant that CCH and URS as basal diets were not capable of supporting optimum weight gain of TSHZin the traditional feedlot system. TRH was found to be the ideal basal diet for fattening TSHZ as the animals fed this diet had the highest body weight gain and average daily weight gain. However, the best basal diet selection should be supported by low feed conversion ratio and high economic return to ensure profitable fattening venture.

The feed conversion ratio (FCR) values in this study were within the range of 6.1 - 11.5 that has been observed in the fattened TSHZ (Asimwe *et al.,* 2015; Kimirei *et al.*, 2022). Lower FCR values reflect higher feed utilisation efficiency because FCR is the ratio of feed intake to the liveweight gained by the animal. Therefore, animals on CCH, URS and URH had the least feed utilisation efficiency as they had high FCR values, meaning that animals fed these diets would require large feed quantity for gaining one kg of live weight and would have high enteric methane emissions (Stergiadis *et al.,* 2016; Hawkins *et al.,* 2021). Methane is the green-house gas of high environmental significance since it has higher global warming potential than carbon dioxide (Stergiadis *et al.,* 2016). Also, the large amount of feed required for one kg of live weight gain would result into high feed cost, thus reduce farm income and profitability of the traditional feedlot system (Asimwe *et al.*, 2016). The animals fed TRH diet showed the highest feed utilisation efficiency as they had lower FCR value. Therefore, TRH is an ideal basal diet for fattening TSHZ cattle as it was efficiently converted into animal live weight. Furthermore, it costed less to produce one kilogram of live weight for the animals fed TRH diet. The low feed cost per kilogram live weight gained in animals under TRH is due to their higher feed utilisation efficiency. It seemed that combining *C. ciliaris* hay and urea treated rice straws improves feed utilisation efficiency.

Overall, the observed feed cost per kilogram live weight gained and total feed cost in this study were higher than the cost of TZS 2 374 – 3 244/= and TZS 216 085 – 258 729, respectively, obtained in previous study for fattened TSHZ (Kimirei *et al.,* 2022). The variations in cost of feed between the two studies is due to differences in ration formulation, feed cost and animal feed intake. On the other hand, the cost differences between treated and untreated rice straws is due to the additional cost of urea, despite the existing subsidies in Tanzania (Cedrez *et al.,* 2020). Similarly, urea treatment increased the roughage cost for TRS compared to CCH, despite the lower cost of rice straws due to their abundancy (Njie & Reed, 1995; Mushi, 2020). It seems that the inclusion of *C. ciliaris* hay in treated rice straws (TRH) reduced the roughage feed cost. Consequently, TRH was found to be the best basal diet for fattening TSHZ under traditional feedlot system as the animals fed this diet showed lower cost per kilogram live weight gained, lower FCR and higher daily weight gain compared to the animals fed other diets. However, the animals on TRH had the lowest percentage profit margin, this means that the use of this diet as the basal diet would not result into high financial return for the farmers. The percentage profit margins in the current study are higher than the value of 6.8 - 16.3% obtained in Nguni cattle (Nkadimeng *et al.,* 2021), but lower than the value of 34.8 - 55.6% estimated from TSHZ (Kimirei *et al.,* 2022). The variations could be attributed to differences in feed types and fattened animal conditions.

The animals on TRS had the highest percentage profit margin compared to those on other dietary treatments. Therefore, the use of TRS diet could result into higher economic return which is appealing to the livestock farmers and the main motivation to adopt feedlot practices in Tanzania (Rangi *et al.,* 2018). The TRS is recommended as the basal diet for fattening of TSHZ if the primary objective is to increase farm income. Additional information on carcass characteristics and meat quality would help to determine the best basal diet among the five treatments used in this study.

4.3 Carcass Characteristics and Meat Quality

The observed empty body weights in this study were within the range of 150 - 263 kg while hot carcass weights were lower than the value of 126 - 150 kg that was obtained in fattened TSHZ (Asimwe *et al.,* 2015; Mushi, 2020). The variations in hot carcass weight between the current study and the previous studies are due to the differences in the fattening diet and period and physiological condition of the animals. Moreover, the lower hot carcass weight observed in this study could be due to the differences in TSHZ strains and age of the animals at slaughter. The hot carcass weight observed in this study is within the range of 99 - 117 kg that was obtained in unfattened TSHZ (Mushi, 2020; Mushi & Baruani, 2021). The results in this study indicated that there were no variations in hot carcass weight among animals subjected to the five dietary treatments. However, animals on URH had the highest values, meaning that this diet is capable of supporting animals to produce large meat quantity. On the other hand, the empty body weight varied among animals fed different diets and this was attributed to the variations in gut fill as the result of feed intake and differences in nutrient composition among the diets, especially NDF. The dressing percentages of fattened TSHZ bulls did not differ among the animals fed dietary treatments and were within the range of 51 - 53% obtained in fattened TSHZ, but slightly higher than the dressing percentage of 47 - 52% for unfattened TSHZ (Mushi & Baruani, 2021). The slightly higher dressing percentage observed in this study compared to unfattened TSHZ study is due to the differences in feed intensity provided which affected the liveweight as well as the fat depth which resulted to higher dressing percent.

Moreover, there were lack of statistical differences in non-carcass components among animals subjected to different dietary treatments. This is because the experimental animals had almost the same body size and were at similar plane of nutrition. However, the empty gastrointestinal tract (GIT) was relatively larger in animals fed CCH and URS diets, despite possessing slightly lower full GIT and GIT contents. This is because these animals were fed more fibrous diets which tend to expand the GIT to accommodate bulky amount of feed to supply the required nutrients (Simões *et al.,* 2005). Other non-carcass components such as spleen, kidney, pluck and internal fats in the current study were higher than the values of 0.3 - 0.4% for spleen and 0.3% for kidney, but lower than 3.9 - 4.1% for pluck and within the range of 0.9 - 2.9% for internal fat (Asimwe *et al.,* 2015). The variations in spleen, kidney and pluck contents between the current and previous studies are possibly due to the differences in prior management of the fattened animals, basal metabolism rate and nutrient composition of the fattening diet. Studies have shown that prior management has significant contribution to the outcomes and quality of the produced red meat under traditional feedlot system (Soulat *et al.,* 2022). Further studies are required to assess the effects of age and other physiological condition like sex on carcass characteristics of TSHZ under feedlot condition. This will enable feedlot practitioners to develop selection criteria that can result in production of quality meat and make the fattening enterprise profitable .

The carcass length observed in this study is within the range of 97 - 111 cm obtained in TSHZ by Mushi & Baruani (2021), except for the animals on CCH diet which had lower values than the mentioned range. The results in this study indicated that CCH diet was incapable of supporting optimum meat production as it has been described for the live weight gain (see section 4.1). The chest depth observed in this study is lower than the values of 58 – 60 cm obtained in zebu cattle (Ojong *et al.,* 2017) and 48 - 52 cm obtained in TSHZ (Asimwe *et al.,* 2015). Similarly, hind limb length in the current study is lower than the values of 69 - 75 cm and its circumference is within the range of 82 - 93 cm, except for animals on CCH (Prado *et al.,* 2008; Asimwe *et al.,* 2015). The chest depth and hind limb length variations between the current study and the previous studies is due to the differences in prior management and nutrition plane. The low chest depth and hind limb length observed in this study indicated that the fattened TSHZ had smaller carcass size. The slow change of carcass temperature observed in the current study is contrary to expectation for the carcass with smaller size as it was stated by Shija *et al.* (2013). The slow changes in carcass temperature and pH are useful in ensuring meat quality by avoiding cold shortening which occurs when sarcoplasmic reticulum in the muscles are incapable of calcium sequestration at a very low temperature (Álvarez *et al.,* 2022; Hwang *et al.,* 2022). The final or ultimate pH (pHu) of the meat of the animals from all dietary treatments were higher than the pH of 5.8 recommended for quality meat (Mushi & Baruani, 2021). High pHu in meat is caused by incomplete muscle breakdown of glycogen reserves into lactic acid due to limited reserves or arrested process by fast drop in temperature (Álvarez *et al.,* 2022; Barrasso *et al.,* 2022).

For all animals slaughtered, high meat pHu was observed, despite the sufficient energy supply which can be stored as glycogen by experimental animals. It can be said that the low glycogen reserve which led to high pHu was due to the fact that the slaughtered animals used the glycogen reserve when they were on their way to the abattoir or during the slaughtering process as the result of poor handling practices (Guerrero *et al.,* 2013). The poor handling such as infighting or stunning method can lead to struggling and stress and make the animals to exhaust their available energy reserves (Barrasso *et al.,* 2022). There is a need for further studies on stress tolerance of TSHZ and how to improve slaughter management for quality and safe meat production in Tanzania. Higher pHu has implications on meat safety and quality because it can reduce shelf life due to possible microbial growth, which, in turn, affect meat colour, tenderness and overall taste (Viljoen *et al.,* 2002; Li *et al.,* 2014). The meat colour in the present study was dark red for all animals subjected to different dietary treatments. This observation has also been reported in animals with high pHu (Li *et al.,* 2014). Studies have shown that meat colour differs between the animals managed under extensive grazing system and those fattened under feedlot conditions (Guerrero *et al*., 2013). Meat colour is an important indicator of meat "*freshness*" and most consumers prefer bright red or pink colour, hence, the darker colour observed in this study could lead to loss in income (Viljoen *et al.,* 2002). Similarly, pHu can affect meat taste and tenderness which are determined by cooking loss and shear force. In this study the initial cooking loss and shear force on day 1 were within the range of 15.7 - 27.2 and 44.0 - 67.8 N/cm^2, respectively, reported by Asimwe *et al.* (2015), likely due to the similar levels of intramascular fat and pHu between the two studies.

In the present study, the cooking loss and shear force declined with an increase of aging duration as was expected because of the physio-chemical effects of cold storage on carcass post-rigor mortis (Cho *et al.,* 2016; Barrasso *et al.,* 2022). Cooking loss did not vary among dietary treatments, implying that the meat of all animals under different treatments retained their juiceness. Meat juiceness is good for chewness and taste. Also, low cooking losses indicates that the meat mass was maintained. This is a good property as it serves as a basis on which retailers and processers of meat products are paid (Watanabe *et al.,* 2018). The shear force of meat varied among animals under different dietary treatments in day 1 and 7 in the current study, mainly because of their differences in intramuscular fat (Mushi, 2020). The meat of animals under TRS and TRH had the highest tenderness due to lower shear force in day 1 and 7. This implies that the animals fed these two diets produced quality meat. Therefore, it can be said that TRS and TRH were the better basal diets as their use resulted in meat with high tenderness. Also, the results revealed further that prolonged aging period of up to day 14 did not result into any variations in meat tenderness (Cho *et al.,* 2016).

The results on tissue composition showed that animals fed TRS diet had the highest lean content in their carcass, indicating that TRS was the best basal diet compared to other dietary treatments. Similarly, the meat from the animals fed TRS had lower fat content compared to the animals on other dietary treatments, except CCH. Meat fat content is important because it provides juiceness and tenderness in the meat. However, high fat content is not preferred by the consumers due to the risk of coronary diseases (Fayet-Moore *et al.*, 2014). On the other hand, fat deposition in muscles is highly energy demanding, thus it is uneconomical to the feedlot practitioners to produce meat with high fat content (Park *et al.*, 2018). In the present study, the lean and fat proportions in the meat of fattened animals were higher than the values of 66 - 69% and 3 - 6%, respectively, but slightly lower than the value of 72-75% for lean obtained in Zebu cattle (Ojong *et al.,* 2017; Nantongo *et al.*, 2021). The differences in fat and lean proportions between the current study and previous studies is due to the differences in the diet and beef cattle breed used and age of the animals at the time of slaughter. Furthermore, total lipids in *Longismus dorsi* in the present study are within the range of 0.2 - 2.0%, except for the animals on URS which had higher than the mentioned range. The reasons for the variations are the same reasons as those affected lean and fat proportions reported in this study. Also, high total lipids in meat of the animals fed URS implies that the meat from these animals might be unhealthy to most consumers. The lowest fat and total lipid contents were observed in meat of the animals fed CCH diet, indicating that the CCH could be the better diet because of the least lipids contents compared to the other diets. However, this is not the case since animals fed CCH diet had the lowest hot carcass weight and lean content, implying that this diet is incapable of producing optimum meat yield. From the current study, it can be concluded that the TRS was found to be the best basal diet for production of quality meat because the animals fed this diet produced meat with relatively lower shear force, total lipids and fat content while at the same time had higher lean proportion and acceptable hot carcass weight.

CHAPTER FIVE

5.0 Conclussion and Recommendation

5.1 Conclussions

The results from this study revealed that urea treatment of rice straws improved nutritive values by reducing NDF and increasing CP, IVDMD and ME. In this study, the animals fed TRH had the highest body weight gain and daily weight gain while those fed CCH had the lowest. Similarly, animals fed TRH had the lowest feed cost per kilogram live weight gain and feed conversion ratio while those on TRS treatment had the highest percentage profit margin. The animals on URH had relatively higher hot carcass yield while those on CCH had the lower carcass weight compared to those on TRS, URH and TRH. The non-carcass components did not vary among the animals on dietary treatments. The meat of the animals fed TRS had higher proportion of lean and lower proportion of fat contents than those on other treatments. Furthermore, the meat of the animals fed TRS had the least total lipids compared to that of animals on other dietary treatments. Therefore, it is concluded that urea treated rice straws is better than both untreated rice straws and *C*. *ciliaris* hay and can replace *C. ciliaris* hay as the basal diet for fattening of TSHZ cattle. Furthermore, the TRS diet is recommended as the best basal diet for fattening cattle because it resulted into high profit margin, proportion of lean and low fat and total lipid contents.

5.2 Recommendations

i. Urea treated rice straws should be used as the basal diet during cattle finishing under traditional system;
ii. Further studies are recommended to establish the optimal concentration of urea to be used in treating rice straw for profitable finishing of TSHZ under traditional sector; and
iii. There is also a need to conduct studies to determine appropriate handling and management practices at abattoirs

in the traditional sector for improving the quality of meat produced.

Reference

Adriansen, H. K., & Nielsen, T. T. (2005). The geography of pastoral mobility: A spatio-temporal analysis of GPS data from Sahelian Senegal. *GeoJournal*, *64*, 177–188. https://doi.org/10.1007/s10708-005-5646-y

Álvarez, C., Koolman, L., Whelan, M., & Moloney, A. (2022). Effect of Pre-Slaughter Practises and Early Post-Mortem Interventions on Sheep Meat Tenderness and Its Impact on Microbial Status. *Foods*, *11*(2), 181. https://doi.org/10.3390/FOODS11020181

AOAC. (1990). Official methods of analysis of the Association of Official Analytical Chemists. In K. Helrich (Ed.), *Association of Official Analytical Chemists* (15th ed., Vol. 1). AOAC International. https://doi.org/10.1371/journal.pone.0013135

Asimwe, L., Kimambo, A. E., Laswai, G. H., Mtenga, L. A., Weisbjerg, M. R., & Madsen, J. (2015). Effect of days in feedlot on growth performance, carcass and meat quality attributes of Tanzania shorthorn zebu steers. *Tropical Animal Health and Production*, *47*(5), 867–876. https://doi.org/10.1007/s11250-015-0801-z

Asimwe, L., Kimambo, A. E., Laswai, G. H., Mtenga, L. A., Weisbjerg, M. R., & Madsen, J. (2016). Economics of finishing Tanzania Shorthorn Zebu cattle in feedlot and optimum finishing period. *Livestock Research for Rural Development*, *28*(11), 201. http://www.lrrd.org/lrrd28/11/asim28201.html

Asimwe, L., Kimambo, A. E., Laswai, G. H., Mtenga, L. A., Weisbjerg, M. R., Madsen, J., & Mushi, D. E. (2015). Growth performance and carcass characteristics of Tanzania Shorthorn Zebu cattle finished on molasses or maize grain with rice or maize by-products. *Livestock Science*, *182*, 112–117. https://doi.org/10.1016/j.livsci.2015.11.001

Barrasso, R., Ceci, E., Tufarelli, V., Casalino, G., Luposella, F., Fustinoni, F., Dimuccio, M. M., & Bozzo, G. (2022). Religious slaughtering: Implications on pH and temperature of bovine carcasses. *Saudi Journal of Biological Sciences*, *29*(4), 2396–2401. https://doi.org/10.1016/J.SJBS.2021.12.002

Benjaminsen, T. A., Maganga, F. P., & Abdallah, J. M. (2009). The Kilosa Killings: Political Ecology of a Farmer-Herder Conflict in Tanzania. *Development and Change*, *40*(3), 423–445. https://doi.org/10.1111/j.1467-7660.2009.01558.x

Benjaminsen, T. A., Rohde, R., Sjaastad, E., Wisborg, P., & Lebert, T. (2006). Land Reform, Range Ecology, and Carrying Capacities in Namaqualand, South Africa. *Annals of the Association of American Geographers*, *96*(3), 524–540. https://doi.org/10.1111/j.1467-8306.2006.00704.x

Bwire, J. M. N., Wiktorsson, H., & Mwilawa, A. J. (2003). A feeding strategy of combining tropical grass species for stall-fed dairy cows. *Tropical Grasslands*, *37*(2), 94–100.

Cedrez, C. B., Chamberlin, J., Guo, Z., & Hijmans, R. J. (2020). Spatial variation in fertilizer prices in Sub-Saharan Africa. *PLOS ONE*, *15*(1), e0227764. https://doi.org/10.1371/JOURNAL.PONE.0227764

Chimwamurombe, P. M., & Mataranyika, P. N. (2021). Factors influencing dryland agricultural productivity. *Journal of Arid Environments*, *189*, 104489. https://doi.org/10.1016/J.JARIDENV.2021.104489

Cho, S., Kang, S. M., Seong, P., Kang, G., Kim, Y., Kim, J., Lee, S., & Kim, S. (2016). Effect of Aging Time on Physicochemical Meat Quality and Sensory Property of Hanwoo Bull Beef. *Korean Journal for Food Science of Animal Resources*, *36*(1), 68. https://doi.org/10.5851/KOSFA.2016.36.1.68

Dunne, T., Western, D., & Dietrich, W. E. (2011). Effects of cattle trampling on vegetation, infiltration, and erosion in a tropical rangeland. *Journal of Arid Environments*, *75*(1), 58–69. https://doi.org/10.1016/j.jaridenv.2010.09.001

Ekpa, O., Palacios-rojas, N., Kruseman, G., Fogliano, V., & Linnemann, A. R. (2019). Sub-Saharan African Maize-Based Foods - Processing Practices , Challenges and Opportunities Sub-Saharan African Maize-Based Foods - Processing Practices ,. *Food Reviews International*, *35*(7), 609–639. https://doi.org/10.1080/87559129.2019.1588290

FAO. (2021). *FAOSTAT Statistical Database*. https://www.fao.org/faostat/en/#data/QCL

Fayet-Moore, F., Cunningham, J., Stobaus, T., & Droulez, V. (2014). Fat Content and Composition in Retail Samples of Australian Beef Mince. *Nutrients*, *6*(6), 2217–2228. https://doi.org/10.3390/NU6062217

Firson, N. E., & Wahyono, T. (2020). Effect of different level of urea addition for rice straw fermentation application : in vitro evaluation. *IOP Conference Series: Earth and Environmental Science*, *465*, 012016. https://doi.org/10.1088/1755-1315/465/1/012016

Galina, M. A., Guerrero, M., Puga, C., & Haenlein, G. F. W. (2004). Effect of a slow-intake urea supplementation on growing kids fed corn stubble or alfalfa with a balanced concentrate. *Small Ruminant Research*, *53*(1–2), 29–38. https://doi.org/10.1016/j.smallrumres.2003.08.009

Glowacki, L. (2020). The emergence of locally adaptive institutions: Insights from traditional social structures of East African pastoralists. *BioSystems*, *198*, 104257. https://doi.org/10.1016/j.biosystems.2020.104257

Godber, O. F., & Wall, R. (2014). Livestock and food security: vulnerability to population growth and climate change. *Global Change Biology*, *20*(10), 3092. https://doi.org/10.1111/GCB.12589

Godde, C. M., Garnett, T., Thornton, P. K., Ash, A. J., & Herrero, M. (2018a). Grazing systems expansion and intensification: Drivers, dynamics, and trade-offs. *Global Food Security*, *16*, 93–105. https://doi.org/10.1016/j.gfs.2017.11.003

Godde, C. M., Garnett, T., Thornton, P. K., Ash, A. J., & Herrero, M. (2018b). Grazing systems expansion and intensification: Drivers, dynamics, and trade-offs. *Global Food Security*, *16*, 93–105. https://doi.org/10.1016/j.gfs.2017.11.003

González, L. A., Manteca, X., Calsamiglia, S., Schwartzkopf-Genswein, K. S., & Ferret, A. (2012). Ruminal acidosis in feedlot cattle: Interplay between feed ingredients, rumen function and feeding behavior (a review). *Animal Feed Science and Technology*, *172*(1–2), 66–79. https://doi.org/10.1016/j.anifeedsci.2011.12.009

Greenwood, P. L. (2021). An overview of beef production from pasture and feedlot globally, as demand for beef and the need for sustainable practices increase. *Animal,* 15, 100295.

Guerrero, A., Sañudo, C., Albertí, P., Ripoll, G., Campo, M. M., Olleta, J. L., Panea, B., Khliji, S., & Santolaria, P. (2013). Effect of production system before the finishing period on carcass , meat and fat qualities of beef. *Animal*, *7*(12), 2063–2072. https://doi.org/10.1017/S1751731113001729

Hamid, A., Singh, S., Agrawal, M., & Agrawal, S. B. (2020). Effects of plant age on performance of the tropical perennial fodder grass, Cenchrus ciliaris L. subjected to elevated ultraviolet-B radiation. *Plant Biology*, *22*(5), 805–812. https://doi.org/10.1111/PLB.13116

Hansen, P. J. (2004). Physiological and cellular adaptations of zebu cattle to thermal stress. *Animal Reproduction Science*, *82–83*, 349–360. https://doi.org/10.1016/J.ANIREPROSCI.2004.04.011

Hawkins, J., Yesuf, G., Zijlstra, M., Schoneveld, G. C., & Rufino, M. C. (2021). Feeding efficiency gains can increase the greenhouse gas mitigation potential of the Tanzanian dairy sector. *Scientific Reports*, *11*(1), 1–15. https://doi.org/10.1038/s41598-021-83475-8

Hwang, K., Claus, J. R., Jeong, J. Y., & Hwang, Y. (2022). Physical and Biochemical Mechanisms Associated with Beef Carcass Vascular Rinsing Effects on Meat Quality : A Review. *Food Science of Animal Resources*, *42*(3), 389–397.

Jung, J., Yngvesson, J., & Jensen, P. (2002). Effects of reduced time on pasture caused by prolonged walking on behaviour and production of Mpwapwa Zebu cattle. *Grass and Forage Science*, *57*(2), 105–112. https://doi.org/10.1046/j.1365-2494.2002.00307.x

Kadigi, R. M. J., Kadigi, I. L., Laswai, G. H., & Kashaigili, J. J. (2013). Value chain of indigenous cattle and beef products in Mwanza region, Tanzania: Market access, linkage and opportunities for upgrading. *Academia Journal of Agricultural Research*, *1*(8), 145–155. http://www.academia.edu/8037416/Value_chain_of_indigenous_cattle_and_beef_products_in_Mwanza_region_Tanzania_Market_access_linkages_and_opportunities_for_upgrading

Kamel, L. (2022). *Production volume of rice in Tanzania from seasons 2010/11 to 2018/19 (Chart)*. https://www.statista.com/statistics/1168387/production-volume-of-rice-in-tanzania/

Kibona, C. A., Yuejie, Z., & Tian, L. (2022). Factors that influence beef meat production in Tanzania. A Cobb-Douglas production function estimation approach. *PLOS ONE*, *17*(8), e0272812.

https://doi.org/10.1371/JOURNAL.PONE.0272812

Kilyenyi, E. H., Mushi, D. E., & Chenyambuga, S. W. (2023). Feed Utilization and Growth Performance of Tanzania Shorthorn Zebu Fed Untreated or Urea Treated Rice Straws as Hay Replacement in Traditional Feedlot System. *International Journal of Animal Science and Technology*, *7*(2), 11–18. https://doi.org/10.11648/j.ijast.20230702.11

Kimirei, G., Chenyambuga, S. W., Mushi, D. E., Msalya, G. M., & Mpenda, Z. (2022). Feedlot Performance and Profitability of Tanzania Shorthorn Zebu Finished on Local Feed Resources in Kongwa District , Tanzania. *International Journal of Animal Science and Technology*, *6*(4), 78–85. https://doi.org/10.11648/j.ijast.20220604.11

Komarek, A. M., Dunston, S., Enahoro, D., Godfray, H. C. J., Herrero, M., Mason-D'Croz, D., Rich, K. M., Scarborough, P., Springmann, M., Sulser, T. B., Wiebe, K., & Willenbockel, D. (2021). Income, consumer preferences, and the future of livestock-derived food demand. *Global Environmental Change*, *70*, 102343. https://doi.org/10.1016/J.GLOENVCHA.2021.102343

Kongphitee, K., Sommart, K., Phonbumrung, T., Gunha, T., & Suzuki, T. (2018). Feed intake , digestibility and energy partitioning in beef cattle fed diets with cassava pulp instead of rice straw. *Asian-Australasian Journal of Animal Sciences*, *31*(9), 1431–1441. https://doi.org/https://doi.org/10.5713/ajas.17.0759

Leweri, C. M., Msuha, M. J., & Treydte, A. C. (2021). Rainfall variability and socio-economic constraints on livestock production in the Ngorongoro Conservation Area, Tanzania. *SN Applied Sciences*, *3*(1), 1–10. https://doi.org/10.1007/S42452-020-04111-0/TABLES/2

Li, P., Wang, T., Mao, Y., Zhang, Y., Niu, L., Liang, R., Zhu, L., & Luo, X. (2014). Effect of Ultimate pH on Postmortem Myofibrillar Protein Degradation and Meat Quality Characteristics of Chinese Yellow Crossbreed Cattle. *The Scientific World Journal*, 174253.

Liwenga, E. T. (2008). Adaptive livelihood strategies for coping with water scarcity in the drylands of central Tanzania. *Physics and Chemistry of the Earth*, *33*, 775–779. https://doi.org/10.1016/j.pce.2008.06.031

Lunsin, R., Duanyai, S., Pilajun, R., Duanyai, S., & Sombatsri, P. (2018). Effect of urea- and molasses-treated sugarcane bagasse on nutrient composition and in vitro rumen fermentation in dairy cows. *Agriculture and Natural Resources*, *52*(6), 622–627. https://doi.org/10.1016/J.ANRES.2018.11.010

Mccabe, J. T., Leslie, P. W., & Davis, A. (2021). The Emergence of the Village and the Transformation of Traditional Institutions: A Case Study from Northern Tanzania. *Human Organisation*, *79*(2), 150–160. https://doi.org/10.17730/1938-3525.79.2.150.The

Mccabe, J. T., Smith, N. M., Leslie, P. W., & Telligman, A. L. (2014). Livelihood Diversification through Migration among a Pastoral People: Contrasting Case Studies of Maasai in Northern Tanzania. *Human Organisation*, *73*(4), 389–400. https://doi.org/10.17730/humo.73.4.vkr10nhr65g18400

Mekonnen, K., Bezabih, M., Thorne, P., Gebreyes, M. G., Hammond, J., & Adie, A. (2022). Feed and forage development in mixed crop–livestock systems of the Ethiopian highlands: Africa RISING project research experience. *Agronomy Journal*, *114*(1), 46–62. https://doi.org/10.1002/AGJ2.20853

Mganga, K. Z., Ndathi, A. J. N., Wambua, S. M., Bosma, L., Kaindi, E. M., Kioko, T., Kadenyi, N., Musyoki, G. K., Van Steenbergen, F., & Musimba, N. K. R. (2021). Forage value of vegetative leaf and stem biomass fractions of selected grasses indigenous to African rangelands. *Animal Production Science*, *61*, 1476–1483. https://doi.org/10.1071/AN19597

Michael, S., Mbwambo, N., Mruttu, H., Dotto, M. M., Ndomba, C., Da Silva, M., Makusaro, F., Nandonde, S., Crispin, J., Shapiro, B., Desta, S., Nigussie, K., Negassa, A., & Gebru, G. (2018). *Tanzania livestock master plan*.

Moritz, M., Hamilton, I. M., Yoak, A. J., Scholte, P., Cronley, J., Maddock, P., & Pi, H. (2015). Simple movement rules result in ideal free distribution of mobile pastoralists. *Ecological Modelling*, *305*, 54–63. https://doi.org/10.1016/j.ecolmodel.2015.03.010

Mushi, D. E. (2020). Feedlot performance of Tanzanian Shorthorn Zebu finished on local feed resources. *Tropical Animal Health and Production*, *52*(6), 3207–3216.

https://doi.org/10.1007/s11250-020-02346-y

Mushi, D. E., & Baruani, J. M. (2021). Preliminary Study on Slaughter and Meat Quality Characteristics of Selected Strains of Tanzania Shorthorn Zebu. *Tanzania Journal of Agricultural Sciences*, *20*(2), 278–294.

Mushi, D. E., Safari, J., Mtenga, L. A., Kifaro, G. C., & Eik, L. O. (2009). Effects of concentrate levels on fattening performance, carcass and meat quality attributes of Small East African × Norwegian crossbred goats fed low quality grass hay. *Livestock Science*, *124*(1–3), 148–155. https://doi.org/10.1016/j.livsci.2009.01.012

Mwacharo, J. M., & Rege, J. E. O. (2002). On-farm characterization of the indigenous small East African Shorthorn Zebu cattle (SEAZ) in the Southeast rangelands of Kenya. *Animal Genetic Resources Information*, *32*, 73–86. https://doi.org/10.1017/s1014233900001577

Nantongo, Z., Kiggundu, M., Moorby, J., Kigozi, A., Walusimbi, H. K., & Mugerwa, S. (2021). The influence of supplemental feed protein concentration on growth and carcass characteristics of Short Horn Zebu bulls grazing natural pastures. *Scientific African*, *13*, e00856. https://doi.org/10.1016/J.SCIAF.2021.E00856

Nazli, M. H., Halim, R. A., Abdullah, A. M., Hussin, G., & Samsudin, A. A. (2018). Potential of feeding beef cattle with whole corn crop silage and rice straw in Malaysia. *Tropical Animal Health and Production*, *50*(5), 1119–1124. https://doi.org/10.1007/s11250-018-1538-2

NBS. (2021). National Sample Census of Agriculture 2019/20. In *The United Republic of Tanzania*.

Ngenzi, O. D., Msalya, G. M., & Maleko, D. D. (2023). Influence of seedbed type and cattle manure level on herbage characteristics and forage nutritive value of Cenchrus ciliaris in a semi-arid area. *Tropical Agriculture*, *100*(3), 191–205.

Ngenzi, O. D., Ruvuga, P. R., Msalya, G. M., & Maleko, D. D. (2024). Participatory establishment of Cenchrus ciliaris forage grass among pastoralists in a semi-arid rangeland area of eastern Tanzania. *African Journal of Range and Forage Science*, *41*(1), 29–38. https://doi.org/10.2989/10220119.2023.2219700

Nguyen, D. V., Tran, N. B. T., Vang, M. A., Le, H. T. T., Nguyen, G. T. T., Nguyen, Q. H., Blanchard, M., Bailey, A., & Ives, S. (2021). Live Weight and Body Conformation Responses of Culled Local Yellow Cows Fed Maize Silage and Urea-Treated Rice Straw in an Intensive Feedlot System in Northwest Vietnam. *Advances in Animal and Veterinary Sciences*, *9*(8), 1283–1291. https://doi.org/http://dx.doi.org/10.17582/journal.aavs/2021/9.8.1283.1291

Nhiem, D. Van, Berg, J., & Kjos, N. P. (2013). Effects of replacing fish meal with soy cake in a diet based on urea-treated rice straw on performance of growing Laisind beef cattle. *Tropical Animal Health and Production*, *45*, 901–909. https://doi.org/10.1007/s11250-012-0304-0

Njie, M., & Reed, J. D. (1995). Potential of crop residues and agricultural by-products for feeding sheep in a Gambian village. *Animal Feed Science and Technology*, *52*(3–4), 313–323. https://doi.org/10.1016/0377-8401(94)00710-Q

Nogueira, G. P. (2004). Puberty in South American Bos indicus (Zebu) cattle. *Animal Reproduction Science*, *82–83*, 361–372. https://doi.org/10.1016/j.anireprosci.2004.04.007

Nyberg, G., Mureithi, S. M., Muricho, D. N., & Ostwald, M. (2019). Enclosures as a land management tool for food security in African drylands. *Journal of Land Use Science*, *14*(1), 110–121. https://doi.org/10.1080/1747423X.2019.1636147

Ojong, W. B., Saccà, E., Corazzin, M., Sepulcri, A., & Piasentier, E. (2017). Body and meat characteristics of young bulls from Zebu Goudali of Cameroon and its crosses with the Italian Simmental. *Italian Journal of Animal Science*, *17*(1), 240–249. https://doi.org/10.1080/1828051X.2017.1326855

Ondier, J. O., Okach, D. O., Onyango, J. C., & Otieno, D. O. (2019). Interactive influence of rainfall manipulation and livestock grazing on species diversity of the herbaceous layer community in a humid savannah in Kenya. *Plant Diversity*, *41*(3), 198–205. https://doi.org/10.1016/j.pld.2019.04.005

Park, S. J., Beak, S. H., Jung, D. J. S., Kim, S. Y., Jeong, I. H., Piao, M. Y., Kang, H. J., Fassah, D. M., Na, S. W., Yoo, S. P., & Baik, M. (2018). Genetic, management, and nutritional factors affecting intramuscular fat deposition in beef cattle — A review. *Asian-Australasian Journal of Animal Sciences*, *31*(7), 1043–1061. https://doi.org/10.5713/AJAS.18.0310

Pfeiffer, M., Langan, L., Linstädter, A., Martens, C., Gaillard, C., Ruppert, J. C., Higgins, S. I., Mudongo, E. I., & Scheiter, S. (2019). Grazing and aridity reduce perennial grass abundance in semi-arid rangelands – Insights from a trait-based dynamic vegetation model. *Ecological Modelling*, *395*, 11–22. https://doi.org/10.1016/ j.ecolmodel.2018.12.013

Prado, I. N., Prado, R. M., Rotta, P. P., Visantainer, J. V, Moletta, J. L., & Perotto, D. (2008). Carcass characteristics and chemical composition of the Longissimus muscle of crossbred bulls (Bos taurus indicus vs Bos taurus taurus) fi nished in feedlot. *Journal of Animal and Feed Sciences*, *17*, 295–306. https://doi.org/https://doi.org/10.22358/jafs/66609/2008

Rangi, W., Ngaruko, D. D., & Gimbi, A. A. (2018). Socioeconomic Benefits of Traditional Beef Cattle Feedlots in The Lake Zone Regions of Tanzania. *Huria Journal*, *25*(2), 118–130.

Ripkey, C., Little, P. D., Dominguez-Salas, P., Kinabo, J., Mwanri, A., & Girard, A. W. (2021). Increased climate variability and sedentarization in Tanzania: Health and nutrition implications on pastoral communities of Mvomero and Handeni districts, Tanzania. *Global Food Security*, *29*, 100516. https://doi.org/10.1016/J.GFS.2021.100516

Robelin, J., & Geay, Y. (1984). Body composition of cattle as affected by physiological status, breed, sex and diet. In F. M. C. Gilchrist & R. I. Mackie (Eds.), *Herbivore Nutrition in the Subtropics and Tropics.* (pp. 525–548). Science Press.

Ruvuga, P. R., Wredle, E., Fupi, G. F., Augustino, C., Kasiba, B. R., Selemani, I. S., & Kronqvist, C. (2022). Dry matter intake , dry matter digestibility and growth performance in goats fed grass-based diet (Brachiaria or Cenchrus) compared with a concentrate-based diet. *African Journal of Agricultural Research*, *18*(1), 52–57. https://doi.org/10.5897/ AJAR2021.15785

Ruvuga, P. R., Wredle, E., Mwakaje, A., Selemani, I. S., Sangeda, A. Z., Nyberg, G., & Kronqvist, C. (2020). Indigenous Rangeland and Livestock Management Among Pastoralists and Agro-pastoralists in Miombo Woodlands, Eastern Tanzania. *Rangeland Ecology and Management*, *73*(2), 313–320. https://doi.org/10.1016/j.rama.2019.11.005

Ruvuga, P. R., Wredle, E., Nyberg, G., Hussein, R. A., Masao, C. A., Selemani, I. S., Sangeda, A. Z., & Kronqvist, C. (2021). Evaluation of rangeland condition in miombo woodlands in eastern Tanzania in relation to season and distance from settlements. *Journal of Environmental Management*, *290*, 112635. https://doi.org/10.1016/j.jenvman.2021.112635

Saeed, O. A., Sazili, A. Q., Akit, H., Alimon, A. R., & Samsudin, A. A. B. (2018). Effect of corn supplementation on purine derivatives and rumen fermentation in sheep fed PKC and urea-treated rice straw. *Tropical Animal Health and Production*, *50*, 1859–1864. https://doi.org/https://doi.org/10.1007/s11250-018-1636-1

Safari, J. G., Mushi, D. E., Mtenga, L. A., Kifaro, G. C., & Eik, L. O. (2011). Growth, carcass yield and meat quality attributes of Red Maasai sheep fed wheat straw-based diets. *Tropical Animal Health and Production*, *43*, 89–97. https://doi.org/10.1007/s11250-010-9658-3

Safari, J., Mushi, D. E., Kifaro, G. C., Mtenga, L. A., & Eik, L. O. (2011). Seasonal variation in chemical composition of native forages, grazing behaviour and some blood metabolites of Small East African goats in a semi-arid area of Tanzania. *Animal Feed Science and Technology*, *164*(1–2), 62–70. https://doi.org/10.1016/j.anifeedsci.2010.12.004

Safari, J., Mushi, D. E., Mtenga, L. A., Kifaro, G. C., & Eik, L. O. (2009). Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished Small East African goats. *Livestock Science*, *125*, 266–274. https://doi.org/10.1016/j.livsci.2009.05.007

Safari, J., Singu, I., Masanyiwa, Z., & Hyandye, C. (2019). Social perception and determinants of Ngitili system adoption for forage and land conservation in Maswa district, Tanzania. *Journal of Environmental Management*, *250*, 109498. https://doi.org/10.1016/j.jenvman.2019.109498

Sala, S. M., Otieno, D. J., Nzuma, J., & Mureithi, S. M. (2020). Determinants of pastoralists' participation in commercial fodder markets for livelihood resilience in drylands of northern Kenya: Case of Isiolo. *Pastoralism*, *10*(1), 18. https://doi.org/10.1186/s13570-020-00166-1

Sangeda, A. Z., & Maleko, D. D. (2018). Rangeland condition and livestock carrying capacity under the traditional rotational grazing system in northern Tanzania. *Livestock Research* *for Rural Development*, *30*(5), 79. http://www.lrrd.org/lrrd30/5/sange30079.html

Sarkar, S., Skalicky, M., Hossain, A., Brestic, M., Saha, S., Garai, S., Ray, K., & Brahmachari, K. (2020). Management of crop residues for improving input use efficiency and agricultural sustainability. *Sustainability (Switzerland)*, *12*(23), 1–24. https://doi.org/10.3390/su12239808

Selemani, I., Eik, L. O., Holand, Ø., Ådnøy, T., Mtengeti, E., & Mushi, D. (2013). Variation in quantity and quality of native forages and grazing behavior of cattle and goats in Tanzania. *Livestock Science*, *157*(1), 173–183. https://doi.org/10.1016/j.livsci.2013.08.002

Selemani, I. S. (2020). Indigenous knowledge and rangelands' biodiversity conservation in Tanzania: success and failure. *Biodiversity and Conservation*, *29*, 3863–3876. https://doi.org/10.1007/s10531-020-02060-z

Seymour, C. L., Milton, S. J., Joseph, G. S., Dean, W. R. J., Ditlhobolo, T., & Cumming, G. S. (2010). Twenty years of rest returns grazing potential, but not palatable plant diversity, to Karoo rangeland, South Africa. *Journal of Applied Ecology*, *47*(4), 859–867. https://doi.org/10.1111/j.1365-2664.2010.01833.x

Shahrai, N. N., Babji, A. S., Maskat, M. Y., Razali, A. F., & Yusop, S. M. (2020). Effects of marbling on physical and sensory characteristics of ribeye steaks from four different cattle breeds. *Animal Bioscience*, *34*(5), 904–913. https://doi.org/10.5713/AJAS.20.0201

Shija, D. S., Mtenga, L. A., Kimambo, A. E., Laswai, G. H., Mushi, D. E., Mgheni, D. M., Mwilawa, A. J., Shirima, E. J. M., & Safari, J. G. (2013). Chemical composition and meat quality attributes of indigenous sheep and goats from traditional production system in Tanzania. *Asian-Australalasian Journal of Animal Sciences*, *26*(2), 295–302. https://doi.org/10.5713/ajas.2012.12432

Shirima, E. J. M., Nsiima, L. M. P., Mwilawa, A. J., Temu, J., Michael, S., Silva Mlau, D. D., & Polidori, P. (2016). Evaluation of Slaughter and Carcass Characteristics from Indigenous Beef Cattle in Six Abattoirs of Tanzania. *Journal of Scientific Research and Reports*, *10*(2), 1–8. https://doi.org/10.9734/JSRR/2016/22397

Simões, J. A., Mira, J. F. F., Lemos, J. P. C., & Mendes, I. A. (2005). Dressing percentage and its relationship with some components of the fifth quarter in Portuguese cattle breeds. *Livestock Production Science*, *96*(2–3), 157–163. https://doi.org/10.1016/j.livprodsci.2005.01.016

Solomon, T. B., Snyman, H. A., & Smit, G. N. (2007). Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management*, *82*(4), 481–494. https://doi.org/10.1016/J.JENVMAN.2006.01.008

Soulat, J., Monteils, V., & Picard, B. (2022). Effects of Rearing Management Applied throughout the Charolais Young Bulls' Life on Carcass and Meat Quality. *Foods*, *11*, 2878. https://doi.org/10.3390/FOODS11182878

Stergiadis, S., Zou, C., Chen, X., Allen, M., Wills, D., & Yan, T. (2016). Equations to predict methane emissions from cows fed at maintenance energy level in pasture-based systems. *Agriculture, Ecosystems & Environment*, *220*, 8–20. https://doi.org/10.1016/J.AGEE.2015.12.023

Subudhi, H. N., Prasad, K. V. S. V, Ch, R., Rameswar, P. S., Pathak, H., Ravi, D., Khan, A. A., Padmakumar, V., Blümmel, M., & Rice, N. (2020). Genetic variation for grain yield , straw yield and straw quality traits in 132 diverse rice varieties released for different ecologies such as upland , lowland , irrigated and salinity prone areas in India. *Field Crops Research*, *245*, 107626. https://doi.org/10.1016/j.fcr.2019.107626

Teague, R., & Barnes, M. (2017). Grazing management that regenerates ecosystem function and grazingland livelihoods. *African Journal of Range & Forage Science*, *34*(2), 77–86. https://doi.org/10.2989/10220119.2017.1334706

Tefera, S., Snyman, H. A., & Smit, G. N. (2007). Rangeland dynamics in southern Ethiopia: (1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management*, *85*(2), 429–442. https://doi.org/10.1016/j.jenvman.2006.10.007

Treydte, A. C., Schmiedgen, A., Berhane, G., & Tarekegn, K. D. (2017). Rangeland forage availability and management in times of drought – A case study of pastoralists in Afar, Ethiopia. *Journal of Arid Environments*, *139*, 67–75. https://doi.org/10.1016/J.JARIDENV.2016.12.014

Truebswasser, U., & Flintan, F. (2018). Extensive (pastoralist) cattle contributions to food and nutrition security. In *Encyclopedia of Food Security and Sustainability* (pp. 310–316). https://doi.org/10.1016/B978-0-08-100596-5.21529-1

Trujillo, A. I., Marichal, M. D. J., & Carriquiry, M. (2010). Comparison of dry matter and neutral detergent fibre degradation of fibrous feedstuffs as determined with in situ and in vitro gravimetric procedures. *Animal Feed Science and Technology*, *161*(1–2), 49–57. https://doi.org/10.1016/j.anifeedsci.2010.08.001

URT. (2022). *Minister budget speech 2022/2023*.

Vadiveloo, J., & Fadel, J. G. (2009). The response of rice straw varieties to urea treatment. *Animal Feed Science and Technology*, *151*, 291–298. https://doi.org/10.1016/j.anifeedsci.2009.03.003

Verdoodt, A., Mureithi, S. M., & Van Ranst, E. (2010). Impacts of management and enclosure age on recovery of the herbaceous rangeland vegetation in semi-arid Kenya. *Journal of Arid Environments*, *74*(9), 1066–1073. https://doi.org/10.1016/j.jaridenv.2010.03.007

Viljoen, H. F., De Kock, H. L., & Webb, E. C. (2002). Consumer acceptability of dark, firm and dry (DFD) and normal pH beef steaks. *Meat Science*, *61*(2), 181–185. https://doi.org/10.1016/S0309-1740(01)00183-8

Wainaina, P., Minang, P. A., Nzyoka, J., Duguma, L., Temu, E., & Manda, L. (2021). Incentives for landscape restoration: Lessons from Shinyanga, Tanzania. *Journal of Environmental Management*, *280*, 111831. https://doi.org/10.1016/j.jenvman.2020.111831

Wanapat, M., Polyorach, S., Boonnop, K., Mapato, C., & Cherdthong, A. (2009). Effects of treating rice straw with urea or urea and calcium hydroxide upon intake , digestibility, rumen fermentation and milk yield of dairy cows. *Livestock Science*, *125*(2–3), 238–243. https://doi.org/10.1016/j.livsci.2009.05.001

Watanabe, G., Motoyama, M., Nakajima, I., & Sasaki, K. (2018). Relationship between water-holding capacity and intramuscular fat content in Japanese commercial pork loin.

Asian-Australas J Anim Sci, *31*(6), 914–918.
Wei, M., Chen, L., Lian, X. M., Chen, Z. Q., & Yan, P. S. (2018). Energy and protein requirements for maintenance of Southern Yellow cattle fed a corn silage or straw-based diet. *Livestock Science*, *207*, 75–82. https://doi.org/10.1016/j.livsci.2017.09.002
Woodhouse, E., & Mccabe, J. T. (2018). Well-being and conservation : diversity and change in visions of a good life among the Maasai of northern Tanzania. *Ecology and Society*, *23*(1), 43. https://doi.org/https://doi.org/10.5751/ES-09986-230143
Yaro, M., Munyard, K. A., Stear, M. J., & Groth, D. M. (2016). Combatting African Animal Trypanosomiasis (AAT) in livestock: The potential role of trypanotolerance. *Veterinary Parasitology*, *225*, 43–52. https://doi.org/10.1016/J.VETPAR.2016.05.003