EVALUATING GROWTH PERFORMANCE OF F2 NGUNI X ANGUS CATTLE UNDER THE TRADITIONAL FEEDLOT AND GROWSAFE SYSTEMS.

by

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DECLARATION

“I declare that the dissertation, which I hereby submitted for the degree Master of Agricultural Sciences (MAgricSci): Animal Science at the Tshwane University of Technology, is my own work, and has not previously been submitted to any tertiary institution of higher education and training. I further declare that all sources cited or quoted are indicated and acknowledged by means of a comprehensive list of references”.

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DEDICATION

This dissertation is dedicated to my mother (Sphiwe Mamba) who is my prayer warrior, my dad (Sipho Mncina) who is my hero and my two children Mkhuseleni and Akhuselwe and to my whole family, for their unconditional love.

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ABSTRACT

Growth performance is a characteristic of relevant economic importance in beef cattle production system. The primary objective of this study was to compare growth performance of F2 Nguni X Angus animals collected with the traditional feedlot and GrowSafe systems and to analyse animal behaviour in the GrowSafe system. Nighty eight (98) F2 Nguni X Angus animals were used for the study, where 48 animals were used under the traditional feedlot and 50 animals under the GrowSafe system. The animals were individually fed a feedlot diet for 90 days. Feed intake was measured daily, and animal weights were measured weekly in both systems. Under the GrowSafe system, feed intake was measured in real time. Traits analysed for both systems were daily feed intake (DFI), average daily gain (ADG), and feed conversion ratio (FCR). For the GrowSafe system, the behavioural traits were meal frequency (MF), eating rate (ER), meal size (MS), meal duration (MD), meal size per body weight (MPW) and per metabolic body weight (MPMW). The analyses for the GrowSafe system consisted of fitting day of feed, mealtime, and sex as fixed effects in Proc GLM of SAS (SAS, 2012).

Feeding system of the animal affected growth performance, with animals in the GrowSafe performing more efficiently than those in the traditional feedlot. There were significant differences ($P<0.05$) between the GrowSafe and traditional feedlot feeding systems for all the traits analysed. The feedlot system had a higher (1.51 ± 0.05 kg) ADG than the GrowSafe system (1.30 ± 0.06 kg). The animals in the GrowSafe system however consumed more feed (8.99 ± 0.25 kg) than their traditional feedlot counterparts (7.92 ± 0.19 kg). Sex also significantly affected ($P<0.05$) all the traits included in the analysis.

Females had 14 more meals than males; however, these females had 0.73 sec shorter MD and 0.08 g smaller MS compared to their male counterparts. Higher MF for animals in the GrowSafe system occurred 8:00AM and 18:00PM, and the highest for males and females were 7 900 and 12 194 visits, respectively. Eating rate followed a similar trend, with males and females recording respective highest values of 28.56 and 65.02 g/sec. During the same periods, MS and MD exhibited opposite trends with lowest values of 191.40 g and 57.52 sec, respectively for males observed. This may be attributed to the effects of heat stress; hence animals may eat more and spent more time eating when it is cooler at night. The respective lowest values for females were 135.16 g and 36.38 sec. The feeding behaviours of the GrowSafe animals may be used to design feeding strategies for feedlot animals.

Keywords: F2 Nguni X Angus, Growsafe, feeding behavior, growth performance, traditional feedlot.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ARC	Agricultural Research Council
TUT	Tshwane University of Technology
rfid	Radio Frequency Identification Device
rfi	Residual Feed Intake
RADG	Residual Average Daily Gain
ADG	Average Daily Gain
BW	Birth Weight
FCR	Feed Conversion ratio
DMI	Dry Matter Intake
ADI	Average Daily Feed intake
STWT	Start Weight
MF	Meal Frequency
BV	Bunk Visit
ER	Eating Rate
MS	Meal size
MD	Meal Duration
MPW	Meal Size Per Weight
MPMW	Meal Size Per Metabolic Weight
TMD	Total Meal Duration
TDI	Total Daily In

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background

Growth performance is a trait of relevant economic importance in beef cattle production system. Crossbreeding with small framed indigenous cows may succeed in improving output from beef cattle farming where managerial skills are better, but conditions are often harsh and poor pastures exists (Calegare *et al*., 2007). Any system producing large feeder offspring for slaughter from smaller breeding dams will be more efficient than one with feeders and breeders of equal weight, merely because small dams eat less than large dams (MacNeil *et al*., 1993). Furthermore, Theunissen *et al*., (2018) demonstrated that effective crossbreeding system, utilizing F1 cows mated to a terminal sire breed, could provide a notable 49.7% increase in beef production efficiency.

Post weaning growth performance is an important trait in all beef production systems, as farmers are paid per unit of animals marketed. Thus, beef production systems should aim to improve both traits to increase productivity. The indigenous Nguni cattle are well adapted to the South African tropical environment and has excellent immunity to ticks and tick-borne diseases (TTBDs) compared to exotic breeds (Muchenje *et al*., 2008; Marufu *et al*., 2010; Marufu *et al*., 2011) even though they have slow growth. The Angus on the other hand, is susceptible to diseases (Muchenje *et al*., 2008) and has excellent post-weaning growth performance (Muchenje *et al*., 2008). This provides an opportunity to produce animals with desirable growth and meat quality as well as good immunity against diseases and parasites and adapted to the local environment, through crossbreeding these breeds.

The Agricultural Research council (ARC) has produced a crossbred herd by crossing the Nguni with the Angus, which has been in existence since 2013. The crossbred animals were reared under two feeding systems, which are the traditional feedlot and the more advanced GrowSafe system. In the traditional feedlot feeding system, the animals are placed in separate pens, where each animal has its own feed *adlib tum*. Each animal being fed according to appetite and feed being measured before given to animals to calculate feed intake and feed conversion ratio at the end of the trial. The GrowSafe system is an electronic monitoring system using radio frequency technology (GrowSafe Systems Ltd. Airdrie, AB) enables documentation of bunk attendance patterns by individual cattle in large groups in settings typical of commercial production. All animals have bar code on a transponder on their necks which records in the computer whenever the animal is feeding or drinking under *adlib tum*. At the end of the trial, all animal recordings were on a computer displaying feed intake.

The system provides detail and is less labor intensive than visual observation or other methods of bunk monitoring. Using the GrowSafe system, researchers can track the number of visits by an animal to the feed bunk each day, the location along the bunk selected by the animal, and the length of time the animal remains at the bunk. This versatility allows the system to monitor feeding behavior by cattle fed total mixed rations and enables numerous diets to be evaluated simultaneously along the length of the bunk. Installation of the system near the water trough can provide similar information on the watering behavior of feedlot cattle. The GrowSafe system can be employed in commercial feedlots with no modification to existing feeding or watering practices. Because the GrowSafe system will detect the presence or absence of an animal in the reader range, its placement in the feed bunk enables determination of feeding duration, frequency and total feeding events.

Although these systems were successfully used at the ARC to finish the Nguni X Angus animals, information is lacking on how the animals perform under these feeding systems. There is need to evaluate the growth performance and behavior of animals kept under these systems.

1.2 Problem Statement

The crossbred F2 Nguni X Angus animals have only been evaluated under the traditional feedlot system. Although this provides an insight on how the crossbred animals perform, more information can be collected to provide an in-depth understanding of their feeding and watering habits or behaviour. The GrowSafe system is the advanced feeding and monitoring system that collects information every time the animal visits the feed or water trough. There has not been a comparison in this breed of these two distinct feeding systems. Comparing the systems will provide an indication of how close the estimated feed intake of the traditional feedlot is to the automated feeding records. In addition, information on the behaviour of animals, such as, frequency of visits to the feed or water troughs, amount of feed consumed per visit, amount of water taken in per visit is not available. Such information is made available by the GrowSafe system.

1.3 Justification

Production costs for beef production systems are high because of high costs of cattle management through disease managements and animal poor performance. These costs need to be reduced, while simultaneously increasing income through higher yield from post-weaning growth. Therefore, there is a need to combine good adaptability to any environment or feeding system and post-weaning growth performance into a single breed, on which selection programs can be applied. The indigenous Nguni breed is resistant to diseases and can adapt to any environment, while it has poor post-weaning growth performance. Although, the Angus has excellent post-weaning growth performance, it is less susceptible to diseases compared to the Nguni. The Agricultural Research Council (ARC) crossbred these two breeds with the aim of lowering production costs and increasing yield in beef production systems.

Two systems are available for finishing animals before slaughter, and these are the traditional feedlot and the more advanced GrowSafe system. However, information is lacking on how the animals perform under these feeding systems. There is therefore a need to evaluate the growth performance and behaviour of animals kept under these systems.

1.4 Aim and Objectives

The aim of the study was to evaluate growth performance and animal behaviour of F2 Nguni x Angus crosses finished in the traditional feedlot and GrowSafe systems:

The specific objectives of the study:

- To compare growth performance of F2 Nguni X Angus animals collected under the traditional feedlot and GrowSafe systems;
    - To analyse animal behaviour in the GrowSafe system during their finishing in the GrowSafe system.

1.5 Hypotheses

- There is no difference in growth performance of F2 Nguni X Angus animals finished using traditional feedlot or GrowSafe system.

- The F2 Nguni X Angus animals have no particular behaviour during their finishing in the GrowSafe system.

1.6. RESEARCH OUTPUTS AND CONFERENCE CONTRIBUTIONS

1.6.1. CONFERENCE PROCEEDINGS

I. Mncina, S., Dube, B., Mtileni, B.J., Mapholi, N.O. 2021. Non-Genetic Factors Affecting Growth and Slaughter Traits in F2 Nguni X Angus Cattle. 52nd South African Society of Animal Science Congress.

CHAPTER 2: LITERATURE REVIEW

2.1 BACKGROUND

The global human population has been predicted to increase by 72% by the year 2050 (De Castro, 1997). While urbanisation increases, the demand for animal protein in the growing markets including South Africa is equally escalating beyond the livestock producers' supply capacity (Scholtz & Theunissen, 2010). Growth performance is a characteristic of relevant economic importance in beef cattle production system. This reduced productivity by beef farmers results in lower profits. The main aim of beef production is to increase the profitability of the enterprise, which depends on various factors that affect it. This can be achieved by lowering production costs or increasing product yield and quality or both (Calegare *et al*., 2007).

Any system producing large feeder offspring for slaughter from smaller breeding dams will be more efficient than one with feeders and breeders of equal weight, merely because small dams eat less than large dams (MacNeil *et al*., 1993). Furthermore, Theunissen *et al*. (2018) demonstrated that effective crossbreeding system, utilizing F1 cows mated to a terminal sire breed, could provide a notable 49.7% increase in beef production efficiency.

Post weaning growth performance is an important trait in all beef production systems, as farmers are paid per unit of animals marketed. Thus, beef production systems should aim to improve both traits to increase productivity. The indigenous Nguni cattle are well adapted to the South African tropical environment and has excellent immunity to TTBDs compared to exotic breeds (Muchenje *et al*., 2008; Marufu *et al*., 2010; Marufu *et al*., 2011) even though they have slow growth. The Angus on the other hand, is susceptible to diseases (Muchenje *et al*., 2008) and has excellent post-weaning growth performance (Muchenje *et al*., 2008). This provides an opportunity to improve the Nguni breed as it has poor post weaning growth. Crossbreeding the Nguni that has good adaptability in any environment and good immunity with the susceptibility to diseases and good post weaning and good meat quality of the Angus provides an opportunity to combine the good adaptability of the Nguni and post-weaning growth performance and good meat quality of the Angus.

2.2. CROSSBREEDING

There is no pure breed of cattle that is outstanding or that can adapt in all environments (Burrow 2006; Anderson; 2009). There is a need for farmers to optimize or reduce economic important traits at a reduced cost of production and that is where crossbreeding step in, where selection is key. Selection is an important tool with traits of moderate to high heritability, such as tick resistance, meat quality or growth performances. Crossbreeding makes it possible to combine desirable characteristics and good adaptations requirements (Kress and McNeil, 1999).

Crossbreeding indigenous cattle may help improve the output from beef cattle industry where management can be better even when conditions are harsh with poor pastures (Calegare *et al.*, 2007). The only feasible production strategy that can be developed in harsh conditions and climate stressing areas are indigenous breeds and crossbreeds. The level of management and nutrition in most of the areas are not sufficient to meet the higher demands of exotic breeds or their crossbreds line (Scholtz and Theunissen, 2016b). Theunissen *et al*., (2018) reported that effective crossbreeding systems, utilizing cows mated to a terminal sire breed, could provide a notable 49.7% increase in beef production efficiency.

The most popular breed types in the emerging and communal sectors are Nguni (35%), Brahman (32%), Bonsmara (17%) and the Afrikaner (8%) (Scholtz *et al.*, 2008). This is mainly due to the ease of management, adaptability and resistance. The good feedlot performance of the F1 crosses of indigenous African breeds such as the Nguni and the Afrikaner in terminal crossbreeding systems, seem to make them ideal suited as dam line (Scholtz and Theunissen, 2016b). The use of indigenous and adapted genotypes as dam lines facilitates the matching of genotypes to production environment.

Bourdon (1997) and Scholtz *et al.* (2013) described that crossbreeding to exploit heterosis under harsh environment is often used in countering genotype X environmental interaction, and heterosis is generally larger under severe environments. Thus, crossbreeding results in increased productivity because ticks and tick-borne diseases can be reduced while having better performances under improvement. Resiling of indigenous and adapted breeds may provide for adaptation to future environmental changes at less cost than mitigation of the environmental effects through managerial interventions.

2.2.1 HETEROSIS

Heterosis can be explained as the level of superior performance of the crossbred, relative to the average of the purebreds involved in the cross. Where genes interact at individual loci from different breed's heterotic will occur (Weaber, 2015). In example, the F2 Nguni X Angus crossbred may have a better growth performance, meat quality and tick resistance than the Angus or Nguni purebred calves. The crossbred may be superior to the average of the pure breeds for both traits. Heterosis generated through crossbreeding may significantly improve an animal's performance in one generation.

About 66% of the economic benefit of crossbreeding to commercial producers comes from having crossbreds' cows (Weaber, 2015). The main purpose of crossbreeding in beef cattle is to utilize heterosis in the different characteristics for which the genotypes were previously selected. However, to fully utilize the effectiveness of heterosis, the genetic merit of parents' breeds is important (Garrick, 2006). Superior traits of different breeds combined during the designation of crossbreeding is advantageous (Khorshidi *et al.,* 2017).

Scholtz *et al*. (1990) and Scholtz and Theunissen (2010b) reported that in most cases maternal breeds (maternal traits like, fertility, calving easy, milk production, efficiency and mothering ability) are crossed bred with paternal breeds (paternal traits such as, growth and efficiency and meat quality and carcass yield). Important things to consider during the crossbreeding system is the amount of heterosis expressed by the progeny (individual heterosis) and heterosis expressed by the dam (maternal heterosis), as well as possible breed complementarity. Maximum individual heterosis will be seen in the system if the breeds of sire and dams are unrelated.

2.2.2 HERITABILITY

Heritability explains how additive genetic variance is associated with observed differences between individuals (Adnan *et al.,* 2010). It can be defined as the correlation of measurements carried out over time or space on the same animal (Lush, 1937). On a scale of 0 to 1, the heritability used to describe the amount of total phenotypic variation in a trait that is due to the (additive) genetic variation in individuals. The phenotype influenced by the animal's genotype, which in turn consists partly of additional genetic effects, including direct and maternal genetic effects (Gullstrand, 2017).

2.3 FUTURE USE OF INDIGENOUS BREEDS IN LIVESTOCK PRODUCTION

The use of indigenous breeds in livestock production is a consideration which should be included in future research, which not only emphasise on the profit yields or general capital gained but also on not neglecting the relation between traits such as reproductive efficiency, health and high environmental adaptability (Assan, 2013).

The Nguni cattle is the outstanding breed with good adaptation to harsh conditions and it is naturally resistant to ticks (Marufu *et al*., 2011). The Angus cattle are exotic to South Africa, and they are susceptible to tick infections, but they have excellent growth and good meat quality characteristics. However, the combination or the cross breeding of the Angus and the Nguni can im prove beef production as composed with tick-infested production. The target is to get an offspring that has good characteristics from both.

2.3.1 BEEF BREEDS

In terms of the Animal Improvement Act (Act No 62 of 1998), there are 34 recognized beef breeds in South Africa. One of these breeds is the Nguni which have been declared as indigenous or locally developed and referred to as Sanga breeds. Makina *et al*. (2017) recently confirmed the lack of *B. indicus* influence in the modern-day Afrikaner and Nguni. Thus, these breeds can be described as taurine tropical adapted breeds,which make them unique.

I. NGUNI

The Sanga cattle originally found along the east coast of Southern Africa are known as the Nguni, and they were found wherever the original African Nguni tribes settled (Swaziland, Zululand, Mozambique, Zimbabwe) during their migration to Southern Africa between 600 and1400 AD (Scholtz, 2010a). Since then, these animals have played an important social and economic role in the country's development. Nguni cattle are known for their fertility, resistance to diseases, and adaptability to punitive climates (Scholtz, 2010a). It can be noted that less than 20% of registered Nguni cattle are subjected to performance recording.

II. ANGUS

Angus or Aberdeen Angus are commonly used in beef production, particularly in North America. They were developed from cattle native to the counties of Aberdeenshire and Angusin Scotland (Encyclopædia Britannica 15th Ed. Vol.10 p.1280). Considering cow weight and efficiency (weaning weight as a percentage of cow weight), Angus cows have increased in weight but have become more efficient. They are also known for maintaining birth weight below the South African national average (34.1kgs). The Angus is the most numerous beef breed in the world and the most numerous British breed in South Africa (Scholtz, 2010a).

2.4 BACKGROUND OF THE GROWSAFE® SYSTEM

The GrowSafe® system is a feed intake acquisition technology that has been previously evaluated for monitoring feeding behaviour in beef cattle (Mendes *et al*., (2011). The system also measures individual average daily gains (ADG), feed and water intake and behaviour of animal in different climatic condition all in real time together with partial body weight every time when an animal is at the water or feeding trough (Huisma *et al*., 2005). The development of electronic radio frequency identification device (RFID) system has enabled researchers and producers to monitor their beef cattle in their typical feedlot environment, without disruption to normal animal behaviour in order to determine, analyse, model and predict different conditions relating to animal health, production, efficiency and quality (Huisma *et al*., (2005).

The GrowSafe® system is traditionally used to quantify intake in cattle so that it may offer more effective and more accurate means of measuring exact consumption and can be applied in-group pens (Dickson *et al*., 2018). The GrowSafe® feed intake system consists of a feeding trough equipped with load bars to measure feed disappearance on a per second time frame and an antenna located within each feed trough to record animal presence through the detection of electronic identification tag (Dickson *et al*., 2018). The system provides details and is less labour intensive than the visual observation methods, which is the traditional feedlot system (McAllister *et al*., 2000). Using this system researcher can track the number of visits by an animal to the feeding trough each day.

2.5 TRADITIONAL FEEDING SYSTEM

In the traditional feedlot feeding system, the animals are placed in separate pens, where each animal has its own feed *adlib tum*. Each animal being fed according to appetite and feed being measured before given to animals to calculate feed intake and feed conversion ratio at the end of the trial. It is labour intensive and animal behaviour is seen through animal observations.

2.6 FACTORS INFLUENCING COW PERFORMANCE AND FEED INTAKE

Cow performance and intake may be affected by the weaning system, residual feed intake (RFI), and residual average daily gain (RADG). Providing feed to animals is a major cost of beef production. Miller *et al*. (2001) stated that feed costs represent over 60% of the total costs in a beef operation.

2.6.1 Feed efficiency

With input costs constantly on the rise, it is becoming over more important for beef producers to be able to get the maximum amount of performance out of their cows with fewer inputs; therefore, being more efficient. Feed costs represent the greatest operating cost for cow-calf producers; accounting for over 60% of the variation in total annual cow costs (Miller *et al.,* 2001). If feed consumption can be decreased without affecting animal production, then there can be an increase in profitability. Feed efficiency can be described in several ways, making feed conversion ratio (FCR) the most common method used. FCR being defined as the ratio between production outputs and feed inputs (Archer *et al.,* 1999). Brelin and Brannang (1982) showed strong correlations (-0.61 to -0.95) between an animal's growth rate and the feed conversion ratio.

This selection for efficiency can be effective in a finishing setting, where maximum growth and large size are desirable. Increased mature cow size could lead to higher feed requirements with a high cost of production (Spies, 2011). Partial efficiency of growth is another, yet less common way to measure efficiency. One of the newer forms of measuring feed efficiency is residual average daily gain (RADG). RADG is defined as the difference between actual weight gain and the gain predicted based on DMI, body weight and fat cover. A regression equation is used to determine the animals predicted ADG, which is then subtracted from the actual ADG resulting in the RADG (www.angus.org). The average animal has a RADG value of zero. Animals having a more positive or higher RADG value would be more desirable. These values can only be compared from animal to animal with the same weaning contemporary group or on the same feed test. RADG has similar issues for the cow-calf producer as gross efficiency because selection of RADG results in heavier cows with higher nutrient requirements.

2.6.2 Body weight (BW)

Body weight change evaluate growth (Otto *et al*., 1992). One of the most important traits in beef production is weaning weight. The weight of the calf is also an indication of cow efficiency (Maree and Casey, 1993). According to the BCRC (2016) the feed to gain ratio (F: G) is a measure of an animal's efficiency in converting feed nutrients into increased body weight. This ratio is one of the most important variables in animal finishing.

2.6.3 Feeding days

Feeding days refer to the number of days the animal remains on feed to achieve the desired slaughter weight (Spies, 2011). According to Oosthuizen (2016), frame size has a big influence on the feeding period. Larger-frame cattle benefit from an early feedlot entry, while the smaller frame cattle benefit from being grown on pastures before entering the feedlot, which is beneficial to feedlot profitability.

2.6.4 Average daily gain (ADG)

Average daily gain weight refers to the average daily live weight gained during the feeding period. The ADG can be influenced by the quality of the feed ration and the quality of the animal on feed (Spies, 2011). Different breeds have different growth rates and can be classified as late-, medium-, or early maturing cattle that have to be managed according to their genetic potential. Breeds have different growth potentials and have to be managed according to their genetic potential (Oosthuizen, 2016). The ADG can be used as an appropriate guideline, because it affects the costs directly through the days fed in the feedlot and the relationship with carcass gain.

2.6.5 Feed conversion ratio (FCR)

Feed conversion ratio is the measure of efficiency with which livestock convert animal feed into body weight. It is possible to lower the costs of production if there is an improvement in the FCR (Maasz, 2006). FCR is defined as the amount of feed needed to add a kilogram of live weight. This may vary depending on the quality of the animal as well as between breeds, weather conditions (ADG declines in colder, wet weather) and stress levels in the feedlot (Spies, 2011). The feeding diet and its quality fed to an animals have an influence on the FCR.

The feed intake and feed conversion also differ from breed to breed. Whenever poor quality feed is given to animal, the FCR will be automatically poor, because the animals will need more feed to gain weight (Oosthuizen, 2016). The FCR benchmark range for beef cattle in South Africa is between 5.5:1 and 7:1 kilogram feed per kilogram of live weight gained (Oosthuizen 2016). If the feed intake of animals is known, it can be used in relation to measure growth to determine the feed conversion ratio of those animals.

As feed efficiency is important to improve profitability, the feed efficiency in young animals may differ from the efficiency of older. Feed efficiency can be heritable and genetic improvement being possible (Robinson and Oddy, 2004).

2.6.6 Feedlot finishing

Feedlot finishing of Brahman crossbred cattle in subtropical environments has been shown to improve carcass and meat quality attributes, including objective and sensory tenderness, and decrease age at slaughter by 7 months relative to pasture finishing (Schutt *et al*., 2009a, 2009b). There are variations in feed efficiency potentially that represent an opportunity for beef producers to significantly reduce production costs by reducing feed intake while maintaining growth rate. However, RFI has been reported to have high genetic correlations with rump and rib fat and intramuscular fat percentage (0.72, 0.48 and 0.22 adjusted for age; Robinson and Oddy 2004).

Therefore, selection of breeds or sires within breed for lower RFI may lead to a consequent decrease in carcass fatness, which may also have implications for female fertility (review by Pitchford 2000). Further, selection for RFI may produce changes in the calpain system, which may consequently affect meat tenderness (McDonagh *et al*. 2001). Other studies report only small positive correlations between RFI or feed conversion ratio (FCR) and fatness (Arthur *et al*. 2001). Though antagonistic correlations between slaughter and breeding herds may be overcome through use of economic selection indices, development of feed efficiency estimated breeding values (EBV) is still in its early stages and measurement of individual feed intake remains expensive. Hence, selection of breeds that have high feed efficiency (low RFI) for the same level of gain as low efficiency breeds, coupled with crossbreeding, may overcome some of the problems associated with within-breed selection.

2.7 GROWTH PERFORMANCE

Growth performance is a characteristic of related economic importance in beef cattle production system (Enrico S *et al.,* (2005) that must improve in the agricultural industry Table 2.1 Presents descriptive statistics for growth performance for each genotype. Charolais was the most widespread genotype, whereas French Crossbred and Polish Friesian genotypes had the lowest number of batches farmed. Average weight at the arrival ranged from 283 (Polish Friesian) to 385 kg (Charolais) with a moderate variability between batches of the same genotype. Charolais and French Crossbred showed the highest values of final average weight, where Charolais Female were lighter than the other genotypes. Average Daily Gain presented the same trend, with higher values for Charolais and French Crossbred and lower values for Charolais Female.

Table 2.1 Descriptive statistics for growth performance for each genotype

Genotype	N. batches	Average weight at Arrival (kg/)		Final average weight (kg)		Average daily gain (kg/d)	
		MEAN	SD	MEAN	SD	MEAN	SD
Charolais	253	385.1	48.4	675.4	30.6	1.37	0.10
Charolais Female	109	303.1	29.1	494.1	23.6	0.95	0.08
French Crossbred	43	374.1	37.3	646.3	26.6	1.28	0.10
Limousin	153	305.4	39.3	580.0	32.9	1.20	0.09
Polish Friesian	25	283.1	23.1	539.4	33.4	1.16	0.06

2.8 GROWTH RATE

Growth rate is important because of its high association with economy of gain in relation to fixed costs. Growth rate can be measured in time constant, post weaning feeding tests. A reasonably high level of feeding for at least 112 days is desirable to appraise differences in growth rate most accurately (Shike,2013). Genetic correlations among measures of growth or size at different ages usually are high. Selection for rapid rate of gain in post weaning feeding tests usually increases both birth weight and mature size. Increases in birth weight contribute to increased calving difficulty. Increased mature size decreases carcass quality when slaughtered at normal market weights and increases the nutrient requirements for maintenance of the cowherd. Ideally, the beef animal should be of moderate weight at birth, grow rapidly, but mature and finish for slaughter early. However, the selection criterion to obtain such a growth curve is complex.

2.9 FEED CONVERSION RATIO

Feed conversion ratio is an excellent measure that can be used to monitor or to describe feedlot cattle performance; however, it is not a good measure to select for. Feed conversion ratio is correlated to growth rate (Shike, 2013). Selecting for improved FCR would result in an increase in genetic merit for growth leading to an increased mature cow size, which would ultimately increase the feed costs for the cowherd.

2.10 MANAGEMENT

Management factors as well as animal performance such as ADG, feed efficiency, dressing percentage, response on growth hormones, mortality, morbidity and the feeding periods of the cattle in feedlot may have an influence on the profitability of feedlots (Oosthuizen, 2016). To save more costs in feedlots the length of stay of the animals can also be decreased (Maree and Casey, 1993), and is it therefore important to determine the correct feeding period to ensure a suitable profit margin in order to produce sustainably (Oosthuizen, 2016). It is very important that the right type of animal be bought at the right price and at the right time. It is also important that the feedlot ration must be balanced in respect of nutrient content, and must match the type of animal to be fed.

This must be the most cost-effective ration available at the time of feeding. The price paid for feedlot cattle (cost/kg) is a critical factor affecting the feedlot profitability, especially when a small or negative feed margin exists. Therefore, a positive feed margin must be realised with a high weight gain and a relatively low cost of feed (DARD, 2018). Oosthuizen (2016) stated that profit would be maximised if the value of the marginal product (value of the weight gain) equals the value of the marginal factor cost, which the feed is fed to the weaners. A positive feed margin can be influenced by the feed price and the efficiency of growth (gain/kg consumed). A positive price margin is when the price per kg body weight realised at selling is higher than the price/kg (body weight) of weaners bought (DARD, 2018).

2.11 FEEDING BEHAVIOUR EVALUATION

There are a number of feeding behaviour traits that can be evaluated including bunk visit (BV) frequency and duration, meal frequency and duration, average length and size of meals and eating rate. BV frequency (event/d) is defined as the number of visits the animal makes to the feeding bunk on a daily basis, and BV duration (min/d) is the sum of the time the animal at the feed bunk (. Some studies use the term BV to define visits to the feed bunk with or without consumption of feed, but others studies consider

BV only when the animal consumed feed (Mendes, 2010). In this study, BV will be defined as a visit to the bunk with or without consumption of feed, and feeding is defined as consumption of feed during bunk visit.

A meal is defined as a bundle of BV events, which can be differentiated from the next meal event by a non-feeding interval that exceeds a meal criterion. Meal criterion is defined as an estimate of the longest non-feeding interval that was considered to be part of a meal (Yeates *et al*., 2002).The non-feeding interval between BV varies according to the animal satiety and this variation can be used to calculate the meal criterion (Tolkamp and Kyriazakis, 1999; Yeates *et al*., 2001; Yeates *et al*., 2002). The biological basis for evaluating meal events in dairy cattle has been reviewed by Tolkamp *et al*. (2000). In dairy cattle, DeVries *et al*. (2003a) reported moderate to high respectabilities for meal-behaviour traits during early (0.34 to 0.72) and late (0.22 to 0.75) lactation.

The development of electronic radio frequency identification (RFID) systems has enabled researchers and producers to monitor individual animal intake and behaviour to more precisely evaluate feed efficiency and health status (Mendes *et al*., 2011). GrowSafe Systems is a feed intake acquisition technology that has previously been validated for monitoring feeding behaviour in beef cattle (Mendes *et al*., 2011). GrowSafe records feeding behaviour traits such as total intake, frequency and duration of feeding, and eating rate for each individual animal through the use of RFID tags that provide a continuous transmission of data to a computer located at the facility.

2.10.1 FEEDING BEHAVIOR

Repeatable feeding behaviour is possible with GrowSafe systems. One-way to evaluate feeding behaviour at the University of Illinois is with GrowSafe bunks, said

Josh McCann, (2013). A study consisted of 222 Angus cross-steers fed via GrowSafe feed intake technology was used to measure individual animal feed intake and behaviour. The bunk visit frequency, the bunk visit duration and the head down duration were more repeatable than the dry matter intake Josh McCann, (2013). The head down during the day or the amount of time an animal puts his head in the bunk was extremely repeatable and more consistent overtime than how much they consumed. As part of the behaviour, analytics package the University of Illinois uses with GrowSafe, they received individual animal performance such as intake trends, off-test dry matter intake (DMI), meal events and feeding order behaviour.

2.10.1.1 Technology used in feedlots

Ethogram of feedlot cattle behaviour used to measure the prevalence of the following behaviours through scan sampling or the frequency and duration of behaviours that occurred through continuous sampling from 08:00 to 17:30 hrs on d -2, -1, 0, 1, 2, 4, 8, 16, 32 and 64. Cattle behaviour in the pen was recorded from 08:00 to 17:30 hrs on d -2,-1, 0, 1, 2, 4, 8, 16, 32 and 64 relative to treatment implementation using a closed circuit video camera recording system. Cameras were installed to ensure no blind spots within the pen. Behavioural data was decoded from video recordings using instantaneous scan samples and continuous sampling methods (Mitlöhner *et al*., 2001). Three trained observers using the VLC Media Player (Version 3.0.1, VideoLan, France) conducted instantaneous scan sampling at 10-minute intervals. For each scan sample, the number of steers within each pen lying, eating and drinking was recorded (Table 2.2). Continuous sampling recorded the frequency and duration that each steer spent engaged in all grooming, bar licking, tongue rolling and utilizing the brush, as well as the frequency of head butting, kicking and mounting (Table 2). Twenty-three trained observers utilizing BORIS (Version 6.1.4; Friard and Gamba, 2016) collected all continuous behavioural data. Inter-observer reliability between observers and trainer, as well as among observers, was assessed prior to data collection in which all participants scored the same pen in a video and Pearson's Rho was calculated. All inter-observer reliability tests produced an R-value above 0.95, indicating excellent agreement between scorers. To continuously measure rumination and activity, individual steers were fitted with collars (All flex Livestock Intelligence, Madison, WI). These devices used sensory microphones to detect the passage of a feed bolus to quantify rumination in minutes. Activity was defined as movement or no movement.

Table 2.2. Parameters recorded in feedlot.

Behaviour	Definition
Scan feeding	
Drinking	Steer has head in water trough
Feeding	Steer has head in feeder
Lying	Steer is recumbent, not supported by legs
Other	Steer is performing other behaviour such as locomotion or standing
Continuous sampling	
Allogroom	Mouth of one steer on the body of another. Characterized by repetitive back-and-forth head movements performed by the actor in direct contact with the recipient.
Bar licking	Mouth of one steer in direct contact with bars of pen
Head butt	Head of steer connects with body of another
Kicking	Leg of steer connects with body of another
Mounting	Steer positions body on top of another subject's topline
Tongue rolling	An open mouth with extended tongue repeatedly moving in and out and/or side-to-side. Characterized by repetitive side-to-side head motion.
Utilizing brush	Any part of steer's body interacting with the brush

*2.10.**2 USE OF TECHNOLOGY FOR FEEDING BEHAVIOUR***

Feeding behaviour refers to the manner in which an animal consumes feed and can be altered depending on the production system. Feeding behaviour has been studied far less than nutrition or health, but it may play a vital role both for beef cattle and dairy cows. One reason behaviour is not studied as frequently may be the lack of quantitative data that can be obtained (Mendes,2010). Technologies such as feed intake monitoring bunks, accelerometers, and GPS collars have helped to shift the data towards quantitative numbers and away from qualitative observations. Thus, feeding behaviour research is more common and will continue to increase in popularity as more technology is used in cattle feeding operations.

2.3 CONCLUSION

Both systems, the traditional feedlot and the GrowSafe can be useful in finishing animals for slaughter. The traditional system may be cheaper, but its limitation may be that it is less accurate and there can be feed spillage. The GrowSafe system on the other hand, can be used to monitor the feeding behaviour of cattle. The GrowSafe system, used with an appropriate meal criterion, provides an accurate estimation of meal-based measures of feeding behaviour. Furthermore, this system provides a reasonable estimate of when animals are present at the feed alley. Recording errors can be reduced by carefully monitoring factors such as transponder position and the number of metallic objects within close proximity of the feeding area. Comparing the two systems may help in finding the best way to finish feedlot animals.

CHAPTER 3: MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted at the South African Agricultural Research Council-Animal Production (ARC-AP) in Irene, which is located between the old Johannesburg Road on the North, Nellmapius road on the east and Olifantsfontein road on the south. It is 25º 55’ south latitude and 28º 12’ east longitudes in Pretoria, South Africa. Taking place under the bull-testing unit.

3.2 DATA COLLECTION

The animals were placed into feedlot after a 28-day adaptation phase in both systems. Then, the animals were individually fed *ad libitum* a feedlot diet for a period of 90 days, where weighing was done once a week and feed intake was measured daily. Nighty eight (98) F2 Nguni X Angus animals were used for the study at the age of 15 months, where 48 animals were used under the traditional feedlot and 50 animals under the GrowSafe system. The parameters measured were average daily feed intake (ADI), average daily gain (ADG) and feed conversion ratio (FCR). The summary statistics of these parameters are presented in Table 3.1.

Table 3.1 Summary statistics of growth parameters for the F2 Nguni X Angus Animals under traditional feedlot and GrowSafe systems

Growth traits	Traditional feedlot				GrowSafe			
	Mean	Min	Max	SD	Mean	Min	Max	SD
ADI (kg)	7.81	4.67	10.30	1.28	8.99	4.13	13.09	2.25
ADG (g/day)	1.47	0.33	2.77	0.55	1.25	0.62	2.01	0.29
FCR	0.20	0.05	0.47	0.08	0.15	0.07	0.31	0.05
STWT (kg)	245.12	126	315	48.00	264.32	189	356	38.85

ADI = average daily feed intake; ADG = average daily gain; FCR = feed conversion ratio; STWT = start weight

Under the GrowSafe system, all animals had bar code on a transponder on their necks, which records real-time feeding and drinking data of the animal feeding. The feeding behaviour parameters recorded under this system were meal frequency (MF), eating rate (ER), meal size (MS) and meal duration (MD). To express feed consumption in relation to growth, meal size per body weight (MPW) and meal size per metabolic body weight (MPMW) were computed. Table 3.2 contains the summary statistics of these parameters.

Table 3.2 Summary statistics of feeding behavior for the F2 Nguni X Angus animals under GrowSafe system

Behaviour patterns	N	Mean	Min	Max	SD
MF	50	53.74	3	149	20.08
ER (g/sec)	50	21.60	0.01	2000	56.82
MS (g)	50	184.11	10	5330	211.28
MD (sec)	50	74.30	0	2695	136.22
MPBW (g/kg)	50	0.61	0.02	15.68	0.69
MPMW (g/kg)	50	2.53	0.10	67.02	2.86

MF – meal frequency; ER – eating rate; MS – meal size; MD – meal duration; MPBW = meal size per body weight; MPMW = meal size per metabolic body weight

3.3 DATA EDITING

Data editing was carried out using the Statistical Analysis System Software (SAS, 2012). Basic edits included removal of records of pregnant cows and sick or injured animals. Animal groups were edited according to feedlot system and the GrowSafe system.

3.4 DATA ANALYSIS

Data was analysed using Proc GLM of SAS (SAS, 2012) to test the effect of feeding system, sex, and initial weight, which was included as a covariate on growth performance of the animals studied. The analyses for the GrowSafe system consisted of fitting day of feed, mealtime, and sex as fixed effects in Proc GLM of SAS (SAS, 2012). Initial weight was fitted as a covariate and the interactions between different effects were also tested.

CHAPTER 4: RESULTS

4.1 FACTORS AFFECTING GROWTH PERFORMANCE

The Least Squares Means for feeding system on growth performance of F2 Nguni X Angus animals crosses is shown in Table 4.1. Feeding system significantly affected ADI ($P<0.001$), ADG ($P<0.01$) and FCR ($P<0.001$). Although the GrowSafe animals grew slower (1.29±0.06 g/day) than the traditional feedlot animals (1.51±0.05 g/day), GrowSafe animals were more efficient (0.16±0.01) in utilizing feed than those in the traditional feedlot system (0.20±0.01).

Table 4.1 Least Squares Means for feeding system on growth performance of F2 Nguni X Angus crosses

Growth traits	Traditional feedlot	Growsafe
ADG	$1.51^{a}\pm0.05$	$1.29^{b}\pm0.06$
ADI	$7.92^{a}\pm0.19$	$8.99^{b}\pm0.25$
FCR	$0.20^{a}\pm0.01$	$0.16^{b}\pm0.01$

Means with different superscripts within row are significantly different. ADG – average daily gain; ADI – average daily intake; FCR – feed conversion ratio

Least Square Means for sex on growth performance of F2 Nguni X Angus crosses are presented in Table 4.2. Sex significantly affected ADI ($P<0.001$), ADG ($P<0.05$) and FCR ($P<0.001$). The males grew faster at 1.58±0.06 g/day than the females, which grew at 1.2±0.05 g/day. Males were however less efficient in utilizing feed compared to the females, as shown by their respective FCR values of 0.20±0.01 and 0.15±0.01.

Table 4.2 Least Squares Means for sex on growth performance of F2 Nguni X Angus crosses

Growth performance	Female	Male
ADG	1.22^{a}±0.05	1.58^{b}±0.06
ADI	8.14^{a}±0.18	8.77^{b}±0.24
FCR	0.15^{a}±0.01	0.20^{b}±0.01

Means with different superscripts within row and feeding system are significantly different. ADG – average daily gain; ADI – average daily intake; FCR – feed conversion ratio

The effect of start weight on growth traits is shown by how a trait changed when start weight increased by 1 kg. The slopes for the two systems are shown Table 4.3, which shows that start weight only significantly affected ADG and FCR. These traits respectively improved by 0.007 g/day and 0.0003 for every 1 kg increase in start weight.

Table 4.3 Effect of 1 kg increase in initial weight on growth traits of F2 Nguni X Angus crosses

Growth traits	Slope
ADG (g/day)	NS
ADI (kg)	0.007±0.003
FCR	-0.0003±0.0001

ADG – average daily gain; ADI – average daily intake; FCR – feed conversion ratio; NS – not significant

4.2 CORRELATIONS AMONG GROWTH TRAITS

The significant correlations among the different growth parameters of F2 Nguni X Angus crosses are presented in Table 4.4. These correlations range very low (0.09), between ADI and ADG, to high (0.64) between ADG and FCR in the feedlot system. The correlation between FCR and ADI was low negative (-0.17) in the traditional feedlot and high negative (-0.60) in the GrowSafe system.

Table 4.4 Correlations among growth traits analyzed in F2 Nguni X Angus crosses under Feedlot (above diagonal) and GrowSafe (below diagonal)

Growth traits	ADG	ADI	FCR
ADG	**-**	**0.09**	**0.64**
ADI	**0.44**	**-**	**-0.17**
FCR	**0.41**	**-0.60**	**-**

. ADG – average daily gain; ADI – average daily intake; FCR – feed conversion ratio

4.3 FACTORS AFFECTING FEEDING BEHAVIOUR OF GROWSAFE ANIMALS

All interactions between behavioral patterns were significant ($P<0.05$), except for some interactions between MPW and MPMW (Table 4.5). Start weight affected all the traits analyzed ($P<0.001$), where MF and ER decreased by 0.07 meals and 0.02 g/sec, respectively, as start weight increased by 1 kg. For every kg increase in start weight, MS and MD increased by 0.74 g and 0.21 sec, respectively. The respective changes for MPW and MPMW were 0.0002 g/kg and 0.003 g/k as start weight increased by 1 kg.

Table 4.5 Factors affecting the behaviour traits for the F2 Nguni X Angus animals under the GrowSafe system.

	MF	ER	MS	MD	MPW	MPMW
Feed Day	***	***	***	***	***	***
Sex	***	***	***	***	***	***
Mealtime	***	***	***	***	*	NS
Start Weight	***	***	***	***	NS	***

* *P*<0.05; ** *P*<0.01; *** *P*<0.001; NS. MF – meal frequency; ER – eating rate; MS – meal size; MD – meal duration; MPW – meal size per weight; MPMW – meal size per metabolic weight

4.3.1 EFFECT OF START WEIGHT ON BEHAVIOURAL TRAITS OF GROWSAFE ANIMALS

The effect of start weight on feeding behaviour of the F2 Nguni X Angus animals is presented in Table 4.6. Start weight affected all the traits except for MPW.

Table 4.6 Effect of 1 kg increase in initial weight on growth traits of F2 Nguni X Angus crosses

Behaviour traits	Slope
MF	-0.05±0.001
ER (g/sec)	-0.01±0.003
MS (g)	0.68±0.01
MD (sec)	0.16±0.01
MPW (g/kg)	NS
MPMW (g/kg)	0.002±0.0002

MF – meal frequency; ER – eating rate; MS – meal size; MD – meal duration; MPW – meal size per weight; MPMW – meal size per metabolic weight

4.3.1 EFFECT OF SEX ON BEHAVIOURAL TRAITS OF GROWSAFE ANIMALS

Table 4.7 contains Least Squares Means for the effect of sex on the behavioural traits for the GrowSafe animals. Each female had a higher MF of 63 meals per day compared to 49 meals per day for the male counterpart. For each meal, the females had lower MD (1.02±0.06 sec) and smaller MS (0.163±0.01 g) compared to their male counterparts. Meal duration and MS for a female were 62 seconds and 0.16 kg, respectively. For each male, the respective figures were 105 seconds and 0.24 kg. Although the females had higher MF than the males, the females spent less time (61.77±4.40 sec) per day eating and their meals were characterized by smaller MS (0.163^a±0.01) than the males. The total time spent eating (TMD) by a female is 61.77 minutes and it consumed 9.78 kg per day. The corresponding values for the male animal were 10.78 kg per day, spending 82.64 minutes. Meal size per metabolic weight was higher ($P<0.001$) in males than females, and the respective values were 2.31±0.01 and 3.00±0.01.

Table 4.7. Least Square Means of sex on feeding behaviour of F2 Nguni X Angus crosses under GrowSafe system

	Female	Male
MF	63.88^a±2.42	49.11^b±3.23
MD (sec)	1.02^a±0.06	1.75^b±.09
MS (g)	0.163^a±0.01	0.24^b±0.010
ER (g/min)	22.89^a±0.15	19.98^b±0.21
TMD (min)	61.77^a±4.40	82.64^b±5.86
TDI (kg)	9.78^a±0.47	10.78^b±0.63
MPW (g/kg)	0.56^a±0.01	0.72^b±0.01
MBMW (k/kg)	2.31^a±0.01	3.00^b±0.01

Means with different superscripts within row are significantly different. MF – meal frequency; MS – meal size; ER – eat rate; TMD – total meal duration; TDI – total daily intake; MPW - meal size per weight; MBMW - meal size per metabolic body weight

4.3.3 EFFECT OF MEALTIME ON BEHAVIOURAL TRAITS OF GROWSAFE ANIMALS

Mealtime affected ($P<0.001$) all the traits, except for MPMW (Table 4.5). Figures 4.1 and 4.2 show the MF and ER during the different times of the day for animals under the GrowSafe system. The animals generally consumed throughout the day and night, with the smallest MF and lowest ER between 4AM and 6AM. Females consistently had more MF than the males and had higher ER than the males. These differences between females and males became more pronounced from midday to midnight.

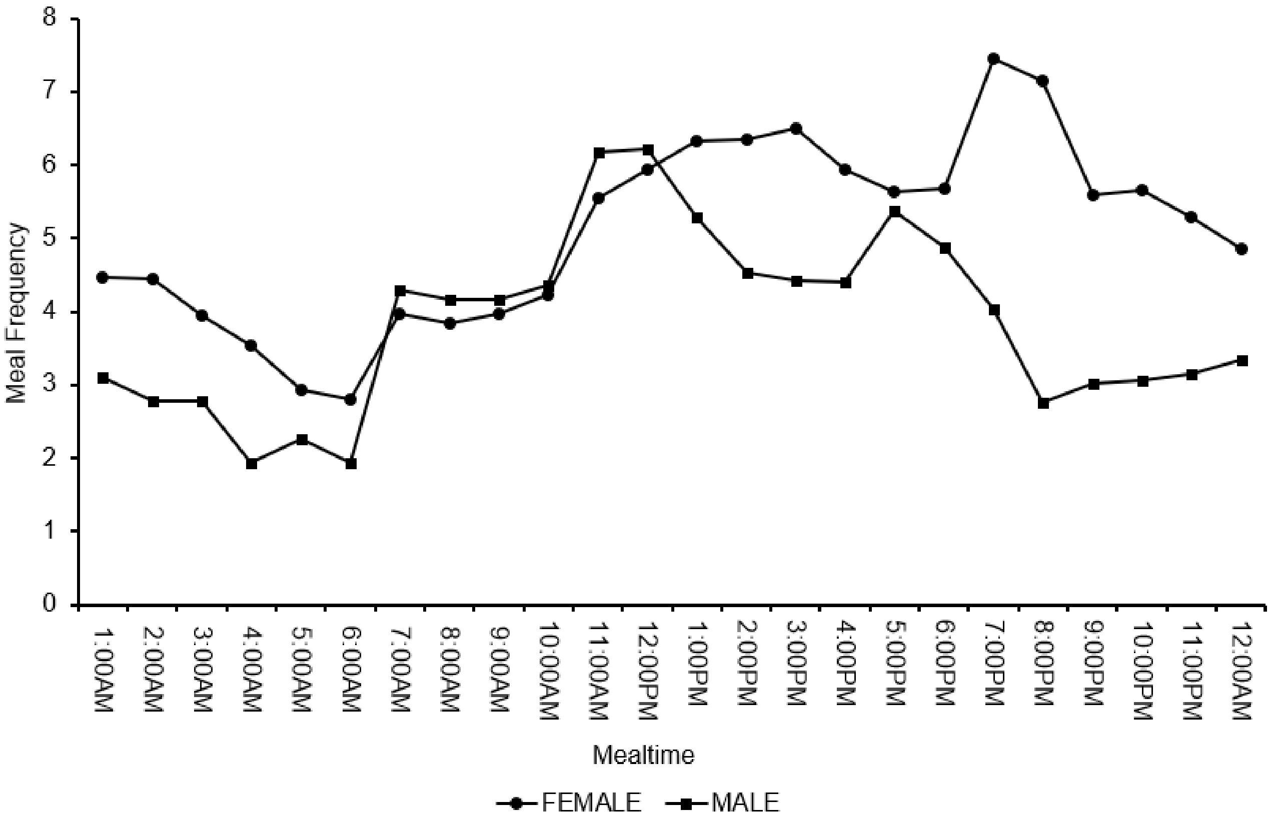

Figure 4.1. Meal frequency of the F2 Nguni X Angus animals under the GrowSafe system

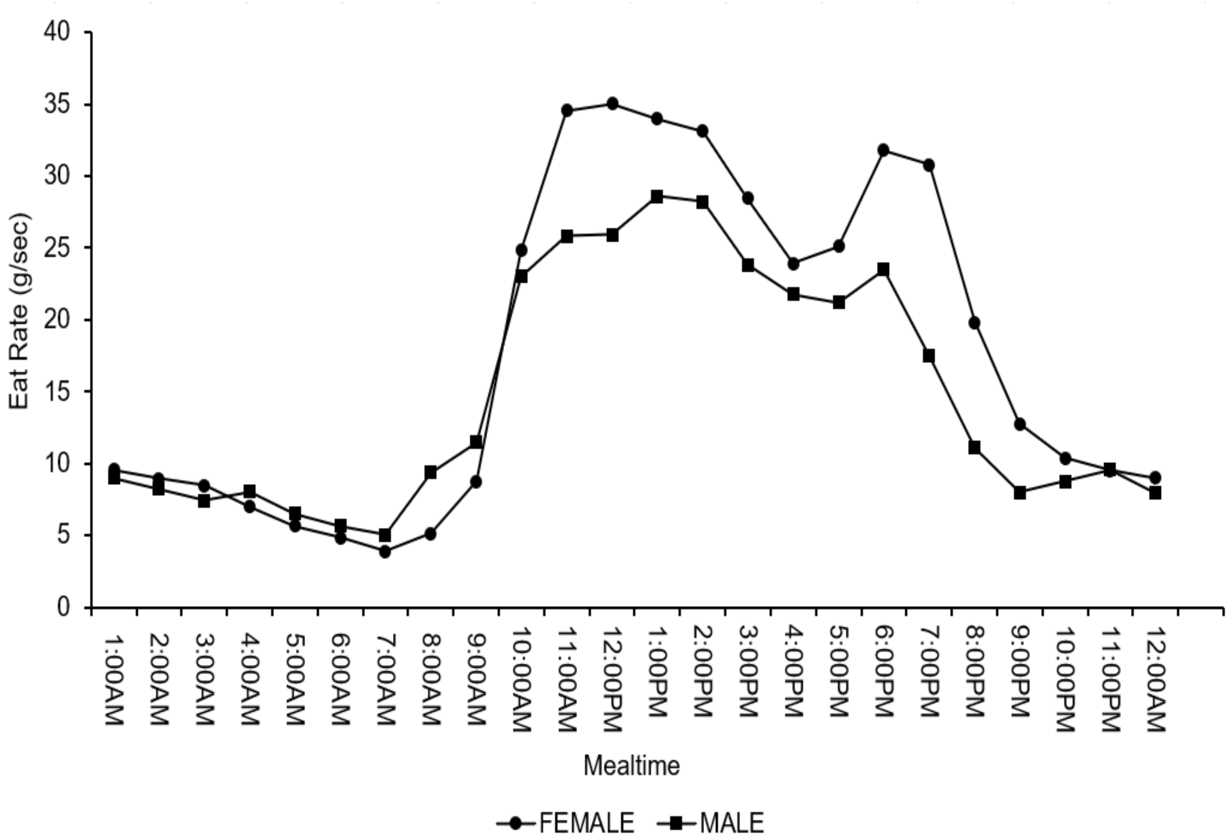

Figure 4.2. Eating rate of the F2 Nguni X Angus animals under the GrowSafe system

The results also show that although the animals had more MF and higher ER between 8AM and 6PM than at other times, they exhibited smaller MS and shorter MD during these times (Figure 4.3 and 4.4, respectively). Also, the females consistently had smaller MS and MD compared to the males.

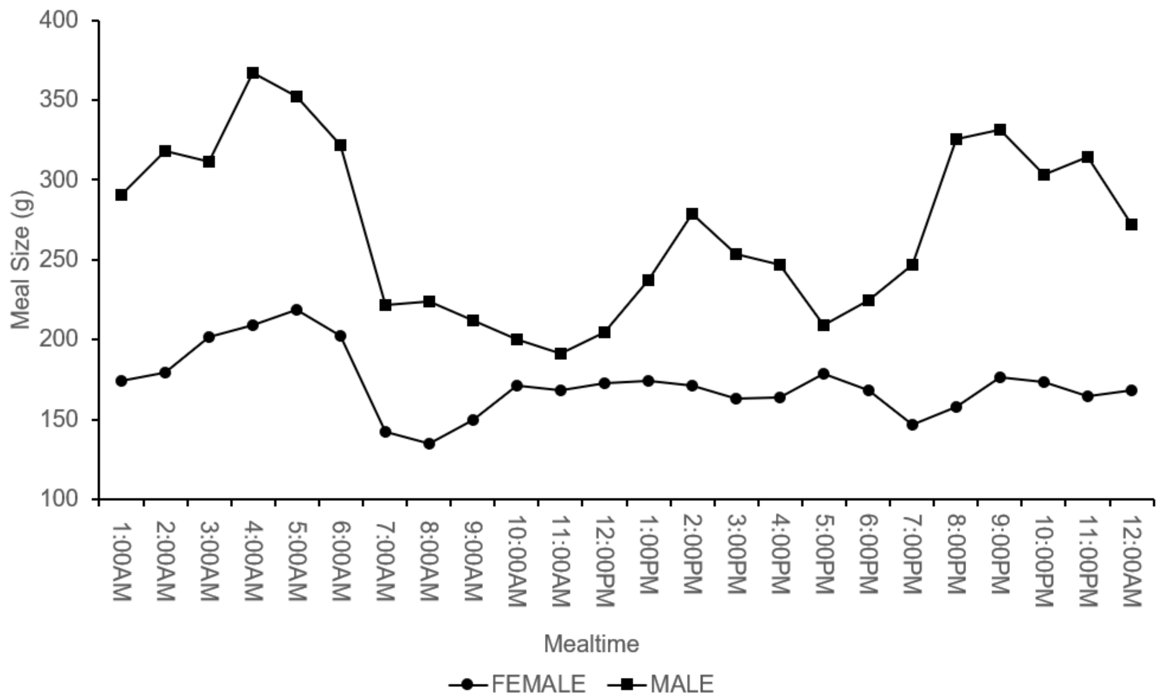

Figure 4.3. Meal size of the F2 Nguni X Angus animals under the GrowSafe system

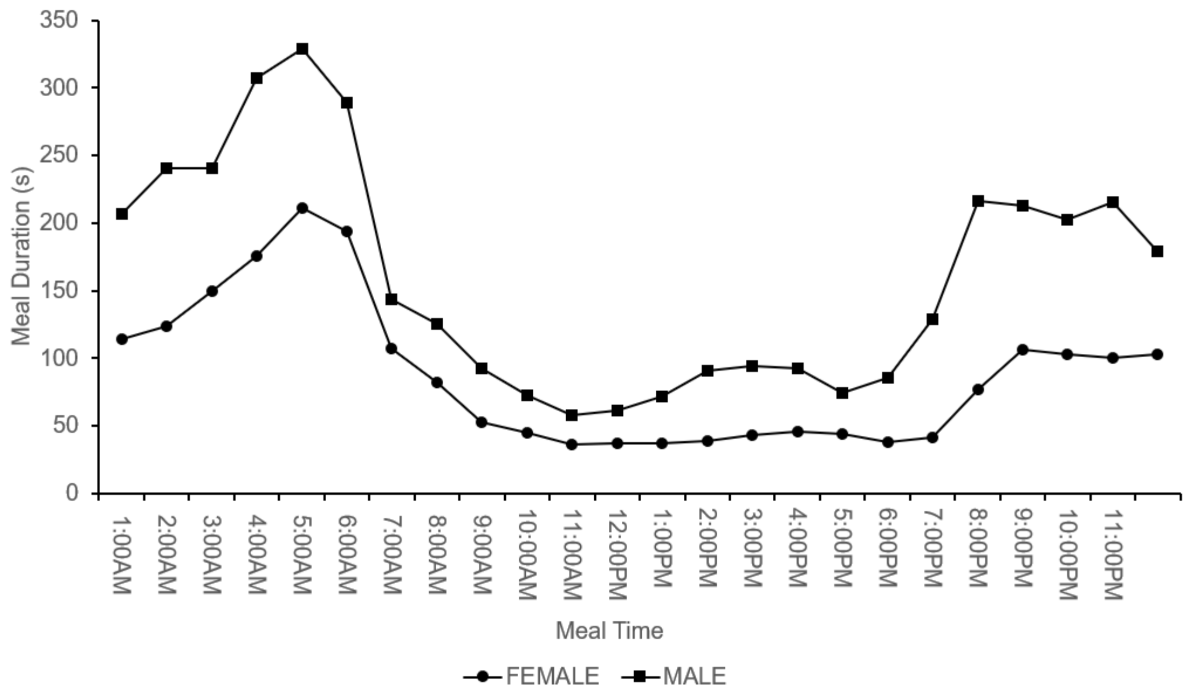

Figure 4.4. Meal duration of the F2 Nguni X Angus animals under the GrowSafe system

When meals sizes were expressed as MPW and MPMW, it was observed that heavier animals had their meals between 8PM and 4AM (Figures 4.5 and 4.6, respectively). Lighter animals generally had their meals throughout the daylight hours. These figures show that males consumed more feed per weight and metabolic weight throughout the daylight and night hours. The differences between males and females were higher between 8PM and 6PM than at other times.

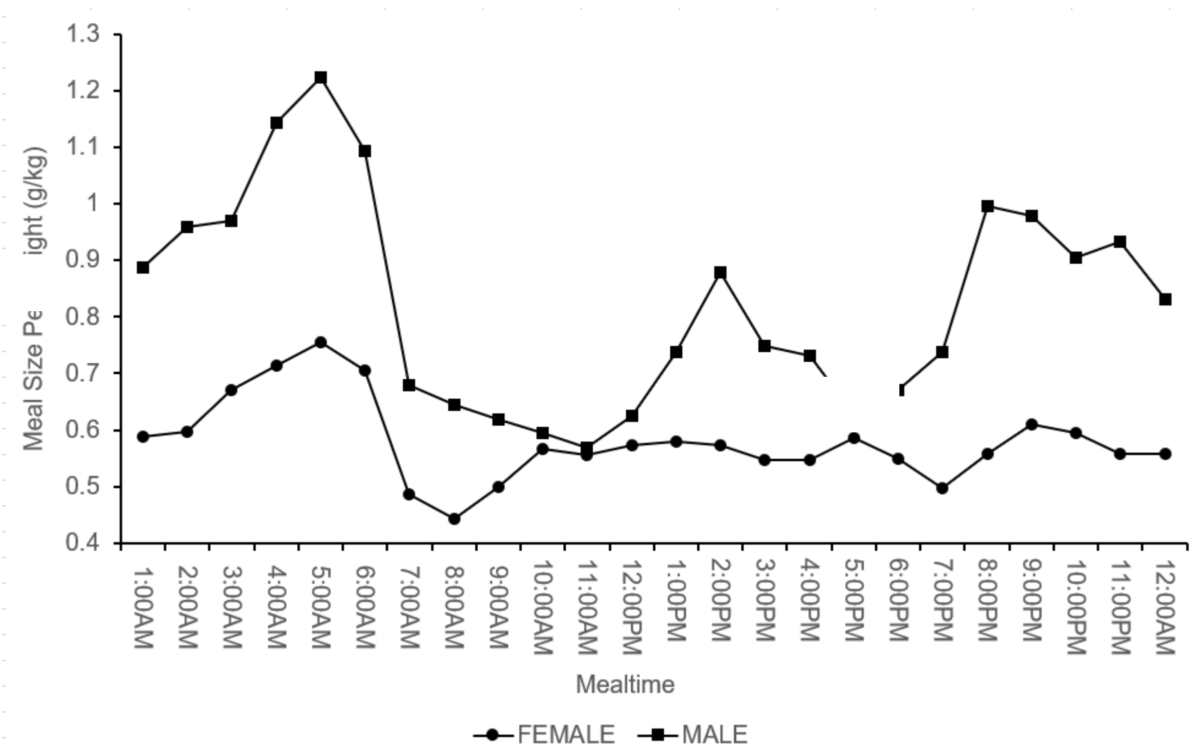

Figure 4.5. Meal size per weight of the F2 Nguni X Angus animals under the GrowSafe system

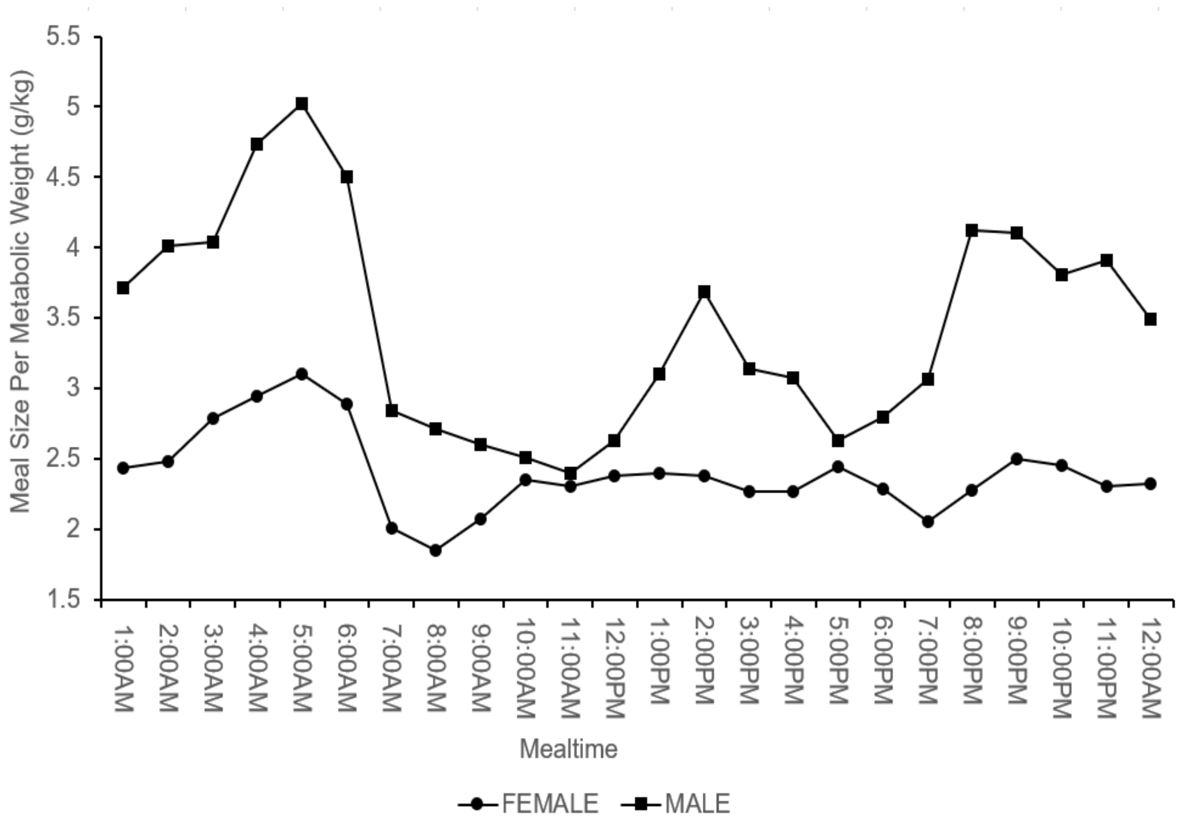

Figure 4.6. Meal size per metabolic body weight of the F2 Nguni X Angus animals under the GrowSafe system

The surface plot in Figure 4.7 illustrates the MF for the different day times during the entire feedlot period for the F2 Nguni X Angus animals. Generally, MF increases from the beginning of the feeding period and then decreases towards the end. The same MF trend across the day is maintained throughout the feeding period. Meal frequency is lowest just before sunrise (2.5 meals) and increases until it reaches its peak at about late afternoon. This late afternoon peak is about 6.5 meals at the beginning of the feeding period and 9 meals at the end of the feeding period. Then, there is a general decrease in MF from late evening until early morning.

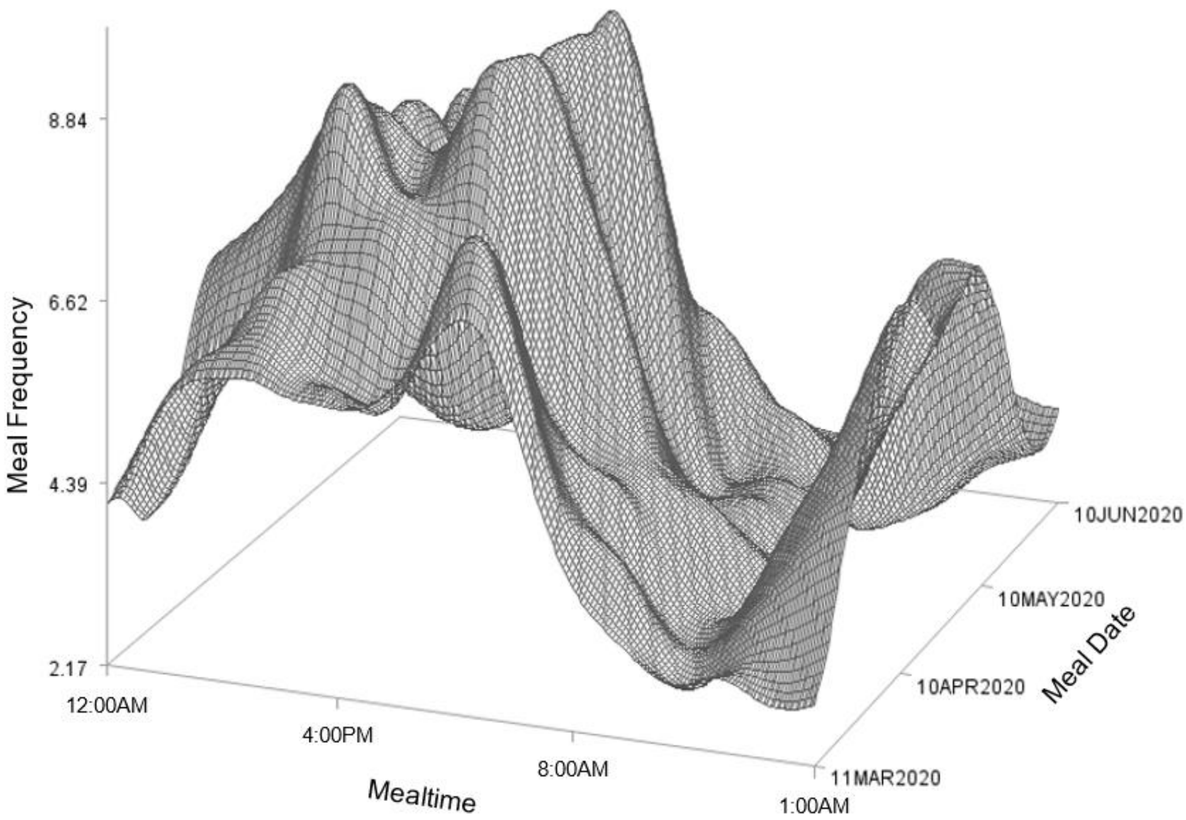

Figure 4.7. Surface plot for meal frequency of the F2 Nguni X Angus animals under the GrowSafe system

The surface plot for ER (Figure 4.8) shows that at the beginning of the feeding period ER has two peaks, one in early morning and the other, around midnight. Then, around the middle of the feeding period, there is a peak which occurs around late afternoon. At end of the feeding period, ER is oscillating with one ER peak around mid-morning and another around midnight, and between these peaks, there is a noticeable drop around midday. There is also a general increase in ER as the feeding period progresses.

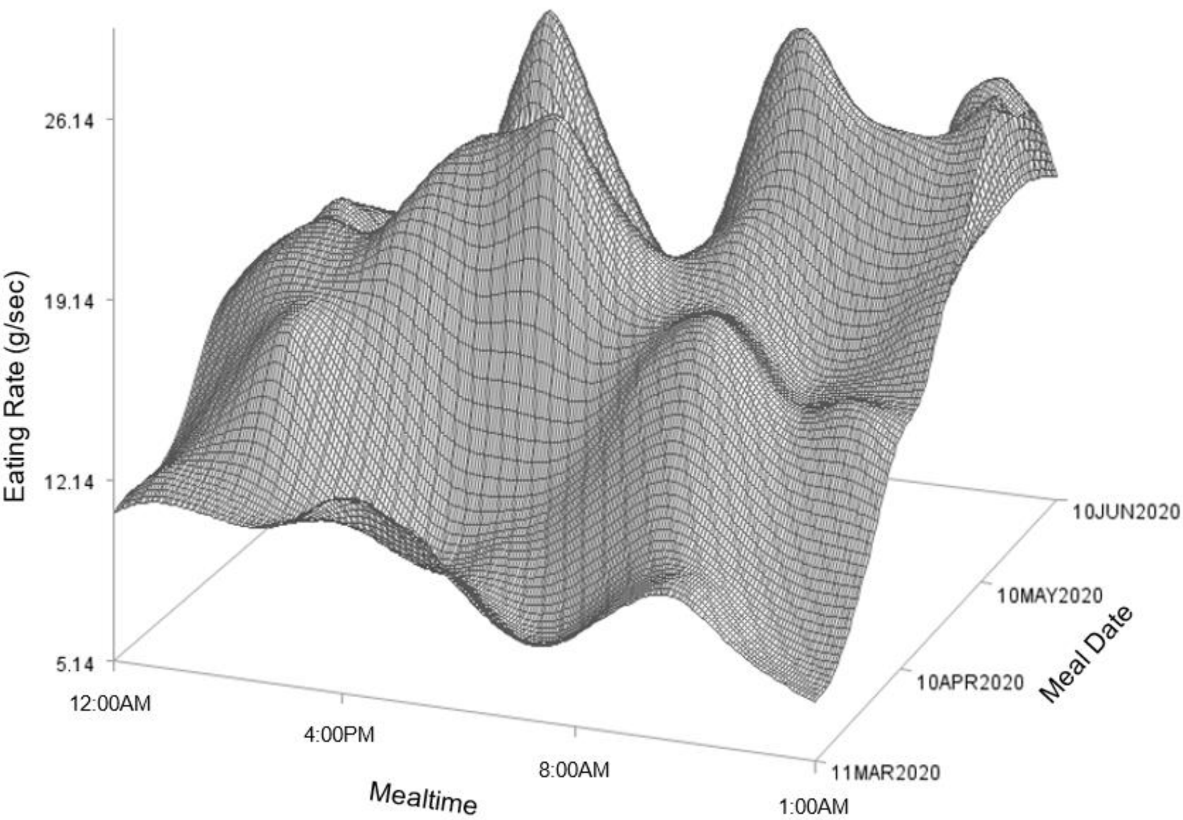

Figure 4.8. Surface plot for eating rate of the F2 Nguni X Angus animals under the GrowSafe system.

The MS and MD for the F2 Nguni X Angus animals under the GrowSafe system are presented in Figure 4.9 and 4.10, respectively, where they increased as the feeding period progressed and then decreased towards the end. The figures show that at the same trend across the day is maintained throughout the feeding period. Meal size and MD were generally lower between 8:00AM and 4:00PM than at other times. There are two distinct peaks on either side of this period of low MS and MD, which occur between late evening and early morning hours. For the first month of the feeding period, MS and MD are almost constant, and then increase towards the end of the feeding period. This is followed by sharp decreases of these traits in the last month of the feeding period.

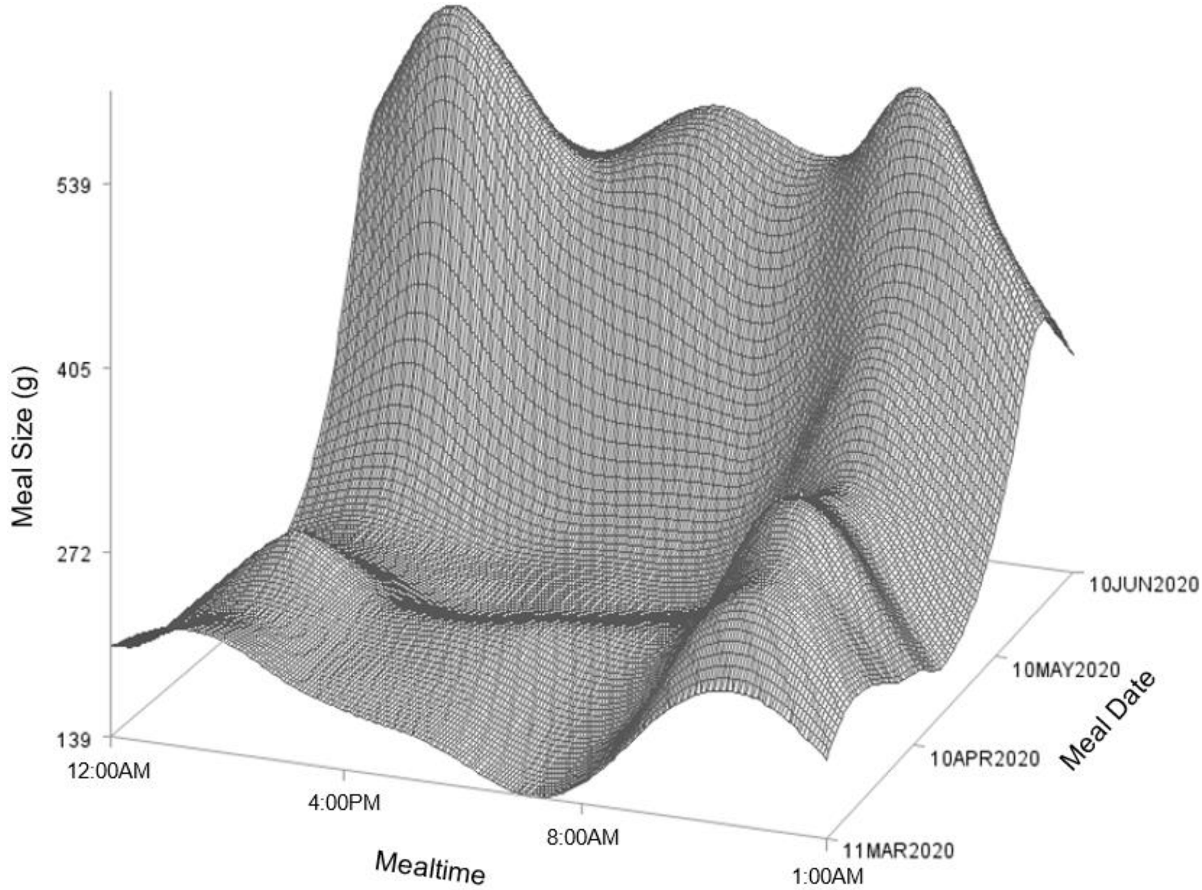

Figure 4.9. Surface plot for meal size of the F2 Nguni X Angus animals under the GrowSafe system

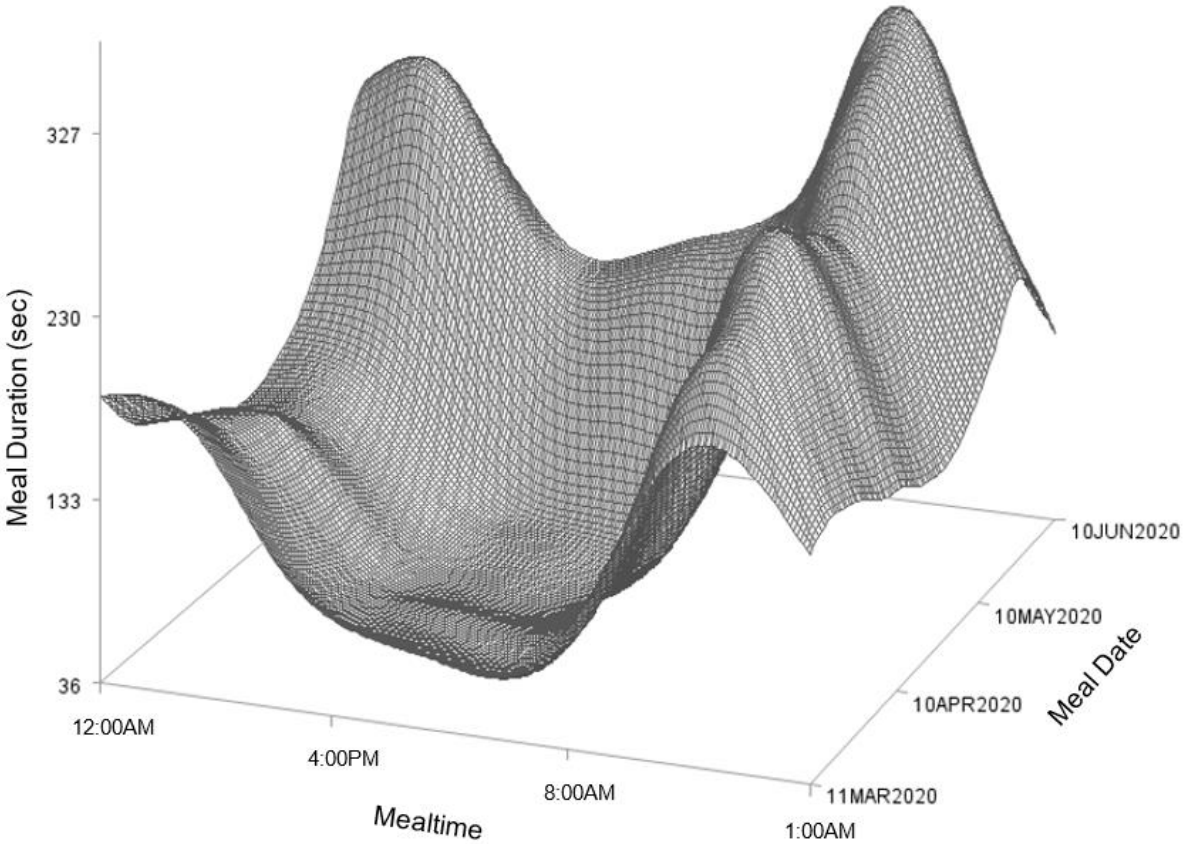

Figure 4.10. Surface plot for meal duration of the F2 Nguni X Angus animals under the Grow Safe system

The surface plots in Figures 4.10 and 4.12, respectively, show that MPW and MPMW were generally constant throughout the day in the first two months. Then, there were sharp increases of MPW and MPMW during daylight hours in the last month of the feeding period.

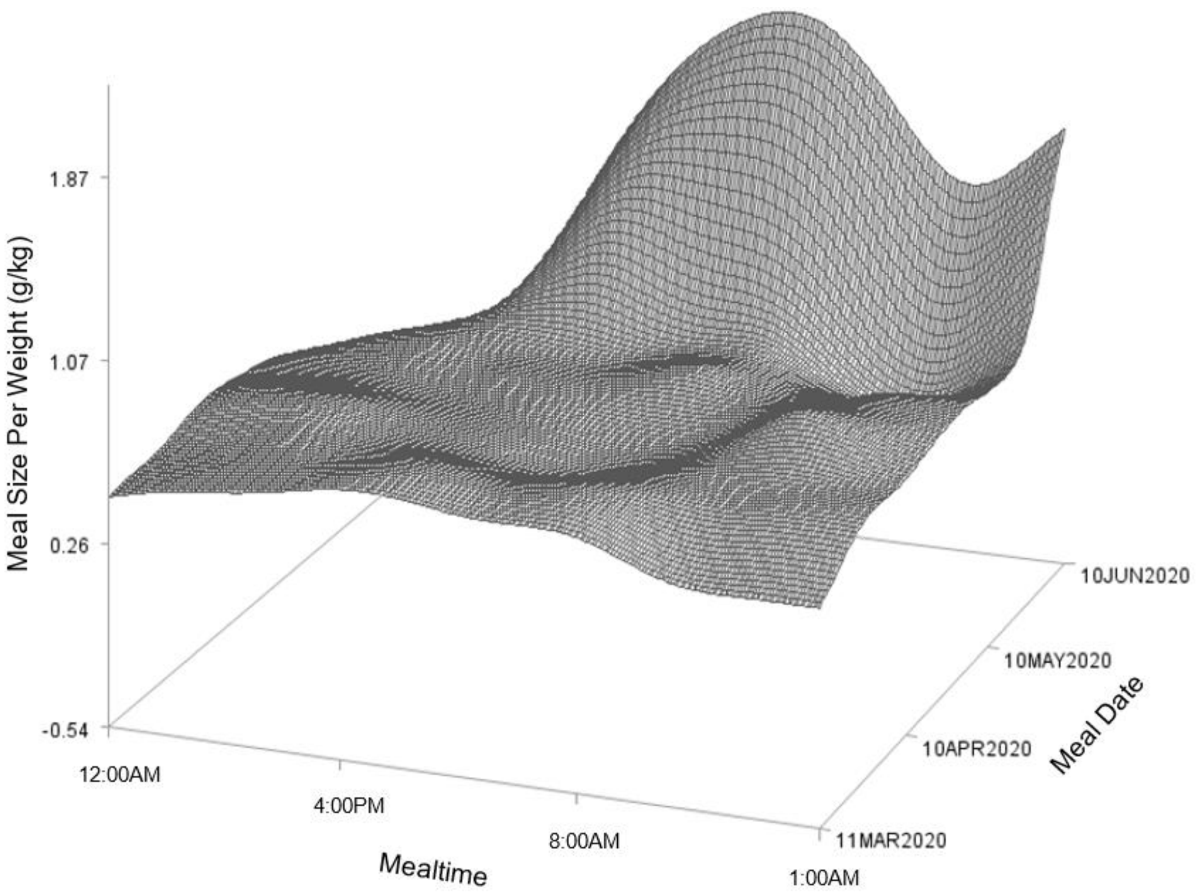

Figure 4.11. Surface plot for meal size per weight of the F2 Nguni X Angus animals under the GrowSafe system

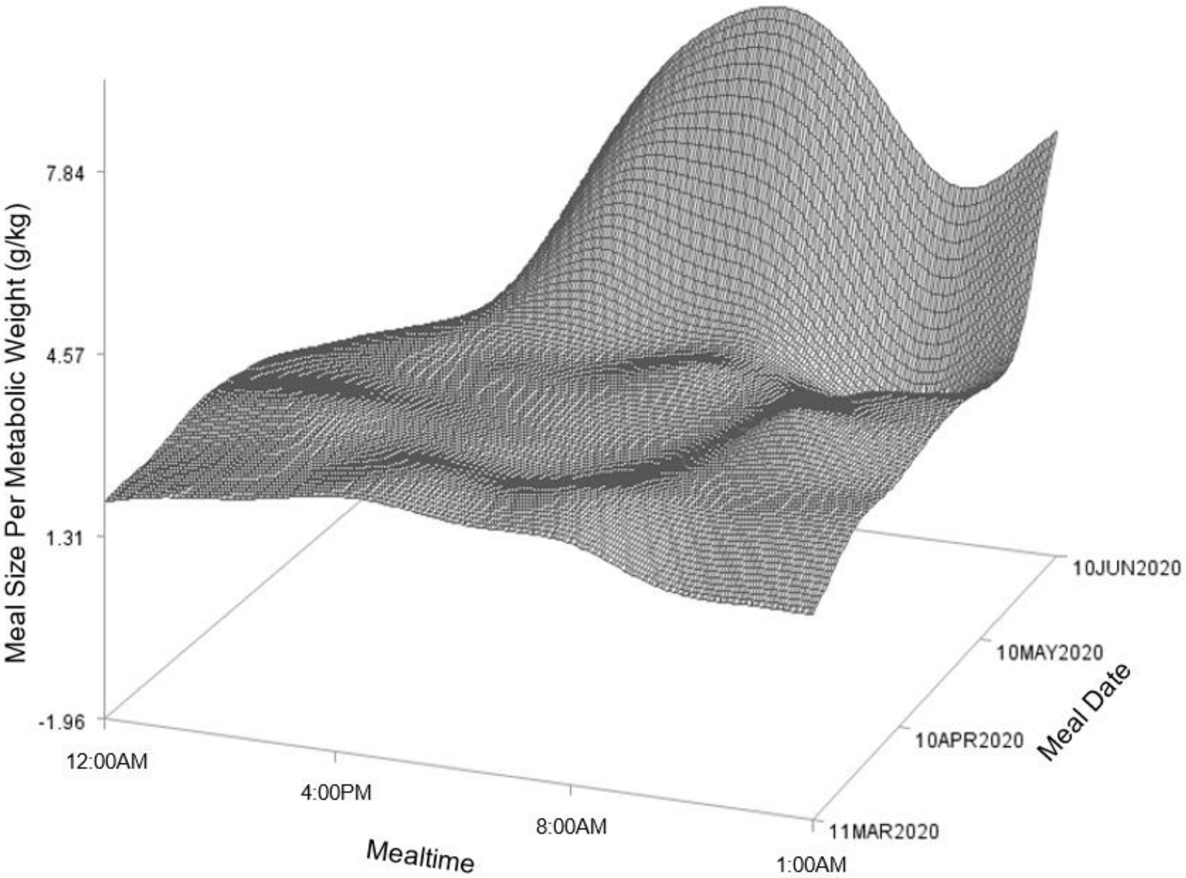

Figure 4.12. Surface plot for meal size per metabolic weight of the F2 Nguni X Angus animals under the GrowSafe system

CHAPTER 5: DISCUSSION

Comparison of traditional feedlot and GrowSafe systems on growth performance and behavioural patterns of F2 Nguni X Angus crosses were studied. Feeding system was identified as one of the main environmental factors affecting feeding behaviour in beef cattle (Sowell *et al*., 1998). In the traditional feedlot feeding system, the animals are placed in separate pens, where each animal has its own feed *adlib tum*. Each animal being fed according to appetite and feed being measured before given to animals to calculate feed intake and feed conversion ratio at the end of the trial. The GrowSafe system is traditionally used to quantify intake in cattle so that it may offer more effective and more accurate means of measuring exact consumption and can be applied in group pens (Dickson *et al*., 2018). The animals in the traditional feedlot system ate less feed and had a higher average daily gain than those in the GrowSafe system, and the latter were more efficient in utilizing feed for growth.

The differences observed in growth performance may be partly attributed to the efficiency and accuracy of recording and animal interactions and freedom of movement. In the GrowSafe system, measurements of feed intake are more accurate compared to the traditional feedlot system. Although the animals are kept in groups, which may affect feeding behaviour because of animal interactions, there is freedom of movement in the GrowSafe. This may result in overall performance of animals which is different from that in the traditional feedlot system, where each animal is confined in a small space with no freedom of movement. In a study by Pas *et al*. (2012), animals kept in confinement feeding systems performed better than those in open lot facilities. However, the superior performance of animals in a confined system may be due to the increased comfort because of the bedding provided, unlike in our study where animals were kept on concrete floors. Patino *et al.* (2015) however found no differences in average daily gain between animals kept in confinement and those fed on pasture. In South Africa, Bonsmara steers kept on feedlot had faster and more efficient growth compared to those kept pasture (Esterhuizen *et al*., 2008). However, their results may have been due to differences in nutritional quality.

The animals in the feedlot system may have enjoyed better thermal comfort than those in the GrowSafe, as the former were under shade, while latter in an open space. Barreto *et al*. (2022) noted thermal comfort plays a significant role in cattle production systems. In a separate study, respiration rates increased with an increasing temperature humidity index, more in pastured cows than in free stall housed cows (Black and Krawczel, 2016). Thus, animals in the GrowSafe system may have been exposed to some degree of heat stress compared to those in the traditional feedlot, which were under shade. Lees *et al*. (2019) provided a detailed review on how heat stress affects production in cattle and pointed out that there are some notable reductions in growth performance during periods of heat stress. Therefore, the GrowSafe system may be recommended as the feeding system of choice as the animals are more efficient. A study on meat quality may provide some additional information on determining which system is desirable for finishing these animals.

Sex significantly affected all the traits included in the analysis, with males consuming more feed and growing faster than the females. The females were however more efficient in utilizing feed growth than the males. These results show that there are significant differences in growth performance between males and females. Such differences due to sex are well documented (Plasse *et al.*, 1995; Muchenje *et al*., 1998; Melka, 2001; Koknaroglu Raphaka and Dzama, 2009; Pogorzelska-Przybyłek *et al*., 2021). In a growth study on the Australian beef cattle, steers and heifers performed differently (McIntyre *et al*., 2009). In Botswana, analysis of adjustment factors for sex and age of dam on beef cattle showed a significant effect of sex, which should be adjusted for during genetic analysis (Raphaka and Dzama, 2009).

Generally, the average weights of bull and heifer calves differ regardless of having been raised under similar environmental conditions, with males always being heavier than females. Females are more affected than males due to their higher precociousness, whereas steers maintain an intermediate position; hence the differences in growth performance (Pogorzelska-Przybyłek *et al*., 2021). de Araujo Marques *et al.* (2006) pointed out that the low final body weight of heifers is due to their lower muscle deposition compared to their male counterparts. Meat analysis was however not evaluated in this study. Thus, for beef cattle, weight is traditionally adjusted for sex of calf, among others, before the data are subjected to genetic analysis (Dzama *et al*., 1997). Rumph and Van Vleck (2004) noted that it is not valid to compare heifers to males without adjustments, hence the need for adjustment factors for sex. The differences in growth performance between males and females may be due to differences in hormonal expressions in these animals. Trenkle and Plouzek (1991) observed that males had higher growth hormone levels compared to their female counterparts. Therefore, differences in growth performance between males and females in our study may be attributed to differences in growth hormone levels.

There was a significant effect of starting weight at the beginning of the trial on ADI and FCR. To increase profitability in feedlots, one should optimize production efficiency and marketing time (Koknaroglu, 2006). One way of increasing production efficiency is to take initial weight into account as initial weight is one of the important factors affecting feedlot cattle performance and profitability (Koknaroglu, 2005). The initial weight in this study was the weight at which the cattle entered the feedlot measured on day one, excluding the 14-day backgrounding phase. It is one of the most important factors affecting dry matter intake and feed efficiency in beef cattle production (Volpi-Lagreca *et al*. (2021). A study to determine the ideal start weight for feedlot animals may be recommended.

The results obtained in the current study are consistent with results obtained from previous studies (Koknaroglu *et al*., 2016; Ngadiyono *et al*., 2019; Wells, 2020) on Beefmaster cattle under feedlot in South Africa. Bozkurt and Kaya (2008) however found no effect of initial on growth performance in in Turkish beef cattle. Like the current study, Volpi-Lagreca *et al*. (2021) also found that initial weight did not affect average daily gain but had a significant on daily feed intake and feed efficiency. Koknaroglu *et al*. (2006) reported that in addition to affecting dry matter intake and feed efficiency, initial weight also affected average daily gain, which was not affected in the current study. Koknaroglu *et al*. (2005) found that steers started on feed at heavier weights had higher average daily gain, daily dry matter intake and were less efficient than those started at lighter weights. The superior feed efficiency of lighter animals than heavier ones can be attributed to their growth potential because of growth hormone level circulating in their blood plasma. Concentration levels of growth hormone were highest in young cattle and gradually decreased with increasing age

(Verde and Trenkle, 1987). Therefore, it may be advantageous to use feedlot animals in this population with a low liveweight as they are more efficient.

The range for the correlations among the growth traits of animals in the traditional feedlot and GrowSafe systems were computed and were significant. They ranged from very low between ADI and ADG in the feedlot system to high between ADG and FCR in the feedlot system. The results show that in the feedlot system, ADI is not associated ADG, while ADG is highly associated with FCR. Although the relationship between ADG and FCR is favourable in the feedlot system, its magnitude is low (-0.17). Conversely, animals that consume more feed in the GrowSafe system are expected to grow faster and efficient in utilizing feed. This is supported by the correlation of 0.41 between ADG and FCR. Most studies in literature report favourable phenotypic correlations among growth performance traits (Nkrumah *et al*., 2007; Rabeya *et al*., 2009; Ceacero *et al*., 2016; Weik *et al*., 2022). They also reported genetic correlations, which were however not computed in the current study due to limitations in animal numbers. Therefore, it can be beneficial if animals in this population are finished in the GrowSafe system.

The study of animal behavior plays an important role in cattle production as the changes imposed by men can interfere with the welfare and productive performance of animals. This human interference can result in stress and diseases, or compromise feed quality. Thus, research should be conducted on the feeding behavior of animals to provide producers with relevant choices to determine the best dietary management strategy to be adopted and increase productivity (Argenta *et al*. 2013). In ruminants, feeding behavior is characterized by the periods of activities of biological and economic importance. These activities are defined by the time the animal takes to consume the feed, how often it visits the trough to eat, rumination activity, and idleness (other activities) (Schwartzkopf-Genswein *et al*. 2011).

The current study compared the feeding behaviours of the F2 Nguni X Angus males and females finished in the GrowSafe system. In literature, studies on the comparison between the feeding behaviours of males and females finished in the feedlot are limited. The results in the current study showed that females visited the bunk more frequently than the males. Male animals in this study had longer meal durations than females. This is consistent with the findings of dos Santos *et al*. (2018), where bulls had longer eating times than cows. They however noted that bulls and cows visited the bunk with the same frequency. Females visited the bunk more frequently than males because females are more excitable than their male counterparts (Llonch *et al*., 018). The fact that the bulls visited the bunk less frequently in the current study may suggest that they spent more time ruminating compared to the females (dos Santos *et al*, 2018). Fibre in the diet of feedlot animals is to stimulate the buffer effect, thereby providing energy and improving performance. The buffer effect occurs through salivation, which is stimulated by rumination, and it is dependent upon the time spent ruminating (Oliveira *et al*. 2012). Males and females have different nutritional requirements and body tissue deposition dynamics, which affect their feed intake (NRC 1996).

The current study showed significant differences in the number of meals and eating rate. In the results, the females had more meals per day and ate at a faster rate than the males. Interestingly, the time spent by females eating and the meal size were less than those for their male counterparts. In a study on Holstein steers, Chase *et al* (1976) found that the steers consumed 10.01 meals per day with a daily total meal duration of 154 minutes. They reported respective means for overall meal duration, actual meal duration, overall eating rate, and actual eating rate of 20.3 min, 13.7 min, 23.1 g/min, and 30.0 g/sec. In the study by Chase *et al* (1976), meal size per weight was computed for males only and found that average meal size was 414.5 g. Meal size per weight and meal size per metabolic body weight were computed and there were significant differences in the males and females. In a study by Gonyou and Stricklin (1981), the daily total meal duration for stall-fed and trough-fed animals were 80.9 and 119.1 min per day, respectively.

The differences observed in the eating behaviour of males and females in this study may be due to differences in their physiological characteristics. The results from the current study indicate that although the females were able to make more visits to the bunk, they could only manage to have a small portion of feed and could not spend a long time eating. This may suggest that the females easily suffer the effects of heat stress faster than the males; hence the relatively short time they spent eating. These feeding behaviours may be used to design feeding programs for beef cattle to achieve optimum performance in feedlots for this population.

The feeding behavior of beef cattle may influence feed intake and overall growth performance. Feeding strategies for beef cattle can thus be improved by obtaining a clearer insight into their feeding behavior (Sowell *et al*., 1998). Understanding how weight at the start the feeding period affects feeding behaviour may add valuable information in developing feeding strategies. Body weight is one of the most important determinants of feeding behavior in cattle (DeHaan *et al.,* 1995; Riaz *et al*., 2014). In the current study, MF and ER decreased as start weight increased, which may suggest lighter or smaller animals tend to eat more frequently and at a faster rate. Weckerly (2013) postulated that for the smaller animals to meet their metabolic demands, their digesta loads (kg digesta/kg body weight) be greater than those of large animals. They concluded that small animals comminuted forage particles more quickly because they chewed ingesta more thoroughly and had a quicker rumen turnover. This provides a means for small animals to meet their greater weight-specific energetic demands than large animals. Thus, small animals are expected to be more efficient than large animals because more frequent and shorter meals are associated with a more efficient use of feed due to improvement of feed digestibility (Llonch *et al*., 2018).

Animals that eat faster, as observed in this study, are forced to spend less time feeding; hence they often compensate for the time debit by eating faster (Llonch *et al*., 2018). In the current study, the smaller animals spent less time eating as shown by the positive relationship between start weight and meal duration. For every kg increase in start weight, meal duration increased. The increase in meal size that was associated with every increase in start weight suggest that larger animals consumed larger meal portions of feed. Similarly, meal size per metabolic weight was positively related to start weight in the current study. lThis is consistent with results obtained by Weckerly (2013), where a positive relationship between body weight and forage intake was observed, indicating that larger animals are expected to have larger meals than smaller animals. Larger animals have a digestive advantage when consuming diets high in concentrations of cell wall carbohydrates (Weckerly (2013). The digesta is retained long enough in larger animals to allow gut microorganisms enough time to ferment cell wall components that are resistant to digestion (Steuer *et al*. 2011). As a result, larger animals can consume larger portions of feed and spend more time eating than smaller animals. However, Weckerly (2013) noted that although body weight is positively related to feed intake, it was not related to rumination time. Therefore, to improve the performance of animals in the GrowSafe feeding system, larger or heavier animals at the start of the feeding period must be used.

The time of eating significantly affected all the feeding behaviour traits of the animals in the GrowSafe system. It was observed that the animals generally consumed throughout the day and night. The lowest number of meals and eating rate occurred just before sunrise, and then peaked during the daylight hours. Gonyou and Stricklin (1981) observed mealtimes that were comparable to those of the current study. They reported two peak feeding times for cattle fed from troughs, one during the day between 9:00AM to 7:00PM and the other, at night (2:00AM). Stall-fed animals in their study fed throughout the day, except for a 2-hour period before sunrise (04:00 – 06:00AM). The surface plots illustrate the feeding behaviour of the animals during the different times of the day over the entire feedlot period. In the surface plot, the same trend is observed across the mealtimes. There is a general decrease in the number of meals as the animals' stay in the feedlot continues.

Although the animals ate more frequently during the daylight hours than at other times, their meal sizes and durations were smaller and shorter, respectively, during these hours. The same trends were maintained throughout the feedlot period as illustrated by the surface plots, which also show general increases in meal size and duration from the beginning of the feedlot period until the end. These animals only managed to have smaller bites for short periods during the daylight hours. This can be due to heat stress as eating generates heat, which increases body temperature and contribute to heat stress (Zoller, 2023). Fermentation in the rumen also creates heat, which contributes to the overall metabolic heat production (Conte *et al*., 2018). Conversely, at night when it cooler, the animals were able eat more feed and spent more time eating. Llonch *et* al. (2018) postulated that high environmental temperature affects feeding behaviour by making heat-stressed cattle concentrate their feeding events in evening hours when it is cooler.

Meal size per weight and per metabolic weight was higher in the early hours of the morning and lower during the daylight hours, which may be because of heat stress. When meal size per weight and metabolic weight were evaluated for the entire feedlot period, they were generally constant throughout the day and night in the first two months. Then, they increased sharply during the daylight hours. These changes may be associated with the change in mass; hence eating behaviour as the animals approach slaughter weight. Therefore, the eating behaviour of these animals may be used to design feeding strategies for this population to optimize their growth performance.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

The results in the current showed the factors that should be considered when conducting genetic evaluation for growth performance in the F2 Nguni X Angus animals. The differences in performance due to feeding system may be due to the environmental and housing conditions. Animals in the GrowSafe system had lower FCR, indicating they were more efficient than those in the traditional feedlot. Thus, finishing animals in the GrowSafe system may be expected to produce more efficient animals than the traditional feedlot system. Although females were more efficient than males, their inferior growth rate may result in longer feeding periods to reach target weight or fetching lower prices at the market. Also, higher initial weight was associated with high feed utilization efficiency. Heavier males at the start of the feeding period should therefore be used in finishing animals. The differences in feeding behaviours between males and females in the GrowSafe system may also be due to their differences in nutritional requirements. The highest number of meals were during the day when the eating rate was also highest, which is maintained throughout the feeding period. However, this does not translate to larger meal sizes and time spent eating, as the largest meals, and time spent eating were during the night.

6.2. RECOMMENDATIONS

The smaller meals and time spent eating during the day may be attributed to heat stress because eating generates heat. Thus, the animals prefer to eat larger meals for longer periods during the night when it is cooler. Females ate more meals at a faster rate than males, however the meals for females were smaller and they also ate for shorter periods per meal compared to males. These differences may be due to the physiological differences between males and females. The animals generally maintained the same daily eating habits throughout the feeding period, despite increasing in mass. The sharp increase in meal size per weight and MPMW as the animals approached the end of the feeding period, which be due to increase in mass. The feeding behaviours of the GrowSafe animals may be used to design feeding strategies for feedlot animals.

LIST OF REFERENCES

ABDULKADIR, O., GULER, O., YANAR, M., AKBULUT, Ö., NECDET, U., NECDET, U. and BIBEROĞLU. Ö. 2006. The Effect of Initial Age of Fattening on the Fattening Performance and Carcass Traits of Eastern Anatolian Red Cattle Reared in Eastern Turkey. Journal of Animal and Veterinary Advances, 15, 1344-1357.

AKSOY, A.R., KIRMIZIBAYRAK, T., MUSAFASAATCI, K. and MUAMMERTILKI, R. 2008. Effect of age on fattening performance and fattening economy in Zavot male cattle. Indian Journal of Animal Sciences, 78, 780–782.

ARGENTA, F. M., BRONDANI, I. L., FILHO, D. C. A., NORNBERG, J. L., SEGABINAZI, L. R., RESTLE, J. AND MOURA, A. F. 2013. Ingestive behaviour of steers fed with Alexander grass silage (Urochloa plantaginea) x sorghum silage (Sorghum bicolor (L.) Moench). Revista Acadêmica de Ciências Agrárias e Ambientais, 11, 243-253.

ARTHUR, P. F. and R. M. HERD. 2008. Residual feed intake in beef cattle. Revista Brasileira deZootencnia. 37: 269-279.

ARTHUR, P.F., J. A. ARCHER, D. J. JOHNSTON, R. M. HERD, E. C. RICHARDSON, and P. F. PARNELL. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. J. Anim. Sci. 79: 2805-2811

ASSAN, N. 2013. Future Priorities on Improved Livestock Production in Zimbabwe. International Journal of Environmental Sciences, 2:77-81.

BACH, A., C. IGLESIAS, AND I. BUSTO. 2004. Technical note: A computerized system for monitoring feeding behavior and individual feed intake of dairy cattle. J. Dairy Sci. 87: 4207-4209.

BARRETO, A.N., JUNIOR, N., PEZZOPANE, W.B., BERNARDI, J.RM., PEDROSO, A.C., MARCONDES, A.F., JACINTHO, C.R., ROMANELLO, M.A.C., de SOUSA, N., COSTA, M.A.P., and GARCIA, A.R. 2022. Thermal comfort and behavior of beef cattle in pasture-based systems monitored by visual observation and electronic device. Applied Animal Behaviour Science. 253, 105687.

BASARAB, J. A., M. A. PRICE, J. L. AALHUS, E. K. OKINE, W. M. SNELLING, AND K. L. LYLE. 2003. Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. 83: 189-204.

BLACK, R.A. and KRAWCZEL, P.D. 2016. A Case Study of Behaviour and Performance of Confined or Pastured Cows During the Dry Period. Animals , 6, 41; https://doi.org/10.3390/ani6070041

BOURDON. R.M., 1997. Understanding Animal breeding. 2nd. Ed. Prentice-Hall, Inc. Upper Saddle River, New Jersey, USA.

BOZKURT, Y. and KAYA, I. 2008. Effect of initial weight on feedlot local breed cattle performance in the Mediterranean conditions. Archiva Zootechnica 11, 54-58.

BRELIN, B. and E. BRANNANG. 1982. Phenotypic and genetic variation in feed efficiency of growing cattle and their relationship with growth rate, carcass traits, and metabolic efficiency.Swedish J. Agric. Res. 12: 29-34.

C.A. PLOUZEK and A. 1991. TRENKLE. Growth hormone parameters at four ages in intact and castrated male and female cattle. Domestic Animal Endocrinology, 8, 63-72.

CALEGARE, L., ALENCAR, M.M., PACKER, I.U., & LANNA, D.P.D 2007. Energy requirements and cow/calf efficiency of Nellore and Continental and British *Bos* Taurus X Nellore crosses. Journal of Animal Science, 85, 2413-2422.

CEACERO, T.M., MERCADANTE, M.E.Z., CYRILLO, J. N., CANESIN, R.C., BONILHA, S.F.M., and de ALBUQUERQUE, L.G. 2016. Phenotypic and Genetic Correlations of Feed Efficiency Traits with Growth and Carcass Traits in Nellore Cattle Selected for Postweaning Weight. PLOS ONE. DOI:10.1371/journal.pone.0161366

CHAPINAL, N., D. M. VEIRA, D. M. WEARY, AND M. A. G. VON KEYSERLINGK. 2007. Technical Note:Validation of a system for monitoring individual feeding and drinking behavior and intake on group-housed cattle. J. Dairy Sci. 90:5732-5736.

CHASE, L.E., WANGSNESS, P.J. and BAUMGARDT, B.R. 1976. Feeding Behavior of Steers Fed a Complete Mixed Ration. Journal of Dairy Science, 59, 1923-1928.

CONTE G., CIAMPOLINI R., CASSANDRO M., LASAGNA E., CALAMARI L., BERNABUCCI U. and ABENI F. 2018. Feeding and nutrition management of heat-stressed dairy ruminants. Italian Journal of Animal Science, 2018, 17:604–620. doi: 10.1080/1828051X.2017.1404944.

de ARAUJO MARQUES, J., do PRADO, I.N. and MOLETTA J.L. 2006. Carcass and meat traits of feedlot finished heifers submitted to surgical or mechanical anoestrous. Revista Brasileira de Zootecnia, 35,1514–22. doi: 10.1590/S1516-35982006000500034.

DE CASTRO, J.J. 1997. Sustainable tick and tick-borne disease control in livestock improvement in developing countries. Veterinary Parasitology. 71, 77–97.

DEHAAN, K.A., VAN KOEVERING, M.T. and GIBSON, M.L. 1995. The effect of age, background and gender on feed intake by feedlot cattle. Proceedings of the

Symposium on Feed Intake by Feedlot Cattle; Stillwater, OK, USA: Oklahoma State University; pp. 9-22.

DEVRIES, T. J., M. A. G. VON KEYSERLINGK, AND K. A. BEAUCHEMIN. 2003a. Measuring the feeding behaviour of lactating dairy cows in early to peak lactation. Journal of Dairy Science. 86, 3354-3361.

DEVRIES, T.J., VON KEYSERLINGK, M.A., WEARY, D.M. and BEAUCHEMIN, K.A. 2003. Technical note: validation of a system for monitoring feeding behaviour of dairy cows. Journal of Dairy Science. 86, 3571–3574. doi:10.3168/jds. S0022-0302(03)73962-9.

DOI: https://doi.org/10.1017/S1751731115000105

DOS SANTOS, P.B., DE SANTANA, JÚNIOR, H. A., DE ARAÚJO, M.J., A.P., OLIVEIRA, DE, SANTANA, E.O.C. and MENDES, F.B.L. 2018. Feeding behavior of categories of feedlot-finished beef cattle. Acta Scientiarum. Animal Sciences, 40, e35528.

DZAMA, K., WALTER, J.P., RUVUNA, F. and TAYLOR, J.F., 1997. Growth characteristics and age of dam adjustment factors of purebred indigenous and exotic cattle in Zimbabwe. Transactions of the Zimbabwe Scientific Association 71, 5-8.

EMILY, C.D, WILLIAM, C.K., CHRISTINE, M.L., JESSICA, L.L., COURTNEY, L.D., and SARAH, H.W., 2019. Evaluating equine feeding behaviour utilizing GrowSafe Systems 2019. Animal Science, 3, 288–294. doi:10.1093/tas/txz002.

ENRICO, S., MARZIO, Q. and MAURIZIO, R. 2005. Factors affecting growth performance in beef production: an on farm survey. Italian Journal of Animal Science, 4:sup3, 128-131, DOI: 10.4081/ijas.2005.3s.128.

ESTERHUIZEN, J., GROENEWALD, I.B., STRYDOM, P.E. and HUG A. 2008. The performance and meat quality of Bonsmara steers raised in a feedlot, on conventional pastures or on organic pastures. South African Journal of Animal Science, 38, 303-314

FRIARD, O. and GAMBA, M. 2016. BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. Methods of Ecological Evolution, 7, 1325-1330.

GONYOU, H.W. and STRICKLIN, W.R. 1981. Eating behavior of beef cattle groups fed from a single stall or trough. Applied Animal Ethology, 7, 123-133.

GULLSTRANDS, P. 2017. Calving ease and stillbirth in dairy herds using beef and

HONIG, A.C., INHUBER, V., SPIEKERS, H., WINDISCH, W., GOTZ, K-U., SCHUSTER, M and ETTLE, T. 2022. Body composition and composition of gain of growing beef bulls fed rations with varying energy concentrations. Meat Science, 184, 108685. https://doi.org/10.1016/j.meatsci.2021.108685

J.W. PASTOOR PAS, D.D. LOY PAS, A. TRENKLE, J.D. LAWRENCE. 2012. Comparing fed cattle performance in open lot and bedded confinement feedlot facilities. The Professional Animal Scientist, 28, 410-416

KOCH, R. M., L. A. SWIGER, D. CHAMBERS, AND K. E. GREGORY. 1963. Efficiency of feed use in beef cattle. Journal of Animal Science, 22, 486-494.

KOKNAROGLU, H., D.D. LOY, D.E. WILSON, M.P. HOFFMAN and J.D. LAWRENCE, 2005. Factors affecting beef cattle performance and profitability. Professional Animal Science, 21, 286-296.

KOKNAROGLU, H., DEMIRCAN, V. and YILMAZ, H. 2017. Effect of initial weight on beef cattle performance and profitability. Custos e Agronegocio.13, 26-38.

KOKNAROGLU, H., TURAN, TOKER, M. and BOZKURT, Y. 2006. Effect of Zeolite and Initial Weight on Feedlot Performance of Brown Swiss Cattle. Asian Journal of Animal and Veterinary Advances, 1, 49-54.

KOKNAROGLU, H., LOY PAS, D.D., WILSON, D.E. , HOFFMAN PAS, M.P. and LAWRENCE, J.D. 2005. Factors Affecting Beef Cattle Performance and Profitability. The Professional Animal Scientist, 21, 286-296.

KRESS, D.D. and MACNEIL, M.D. 1999. Crossbreeding beef cattle for western range environments. Ed. II. Montana State University, Bozeman, MT: The Samuel Roberts Noble Foundation Ardmore. Pp 3-23.

KVADSHEIM, P.H., GOTAAS, A.R.L., FOLKOW, L.P., and BLIX, A. S. 1997. An experimental validation of heat loss models for marine mammals. Journal of Theoretical Biology. 184, 15-23. doi: 10.1006/jtbi.1996.0256

LANCASTER, P.A., G.E. CARSTENS, D.H. CREWS JR., T.H. WELSH JR., T.D.A. FORBES, D.W., FORREST, L.O., TEDESCHI, R.D., RANDEL, and ROUQUETTE, F.M. 2009. Phenotypic and genetic relationships of residual feed intake with performance and ultrasound carcass traits in Brangus heifers. Journal of Animal Science, 87, 3887–3896.

LEES, A.M., SEJIAN, V., WALLAGE, A.L., STEEL, C.C., MADER, T.L., LEES, J.C. and GAUGHAN, J.B. 2019. The Impact of Heat Load on Cattle. Animals, 9, 322. doi: 10.3390/ani9060322

LLONCH, P., MAINAU, E., IPHARRAGUERRE, I.R., BARGO, F., TEDÓ, G., BLANCH, M. and MANTECA, X. 2018. Chicken or the Egg: The Reciprocal Association Between Feeding Behavior and Animal Welfare and Their Impact on Productivity in Dairy Cows. Frontiers of Veterinary Science, 5. https://doi.org/10.3389/fvets.2018.00305

LUSH, J.L., 1937. Animal Breeding Plans. Collegiate Press. Inc. Ames.lowa.

MAASZ, D.J. 2006. The effect of supplemented light on certain production parameters of young beef bulls fed intensively. (Unpublished MSc dissertation) Central University of Technology, Free State: Bloemfontein.

MAFURU, M.C., CHIMOYO, M., DZAMA, K. and MAPIYE, C. 2010. Seroprevalence of tick-borne diseases in communal cattle reared on sweet and sour ranglands in semiarid areas of South Africa. The Veterinary Journal, 81, 71-76.

MAFURU, M.C., QOKWENI, I., CHIMOYO, M. & DZAMA, K. 2011. Relationships between tick counts and coat characteristics in Nguni and Bonsmara cattle reared on semiarid rangelands in South Africa. Ticks and Tick-borne Diseases. 2, 172-177.

MAREE, C. and CASEY, N.H. 1993. Livestock Production Systems principles and practice. Brooklyn: Agric-Development Foundation. p. 7

MCCANN, J.C., WILEY, L.M., FORBES, T.D., ROUQUETTE, F.M. and TEDESCHI, L.O. 2013. Relationship between the rumen microbiome and residual feed intake-efficiency of Brahman bulls stocked on Bermudagrass pastures. Plos One 9, e91864.

MCDONAGH M.B., HERD, R.M., RICHARDSON, E.C., ODDY, V.H., ARCHER, J.A., ARTHUR, P.F. 2001. Meat quality and the calpain system of feedlot steers following a single generation of divergent selection for residual feed intake. Australian Journal of Experimental Agriculture, 41, 1013–1021.doi: 10.1071/EA0002

MCINTYRE, B.L., TUDOR, G. D., READ, D., W. SMART, T.J., BOSCA D., SPEIJERS, E.J. and ORCHARD, B. 2009.Effects of growth path, sire type, calving time and sex on growth and carcass characteristics of beef cattle in the agricultural area of Western Australia. Animal Production Science, 49, 504-514. https://doi.org/10.1071/EA08180

MEISSNER, H.H., SCHOLTZ, M.M., and PALMER, A.R. 2013. Sustainability of the South African Livestock Sector towards 2050. Part 1: Worth and impact of the sector. South African Journal of Animal Science, 43, 282-297.

MELKA, H.D., 2001. Genetic parameter estimates for weaning traits in a multibreed beef cattle population. MSc (Agric) thesis, University of Stellenbosch, Stellenbosch, South Africa.

MENDES, E.D., 2010. Characterization of Feeding Behaviour Traits and Associations with Performance and Feed Efficiency in Finishing Beef Cattle. *Animal Science, 2010.* Journal of Animal Science, 89, 2904-2910. doi:10.2527/jas.2010-3489.

MENDES, E.D., G.E. CARSTENS, L.O. TEDESCHI, W.E. PINCHAK, AND T.H. FRIEND. 2011. Validation of a system for monitoring feeding behaviour in beef cattle. Journal of Animal Science, 89, 2904–2910. doi:10.2527/jas.2010-3489.

MILLER, A.J., D FAULKNER, B., KNIPE, R.K., STROHBEHN, D.R., PARRETT, D.F. and BERGER, L.L. 2001. Critical control points for profitability in the cow-calf enterprise. Professional Animal Scientist, 17, 295-302.

MITLOHNER, F.M. MORROW-TESCH, J.L. WILSON, S.C. DAILEY J.W. and MCGLONE, J.J. 2001. Behavioural sampling techniques for feedlot cattle. Journal of Animal Science, 79, 1189-11.

MUCHENJE, V., DZAMA, K., CHIMONYO, M., RAATS, J.G. and STRYDOM, P.E. 2008. Tick susceptibility and its effects on growth performance and carcass characteristics of Nguni, Bonsmara and Angus steers raised on natural pasture. Animal, 2, 298-304.

MUCHENJE, V., MHLANGA, F.N. and MAKUZA, S.M., 1998. Adjusting lactation milk yield of Zimbabwean Holstein dairy cows for the joint effects of age at calving and month of calving. Journal of Applied Science in Southern Africa, 4, 35-42.

NGADIYONO, N., BALIARTI, E., WIDI, T.S. M., MAULANA, H., and ATMOKO, B.A. 2019. Effect of breed and initial body weight on daily weight gain of Simmental Ongole Crossbred Cattle and Ongole Grade Cattle. Earth and Environmental Science, 387. doi:10.1088/1755-1315/387/1/012044

NKRUMAH, J.D., BASARAB, J.A., WANG, Z., LI, C., PRICE, M.A., OKINE, E.K., CREWS, D.H. Jr., and MOORE, S.S. 2007. Genetic and phenotypic relationships of feed intake and measures of efficiency with growth and carcass merit of beef cattle. Journal of Animal Science, 85, 2711–2720. https://doi.org/10.2527/jas.2006-767

NRC. 1996. Predicting Feed Intake of Food-Producing Animals. Natl. Acad. Press, Washington, D.C.

OLIVEIRA, M.D.S., RÊGO, A.C., SFORCINI, M.P.R., FREITAS JÚNIOR, J.E., SANTOS, J. and CARVALHO, M.V. 2012. Bromatological characteristics and in vitro digestibility of four sugarcane varieties subjected or not to the application of quicklime. Acta Science Animal Science, 34, 355-361.

OOSTHUIZEN, P.L. 2016. The profit-maximising feeding period for different breeds of beef cattle. Faculty of Natural and Agricultural Sciences, Department of Agricultural Economics. (Unpublished thesis). University of the Free State, Bloemfontein.

OTTO, M.J., WOODS, A.J. and ABUABARA, Y. 1992. Live weight estimation of cattle by scale and tape - A method comparison study. Tropical Animal Health and Production, 24, 109-114.

PATINO, H.O., MEDEIROS, F.S., PEREIRA, C.H., SWANSON, K.C. and MCMANUS, C. 2015. Productive performance, meat quality and fatty acid profile of steers finished in confinement or supplemented at pasture. Animal, 9, 966–972.

PITCHFORD, W.S. 2000. Improving feed efficiency of beef cattle: what lessons can be learnt from other species? In 'Feed efficiency in beef cattle. Proceedings of the feed efficiency workshop'. (Eds JA Archer, RM Herd, PF Arthur) pp. 19–28. (University of New England: Armidale)

PLASSE, D., FOSSI, H., HOOGENSTEIJN, R., VERDE, O., RODRIGUEZ, R., RODRIGUEZ, M.C. and BASTIDAS, P., 1995. Growth of F1 Bos taurus x Bos indicus vs Bos indicus beef cattle in Venezuela. I. Weights at birth, weaning and 18 months. Journal of Animal Breeding and Genetics, 112, 117-132.

POGORZELSKA-PRZYBYŁEK, P., NOGALSKI, Z., SOBCZUK-SZUL, M. and MOMOT, M. 2001. The effect of gender status on the growth performance, carcass and meat quality traits of young crossbred Holstein-Friesian×Limousin cattle. Animal Bioscience, 4, 914-921. doi: 10.5713/ajas.20.0085.

PRESTON, T.R. and Ve WILLIS, M.B. 1982. Intensive Beef Production. Second ed. Pergamas press, Oxford, England

RABEYA, T., BHUIYAN, A.K.F.H., HABIB, M.A and HOSSAIN, M.S. 2009. Phenotypic and genetic parameters for growth traits in Red Chittagong Cattle of Bangladesh. Journal of Bangladesh Agricultural University 7, 265-271.

RAPHAKA, K. and DZAMA, K. 2009. Sex of calf and age of dam adjustment factors for birth and weaning weight in Tswana and Composite beef cattle breeds in Botswana. South African Journal of Animal Science, 39.

RIAZ, M.Q., SÜDEKUM, K.H., CLAUSS, M. and JAYANEGARA, A. Voluntary feed intake and digestibility of four domestic ruminant species as influenced by dietary constituents: a meta-analysis. Livestock Science, 162, 76-85. doi: 10.1016/j.livsci.2014.01.009.

ROBINSON, D. L., AND V. H. ODDY. 2004. Genetic parameters for feed efficiency, fatness, muscle area and feeding behaviour of feedlot finished beef cattle. Livestock Production Science, 90, 255-270.

SCHOLTZ M.M., BESTER J., MAMABOLO J.M. and RAMSAY, K.A. 2008. Results of the national cattle survey undertaken in South Africa, with emphasis on beef. Applied Animal Husbandry and Rural Development, 1: 1-9.

SCHOLTZ, M.M. and THEUNISSEN. A. 2010. The use of indigenous cattle in terminal crossbreeding to improve beef cattle production in Sub-Saharan Africa. Animal Genetics Research, 33-40.

SCHOLTZ, M.M., MCMANUS, C., LEEUW, K.J., LOUVANDINI, H., SEIXAS, L., DE MELO, D.B., THEUNISSEN, A. and NESER, F.C.W 2013. The effect of global warming on beef production in developing countries of the Southern Hemisphere. Journal of National Science, 5, 106-119.

SCHOLTZ, M.M., PYOOS, G.M, SESHOKA, M.M. and THEUNISSEN, A. 2018. The effect of climate on the pre- and post-weaning performance of different beef cattle genotypes. 12th World Cong. Anim. Prod., 5 - July, Vancouver, Canada. *https://www.eventscribe.com/2018/ASAS-Annual/posteragenda.asp*

SCHOONMAKER, J.P., LOERCH, S.C., FLUHARTY, F.L., ZERBY, H.N. and TURNER, T.B. 2002. Effect of age at feedlot entry on performance and carcass characteristics of bulls and steers. Journal of Animal Science, 80, 2247–2254, https://doi.org/10.1093/ansci/80.9.2247

SCHWARTZKOPF-GENSWEIN, K. S., S. ATWOOD, and T. A. MCALLISTER. 2002. Relationships between bunk attendance, intake and performance of steers and heifers on varying feeding regimes. Applied Animal Behavioural Science, 76, 179-188.

SCHWARTZKOPF-GENSWEIN, K.S., HICKMAN, D.D., SHAH, M.A., KREHBIEL C.R., GENSWEIN, B.M.A., SILASI, R., GIBB, D.G. and MCALLISTER, T.A. 2011. Relationship between feeding behavior and performance of feedlot steers fed barley-based diets. Journal Animal Science, 89, 1180-1192.

SPEAKMAN, J.R. 2018. Chapter 26 - Obesity and thermoregulation. Handbook of Clinical Neurology, 156, 431-443.

SOWELL, B.F., BOWMAN, J.G.P., BRANINEM, M.E. and HUBBERT, M.E. Radio frequency technology to measure feeding behavior and health of feedlot steers.

Applied Animal Behaviour Science, 1998, 59:277–284. doi: 10.1016/S0168-1591(98)00110-5.

SPIES, D.C. 2011. Analysis and quantification of the South African red meat value chain. (Doctoral dissertation). Department of Agricultural Economics, University of the Free State, Bloemfontein.

STEUER, P., SÜDEKUM, K-H., MÜLLER, D.W.H., FRANZ, R., KAANDORP, J., CLAUSS and HUMMEL, J. 2011. Is there an influence of body mass on digesta mean retention time in herbivores? A comparative study on ungulates. Comparative Biochemistry and Physiology, 160,355-36.

THEUNISSEN, A. 2018. Characterization of breed additive and heterosis effects in beef cattle using experimental results. M. Sc. Dissertation. University of the Free State South Africa.

THEUNISSEN. A., SCHOLTZ. M.M., NESER, F.W.C., & MACNEIL, M.D. 2013. Crossbreeding to increase beef production: additive and non-additive effects on weight traits. South African Journal of Animal Science, 43, 143-152.

TOLKAMP, B. J., AND I. KYRIAZAKIS. 1999A. A comparison of five methods that estimate meal criteria for cattle. Animal Science, 69, 501-514.

TOLKAMP, B. J., D. P. N. SCHWEITZER, AND I. KYRIAZAKIS. 2000. The biologically relevant unit for the analysis of short-term feeding behaviour of dairy cows. Journal of Dairy Science, 83, 2057-2068.

VERDE, L.S. and A. TRENKLE, 1987. Concentration of hormones in plasma from cattle with different growth potentials. Journal of Animal Science, 64, 426-432.

VOLPI-AGRECA, G.L., GIELD, M., ALENDE, E.R., BRESSAN, A.B., PORDOMINGO, A.L and PORDOMINGO, J. 2021. Effect of placement weight and days on feed on feedlot cattle performance and carcass traits. Livestock Science 244, 104392.

WEABER, R.L. 2015. Crossbreeding strategies: including terminal vs. maternal crosses. Proceedings, the Range Beef Cow Symposium XXIV November 17, 18 and 19, Loveland, Colorado, USA.

WECKERLY, F.W. 2013. Conspecific body weight, food intake, and rumination time affect food processing and forage behavior. Journal of Mammalogy, 94, 120-126.

WEIK, F., HICKSON, R.E., HICKSON, R.E., MORRIS, S.T., GARRICK, D.J. and ARCHER, J.A. 2022. Genetic Parameters for Growth, Ultrasound and Carcass Traits in New Zealand Beef Cattle and Their Correlations with Maternal Performance. Animals, 12, 25. https://doi.org/10.3390/ani12010025

WELLS, S. 2020. Prediction of the growth performance of feedlot cattle using phenotypic and anthropometric measures. MSc Thesis, University of Pretoria.

YEATES, M. P., B. J. TOLKAMP, AND I. KYRIAZAKIS. 2002. The relationship between meal composition and long-term diet choice. Journal of Animal Science 80, 3165-3178.

YEATES, M.P., TOLKAMP, B.J., ALLCROFT, D.J. and KYRIAZAKIS, I. 2001. The use of mixed distribution models to determine bout criteria for analysis of animal behaviour. Journal of Theoretical Biology, 213, 413-425.

ZOLLER, C. 2023. Recognizing and Managing Heat Stress in Dairy Cattle. Buckeye Dairy News, 24(4).

APPENDICES

APPENDIX A :TUT ethics approval

Tshwane University of Technology

Animal Research Ethics Committee

The TUT Animal Research Ethics Committee is registered in South Africa with the National Health Research Ethics Council (AREC- 010411-009) (Valid until 2021).

December 07, 2021

Ref #: AREC2021/05/001
Name: Mncina S

Ms S Mncina
Department of Animal Production
Faculty of Science

Dear Mncina S,

Decision: Accepted and noted

Name: Mncina S

Project title: Evaluating the resistance of ticks and growth performance on F2 Nguni X Angus Crosses.

Qualification: Master of Agriculture (Animal Science)

Supervisor: Dr B Dube

Co-supervisor: Dr BJ Mtileni

Thank you for submitting your progress report. The TUT AREC takes note and accepts the progress report for the following project:

AREC REF: #AREC202105001

Animal Research Ethics Committee, Tshwane University of Technology, reviewed the project documents virtually at its meeting on November 29, 2022.

The proposed research project may now continue with the proviso that:

1) The researcher/s will conduct the study according to the procedures and methods indicated in the approved proposal, particularly in terms of any undertakings and/or assurances made regarding the confidentiality of the collected data.
2) The proposal will again be submitted to the Committee for prospective ethical clearance if there are any substantial changes from the approved proposal.
3) The Committee must be promptly informed of any serious adverse event and/or termination of the study.
4) The researcher will act within the parameters of any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.

Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants.

Kind regards,

Mrs S Steenkamp-Jonker
Chairperson: Animal Research Ethics Committee
[Ref#: AREC2021/05/001]

We empower people

APPENDIX B :ARC ethics approval

ARC • LNR
Excellence in Research and Development

Date: 09 March 2018

Dear Dr B Dube,

Re: "Detection of QTLs for tick resistance in beef cattle "

Your application for the ethical evaluation of the project entitled "Detection of QTLs for tick resistance in beef cattle" has been finalized and approved; its reference number is APIECI 8/05.

I would like to inform you that the project was evaluated and found to be ethically acceptable.

Please note that should any more amendments or changes be made to the protocol, you are obliged to submit an application to the Animal Ethics Committee. A copy of this application letter approval must be available at the site office where animals are kept, including a copy of the protocol and application.

Regards,

Dr. Klaas-Jan Leeuw

Chairperson ARC-API Animal Ethics Committee