The effect of fenugreek seed cotyledon extract (*Trigonella foenum-graecum L.*) supplementation on feedlot beef cattle production

by
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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third-party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

Globally, beef producers are constantly improving and expanding their production systems to keep up with the demand for beef. Consumer preferences further pressure producers to reduce chemicals as additives in favour of a more natural approach. This natural approach includes the use of effective natural “in-feed” additives to improve parameters like dry matter intake (DMI), feed conversion and manipulating microbe in the rumen to improve the animal productivity and eliminate harmful microorganisms. Consumer concern about the use of growth promoters and “infeed” antibiotics to prevent disease and increased feed efficiency, has propelled animal scientists to research natural alternatives to replace growth promoters and antibiotics. Supplementing animals with fenugreek extract have showed promising improvement in production parameters of dairy cows. A study done by Prof Cruywagen and a student of him, where they included fenugreek extract in the diet of the animals, resulted in increased daily milk yields. This study was conducted to evaluate the effect of dietary fenugreek extract on the production parameters and meat quality of beef feedlot cattle

In the first part of the study, the effect of two different diets were evaluated under feedlot conditions and included a control, without fenugreek and a trial, with 120g of NutrifenPLUS® per animal per day which was included in the basal feedlot diet. NutrifenPLUS® is the commercial product used in the study and is a combination of fenugreek cotyledon extract (*Trigonella foenum Graecum*), fennel seeds (*Foeniculum vulgane*), saw palmetto berries (*Serenoa repens*), brown kelp (*Laminariales*), a natural source of methylsulfonylmethane (MSM) and white distilled vinegar powder. The two diets were fed to 24 Angus bulls (12 bulls per treatment) for 90 experimental days. Starting weight (kg), final weight (kg), DMI (kg/animal/day), total weight gain (kg), average daily gain (kg) and FCR (kg) parameters were determined. The results obtained from the experiment showed no significant differences between the fenugreek and the control treatments in any of the phases for starting weight (kg), final weight (kg), total weight gain (kg), ADG (kg) and FCR. A significant difference ($P< 0.04$) was however observed during the finisher phase (include Zilmax® - zilpaterol hydrochloride) where the total gain was negatively impacted by the addition of fenugreek.

In the second part of the study, the effect of two different diets were evaluated under pasture rearing conditions and consisted of a control group without fenugreek extract and a trial with 120g of NutrifenPLUS® per animal per day in a supplementary basal diet. The two diets were fed to 28 cross-Brahman bulls (14 bulls per treatment) for 90 experimental days. Parameters determined included starting weight (kg), final weight (kg), total weight gain (kg), DMI (kg/animal/day), FCR, feed cost (R), weaner cost (R), carcass income (R) and margin/head (R). The results conducted from the experiment showed no significant differences between

the fenugreek and the control treatments for starting weight (kg), final weight (kg), total weight gain (kg), DMI (kg), FCR (kg), feed cost (R), weaner cost (R), carcass income (R) or the margin/head (R) when compared over the total feed period. The results indicate that the addition of fenugreek had no significant effects on the parameters measured.

The results found in the study suggest that additional research is required to further investigate the effect of dietary fenugreek extract on the production parameters and meat quality of beef cattle. Different rates of inclusion and different circumstances might however produce different results from that of the current study and should be evaluated in future studies.

Opsomming

Beesvleisprodusente is wêreldwyd geforseer om produksie te optimalseer om aan verhoogde beesvleisaanvraag te voldoen. Produsente word verder deur verbruikersaandrang aangemoeding om meer natuurlike byvoegings te gebruik ten einde produktiwiteit te verbeter. Hierdie sluit die gebruik van effektiewe natuurlike bymiddels in veevoer in om droëmateriaal inname (DMI), voerdoeltreffendheid en rumen mikrobiese werking te verbeter ten einde die diere se produktiwiteit te verhoog en om die nadelege effek van skadelike mikroorganismes te verminder.Toenemende verbruikersweerstand teen die gebruik van chemiese groeibevorderaars en antibiotika in veevoere dryf huidige navorsing ten opsigte van natuurliker opsies om steeds aanvaarbare diereprestasie te bewerkstellig. Fenugreekekstrak dieetaanvulling het belowende resultate met melkkoeie (verhoogde melkproduksie) getoon. Prof Cruywagen en sy student het in die bogenoemde studie verhoogde daaglikse melkproduksie in liters per koei per dag ervaar met die insluiting van fenugreekekstrak in die diete van die koeie.

Die eertse deel van die studie is uitgevoer om die effek van fenugreek op produksieparameters en vleiskwaliteit van voerkraalbeeste te evalueer.

Die eerste deel van die studie was daarop gemik om die invloed van twee verskillende diëte in ‘n voerkraal te ondersoek. Dit het bestaan uit ‘n kontrole met geen Fenugreekekstrak en n proef met 120g NutrifenPLUS® per dier per dag in ‘n totaal gemengde dieet. NutrifenPLUS® is fenugreekekstrak (*Trigonella foenum Graecum*) gekombineer met vinkelsade (*Foeniculum vulgane*), Palmetto bessies (*Serenoa repens*), bruin kelp (*Laminariales*), natuurlike bron van metielsulfonielmetaan (MSM) en wit gedistilleerde asynpoeier.Parameters bepaal het aanvangsmassa (kg), finale massa (kg), droëmateriaal inname (DMI) (kg/dierdag), totale massatoename (kg), gemiddelde daaglikse toename (GDT) (kg) en voeromsetverhouding van voerkraal vleisbeeste ingesluit. Die twee diëte is vir 90 dae aan 24 Angus bulle (12 bule per behandeling) gevoer. Die resultate het geen betekenisvolle verskille in aanvangsmassa (kg), finale massa (kg), DMI (kg), gemiddelde daaglikse toename (GDT) (kg) of voeromsetverhouding tussen die fenugreek groep en die kontrole groep vir enige van die verskillende fases aangedui nie. Daar is wel 'n betekenisvolle ($P < 0.04$) verskil in totale massatoename (kg) tydens die afrond met Zilmax® fase, waar die totale groei (kg) negatief deur fenugreek aanvulling beinvloed is.

Die tweede deel van die studie was daarop gemik om die invloed van twee verskillende diëte op weiding te ondersoek. Die kontrole sonder Fenugreek en proefgroep met 120 g NutrifenPLUS®/dier dag ingesluit ‘n basale aanvullende dieet. Parameters bepaal en het aanvangsmassa (kg), finale massa (kg), totale massatoename (kg), DMI (kg/dier/dag),

voeromsetverhouding, weidingskoste (R), speenkalfkoste (R), karkasinkomste (R) en marge/kop (R) ondersoek. Die 2 diëte is vir 90 dae aan 28 Brahman kruisbulle (14 bulle per behandeling) gevoer. Die resultate het geen betekenisvolle verskille in aanvangsmassa (kg), finale massa (kg), totale massatoename (kg), DMI, voeromsettingsverhouding, voerkoste (R), speenkalfkoste (R), karkasinkomste (R) of marge/kop (R) gelewer nie. Hierdie resultate toon dat die insluiting van fenugreek geen betekenisvolle effek op al die gemete parameters uitgeoefen h nie.

Hierdie resultate dui daarop dat verdere toekomstige navorsing nodig is om die invloed van dieet-fenugreek op die produksieparameters en vleiskwaliteit van vleisbeeste te bepaal. Verskillende insluitingpeile van NutrifenPLUS® en onder ander omstandighede mag moontlik verskillende resultate lew en behoort in die toekoms ondersoek te word.

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List of Abbreviations

ADF	Acid Detergent Fibre
ADG	Average Daily Gain
AGP	Antibiotic growth promoter
BW	Body Weight
CP	Crude Protein
DE	Digestible Energy
DM	Dry Matter
DMI	Dry Matter Intake
DWI	Daily Water Intake
EBW	Empty Metabolic Weight
EU	European Union
FAO	Food and Agriculture Organisation
FCR	Feed Conversion Ratio
FCE	Fenugreek Cotyledon Extract
FE	Feed Efficiency
FI	Feed Intake
FSE	Fenugreek Seed Extract
GE	Gross Energy
GPS	Global Positioning System
IU	International Units
LBW	Live Body Weight
LD	*Longissimus Dorsi*
ME	Metabolizable Energy
MP	Metabolizable Protein
NDF	Neutral Detergent Fibre
NEg	Nett Energy for gain
NEm	Nett Energy for maintenance
NPN	Non-Protein Nitrogen
NRC	National Research Council
RPM	Rising Plate Meter
SASAS	South African Society of Animal Science
Ta	Ambient Temperature
TMR	Total Mixed Ration

USDA	United States Department of Agriculture

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Notes

The language and style used in this thesis is in accordance with the *South African Journal of Animal Science,* with changes to increase readability. This thesis represents a compilation of manuscripts, where each chapter is an individual entity; thus, some repetition between chapters has been unavoidable.

CHAPTER 1: General Introduction

1.1 Introduction

Human population has shown explosive growth from as early as the year 1700. The census done by the United States Census Bureau in 1700 showed a human population of six million people and this number of people have exponentially grown to 6.3 billion people recorded in the census done in in the year 2003 (United States Census Bureau, 2003). It took only 47 years, from 1927 to 1974 for the human population to grow by a number of two billion people. During the subsequent 25 years, from 1974 to 1999, the population grew a further two billion people (United States Census Bureau, 2003). According to Cohen (2003) over the last four decades the human population increased two fold.

The Food and Agriculture Organization (FAO) of the United Nations reported that the livestock industry has shown growth unmatched to any other industry (FAO, 2019). Forty percent of the global value of the agricultural output is from the livestock sector. The livestock sector is responsible for the livelihood and food security of 1.3 billion people (FAO, 2019).

According to a report by the Department of Agriculture, Forestry and Fisheries (2015), the beef production industry in South Africa is an agricultural sector that have shown significant growth. The South African beef production sector provides food security to thousands of people and livestock is considered an asset to South Africa (DAFF, 2015).

Animal welfare and ethical animal husbandry practices constantly improved over the last few decades. New methods of pain control, better animal welfare and husbandry and the development of analgesic drugs have been propelled by major food producing companies and consumer and animal welfare activists (Bomzon, 2011). Animal production systems used is associated with some stress (Corkum *et al.*, 1994). The feedlot system is affectively used to get animals to a desired market weight in a shorter period, as the seasons and climate are variable and can make this difficult on an extensive system in the same amount of time. Adaptation problems are therefore often a risk with pasture reared calves or lambs in the feedlot. The animals are often unfamiliar with the new diet, the amount of available feed, higher stocking density, new social groups, exposure to new and more diseases and also more human contact (Waiblinger *et al.*, 2006). It has been postulated that natural additives can improve production parameters and help these animals to adapt better to their new environments (Park & Kim, 2016).

The protein requirement of the ever increasing modern society is drawn to products that is free from harmful substances (Scollan *et al.*, 2006), which could be introduced through growth

enhancers (Lusk *et al.*, 2003). The use of antibiotic growth promoters is more and more a major concern to modern consumers as the consumers have a fear of antibiotics ending up in the product which may lead to human antibiotic resistance (Levy, 1987). The European Union have therefore banned the use of most antibiotic growth enhancers commonly used in animal nutrition (Demir *et al.*, 2005). Due to the banning of these antibiotics, there is pressure on the manufacturers of growth promoters and an increasing demand to find alternatives. Promising alternatives for antibiotic growth promoter use include natural growth promoters like the extracts or concentrated active components from plants (Demir *et al.*, 2005). By using natural additives, animal protein can be produced without traces of any harmful substances which will be considered safer by the consumer (Rahmani & Speer, 2005). According to Williams (2019), promoting and expanding the use of natural additives will result in a more eco-friendly and more sustainable solution to the problem.

For the purpose if this study, Fenugreek (*Trigonella foenum-graecum L. Leguminosae*) will be evaluated as a natural additive in the nutrition of grazing and feedlot cattle. Fenugreek is an historical medicinal plant which is widely cultivated in India and Northern Africa (Basch *et al.*, 2003). The leaves and seeds of the Fenugreek plant for medicinal uses can be prepared in either powdered or oil form (Basch *et al.*, 2003). Fenugreek provides a good source of protein, fat and dietary fibre, which is essential for good gut health for humans and animals (Srinivasan, 2006). Fenugreek has been used in a few studies as a nutritional additive and showed promising increases in production parameters. Early weight gain, dry matter and nitrogen retention with broiler chickens increased with the addition of dietary fenugreek (Park & Kim, 2016). According to Williams (2019), fenugreek encourage feed intake which has a positive impact on the animals' body condition. Broilers fed fenugreek showed improved crypt depth, an increase in villus height and width and a larger surface area for absorption in the small intestine of the bird (Abdel-Rahman *et al.*, 2014). A larger surface area will lead to increased utilization of nutrients (Adil *et al.*, 2015) and better gut health (Petrolli *et al.*, 2012). Fenugreek also showed improved production parameters in dairy cows (Biggs, 2022).

A study was therefore conducted at the University of Stellenbosch to:

- Evaluate the effect of dietary fenugreek (NutrifenPLUS®) on production and profitability parameters of TMR feedlot beef animals
- Evaluate the effect of dietary fenugreek (NutrifenPLUS®) on production and profitability parameters of grass-fed feedlot beef animals
- Evaluate the effect of dietary fenugreek (NutrifenPLUS®) on meat characteristics of TMR feedlot beef.

1.2 References

Abdel-Rahman, H. A., Fathallah, S. I., Helal, M. A., Nafeaa, A. A. &Zahran, I. S. 2014. Effect of turmeric *CurcTrigonella foenum-graecum L. Leguminosae*) and / or bioflavonoid supplementation to the broiler chicks diet and drinking water on the growth performance and intestinal morphometeric parameters. Glob. Vet. 12, 627–635. https://doi.org/10.5829/idosi.gv.2014.12.05.83148.

Adil, S., Qureshi, S. & Pattoo, R. A. 2015. A review on positive effects of fenugreek as feed additive in poultry production. Int. J. Poult. Sci. 14, 664–669. https://doi.org/10.3923/ijps.2015.664.669.

Basch, E., Ulbricht, C., Kuo, G., Szapary, P. & Smith, M. 2003. Therapeutic applications of Fenugreek. Altern. Med. Rev. 8, 20–27. https://doi.org/10.1007/978-1-60327-295-7.

Biggs, S. 2022. The effect of fenugreek seed cotyledon extract on milk yield and composition in Holstein cows. MSc Thesis, Stellenbosch University.

Bomzon, A. 2011. Pain and stress in cattle: A personal perspective. Isr. J. Vet. Med. 66, 12–20. http://www.ijvm.org.il/sites/default/files/4_pain_and_stress_in_cattle.pdf.

Cohen, J. E. 2003. Human Population: The Next Half Century. Science. 302, 1172–1175. https://doi.org/10.1126/science.1088665.

Corkum, M. J., Bate, L. A., Tennessen, T. & Lirette, A. 1994. Consequences of reduction of number of individual feeders on feeding behaviour and stress level of feedlot steers. Appl. Anim. Behav. Sci. 41, 27–35. https://doi.org/10.1016/0168-1591(94)90049-3.

Demir, E., Sarica, Ş., Özcan, M. A. & Suiçmez, M. 2005. The use of natural feed additives as alternative to an antibiotic growth promoter in broiler diets. Arch.Geflügelk 69, 110–116. https://doi.org/10.1080/713655288.

Department of Agriculture, Forestry and Fisheries. 2015. A Profile of the South African Beef Market Value Chain, 3-9. www.daff.gov.za.

FAO, 2019. Climate change and the global dairy cattle sector - the role of the dairy sector in a low-carbon future. Rome. https://www.fao.org/3/CA2929EN/ca2929en.pdf.

Lusk, L.J., Roosen, J. & Fox, A.J, 2003. Demand for beef from cattle administered growth hormones or fed genetically modified corn: A comparison of consumers in France, Germany, the United Kingdom, and the United States. American Journal of Agricultural Economics. 85(1), 16-29. http://hdl.handle.net/10.1111/1467-8276.00100.

Levy, S. B. 1987. Antibiotic use for growth promotion in animals: Ecologic and public health consequences. J. Food Prot. 50, 616–620. https://doi.org/10.4315/0362-028x-50.7.616.

Park, J. H. & Kim, I. H. 2016. Interactive effects of fenugreek (*Trigonella foenum-graecum L.*) seed extract supplementation and dietary metabolisable energy levels on the growth performance, total tract digestibility, blood profiles, and excreta gas emission in broiler chickens. Anim. Prod. Sci. 56, 1677–1682. https://doi.org/10.1071/AN14834.

Petrolli, T. G., Fernando, L., Albino, T., Rostagno, H. S., Gomes, C., Tavernari, F. D. C. & Balbino, E. M. 2012. Herbal extracts in diets for broilers. Rev. Bras. Zootec. 41, 1683–1690. https://doi.org/10.1590/S1516-35982012000700018.

Rahmani, H. R. & Speer, W. 2005. Natural additives influence the performance and humoral immunity of broilers. Int. J. Poult. Sci. 4, 713–717. https://doi.org/10.3923/ijps.2005.713.717.

Scollan, N., Hocquette, J. F., Nuernberg, K., Dannenberger, D., Richardson, I. & Moloney, A. 2006. Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. Meat Sci. 74, 17–33. https://doi.org/10.1016/j.meatsci.2006.05.002.

Srinivasan, K. 2006. Fenugreek (*Trigonella foenum-graecum*): A review of health beneficial physiological effects. Food Rev. Int. 22, 203–224. https://doi.org/10.1080/87559120600586315.

United States Census Bureau. 2003. Historical estimates of world population.

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.-V., Janczak, A. M., Visser, E. K. & Jones, R. B. 2006. Assessing the human–animal relationship in farmed species: A critical review. Appl. Anim. Behav. Sci. 101, 185–242. https://doi.org/10.1016/j.applanim.2006.02.001.

Williams, C. A. 2019. The effect of Nutrifen® and Nutrifen Plus® in the diet of Hy-Line layers on egg production, egg quality and egg shelf life. MSc Thesis, Stellenbosch University, Stellenbosch.

CHAPTER 2: Literature Review

2.1 Natural feed additives.

Beef farmers are encouraged by the community to implement more natural farming practices using medicinal herbs and plants to replace or minimize the use of chemicals as additives to feed of the animals (Griffin *et al.,* 1999). A modern trend is to revert back to the use of effective natural additives in feed to increase feed intake, improve feed utilization and rumen manipulators to optimise productivity and eliminate harmful microorganisms (Ahmed *et al.*, 2009). Some vegetables and fruits contains oils and citric acid properties that inhibit spoilage and pathogenic microorganisms and this prove to have positive effects as an alternative for antimicrobial additives in animal feed (Ahmed *et al.*, 2009). Improvement in the digestibility coefficients of different nutrients is probably due to improved gross activity of rumen microflora, increased immunity alternation in numbers and species of microorganisms in the rumen on inclusion of vegetables and fruit (Aiad *et al.,* 2005; Gupta *et al.,* 2011). The inclusion of vegetables and fruits into diets will lead to increased volatile fatty acids concentrations, higher dry matter intake and ultimately higher gains (Aiad *et al.*, 2005).

An interdependent relationship is established by ruminants with the microorganism within the rumen. The ruminants provide the microorganisms ideal environmental conditions and nutrients to ferment feeds, and these microorganisms break down fibre and synthesise microbes' protein supply while producing volatile fatty acids as energy to the host animal (Calsamiglia *et al.,* 2007). The symbiotic relationship between the ruminant and the microorganism has methane (energy) and ammonia N (protein losses) (Van Nevel & Demeyer, 1988) and ruminant nutritionists have turned their attention to modulating the competition between the different microorganism populations with the main objective to increase the energy and protein efficiency in the rumen of the animals (Calsamiglia *et al.,* 2007). Through optimising the diet formulations of the ruminants and including feed additives that modify the rumen environment and enhance or inhibit specific microbial populations (Tamminga, 1996), have successfully been implemented to address the latter problem. Essential oil compounds with strong antimicrobial activities like Terpenoids and Phenylpropanoids express their resistance against bacteria through interacting with cell membranes (Griffin *et al.,* 1999). The hydrophobic nature of the cyclic hydrocarbons of the bacteria allows the essential oil compounds to accumulate in the lipidic bilayer and occupy the space between the chains of fatty acids (Sikkema, *et al.,* 1994). Conformational changes in the membrane structure are forced through these actions causing fluidification and expansion of the bacteria membrane. Stability of the membrane is lost which leads to the leakage of ions across the cell membrane of the bacteria. A decrease in the transmembrane ionic gradient is caused by these actions.

Bacterial growth is slowed down by the large amounts of energy needed to counterbalance the effects of the compounds on the membrane through ionic pumps (Griffin *et al.,* 1999). Gustafson & Bowen (1997) concluded that essential oils have the potential to coagulate cell constituents by the action of protein denaturation, which is another mechanism of action for the essential oils.

Ahmed *et al.* (2009) conducted a study with natural additives on growing buffalo calves. The calves were fed garlic, onion and lemonade juice as additives. A inclusion level of 2.5% natural additives had a significant positive difference in daily weight gain compared to the control group which did not receive any natural additives (Ahmed *et al.*, 2009).

High grain (80-95% concentrate) diets being fed to beef cattle has brought forward digestive disorders related to ruminal acidosis (Krehbiel *et al.,* 1995). Britton & Stock (1987) defined ruminal acidosis as an array of biochemical and physiological stresses caused by rapid production and absorption of ruminal organic acids. Secondary feedlot disorders like laminitis, polio encephalomalacia, rumenitis and liver abscesses have been proven related to ruminal acidosis (Brent, 1976). Fell & Weekes (1975) concluded that ruminal acidosis may cause keratinization of the ruminal epithelium and this consequence may affect the absorption of volatile fatty acids and other solutes from the rumen. Volatile fatty acids contribute 65 to 75% of the total ME supply in ruminant animals and a reduction in absorption will reduce gain and performance of the animals (Fell & Weekes, 1975). In-feed antibiotics are normaly used to prevent disease and increase the feed efficiency of the animals. There is however, currently a high consumer concern about the use of growth promoters and in-feed antibiotics which has propelled scientists to do research on natural alternatives as alternatives to conventional chemical growth promoters and antibiotics. Recently interest gained popularity within the commercial feed supply chain to use plant extracts as additives in order to increase fermentation and feed effiiency of ruminant animals. Essential oils, which is the extract from plant tissues, are natural secondary metabolites (Benchaar *et al.*, 2006) like saponins and tannins (Benchaar *et al.*, 2008) with antimicrobial capabilities against microorganisms like protozoa, fungi, bacteria and some viruses (Greathead, 2003). Natural additives have positive potential in possibly replacing antibiotics with enhancing animal production, without changing or even improving meat quality of the animals (Ornaghi *et al.,* 2020). Natural compounds vanillin, eugenol and thymol are known to be performance enhancers in animal production (Hausmann *et al.,* 2018). Possible benefits of encapsulating these compounds and adding them to animal feed might have a positive impact on meat quality, since the desired action on the metabolism is placed at the intestinal level (Vinceković *et al.,* 2017). The possibility of absorption of these compounds in the gut and without encapsulation compounds being degraded in the rumen, these compounds might be absorbed and their properties, such as

antioxidant activity and possible being transferred to the meat of the animals (De Oliveira Monteschio *et al.,* 2017). The collaborative effect between natural compounds can possibly increase the antioxidant and antimicrobial effects when these natural compounds are blended. In addition, each compound can perform specific functions (Ornaghi *et al.,* 2020). Therefore, it would be of great value to search for products that improve animal production and bring benefits or do not change the quality of the end product like meat (Rivaroli *et al.,* 2016). In this regard, the development of products that have potential in animal production and maintain or improve the quality of end products like meat, remain a challenge.

Noori *et al.* (2013) evaluated three different feed additives and the reaction these feed additives had on lameness and the performance of the animals. The researchers used 200 Holstein bull calves and these calves were used in a completely randomised design. The experimental period lasted for 42 days, and the calves were group fed a similar basal diet. The three treatments used in the study were (1) basal diet without any feed additives, (2) basal diet plus the addition of 50 g/day bicarbonate sodium, (3) basal diet with the addition of 7 g/day organic micro-mineral complex including amino acid complex of Cu, Zn, Mn and glucoheptonate Co and (4) basal diet with the addition of 3 g/day $ZnSO_4$. The feed additives were top dressed on the basal diet. In the study Dry Matter Intake (DMI), Average Daily Gain (ADG), gain:feed ratio and blood metabolites were evaluated. The DMI of the experimental treatments were not affected significantly. Average daily gain during the total period was affected ($P < 0.05$) by the treatments and had a bigger affect in groups with the addition of organic micro-mineral complex. A similar pattern was observed in the gain:feed ratio ($P < 0.002$). The authors observed that the prevalence of lameness was the highest in the treatment group ($P < 0.05$) that did not receive any feed additives compared to the treatment groups who had feed additive included in the basal diet.

Ran *et al.* (2019) evaluated naturally sourced feed additives that consisted of lactobacillus fermentation products, plant-based enzymes, and prebiotics as possible alternatives to antibiotic promoters in the diets of growing and finishing beef steers. The authors used two commercial products, Bio-Lac Plus and Boviglo as feed additives in the study. For the experiment the researchers used 75 crossbred steers and the steers were blocked by weight and randomly allocated into five treatment groups: control; implant (Elanco-Component TE-100 with Tylan); implant plus antibiotics (330 mg monensin + 110 mg chlortetracycline/steer per day); implant plus Bio-Lac (30 g/steer per day); and Boviglo (5 mL/steer per day). The steers were fed a basal diet which consisted of 600g/kg maize silage, 350g/kg dry rolled barley grain, and 50 g/kg protein, vitamin and mineral supplement (DM basis). The finishing diet were comprised of 100 g/kg maize silage, 870 g/kg dry-rolled barley grain, and 30 g/kg vitamin and mineral supplement (DM basis). No DMI differences were observed during the first 112 days

of the trial, but the researchers did observe a significant difference ($P < 0.05$) in final body weight, ADG and gain:feed ratio when the treatment groups that received additives were compared to the control group that did not receive any additives. The researchers also added that the need to use of therapeutic antimicrobials was lower ($P < 0.01$) for all the treatment groups in comparison with the control treatment. During the finishing period of the experiment, neither Bio-Lac or Boviglo expressed any significant effects on growth performance or carcass characteristics. Greater antioxidant capacities ($P < 0.05$) were observed in the treatments when compared to the control, which indicates that Bio-Lac and Boviglo supplementation improved the ADG and feed efficiency of the steers during the early stressful portion of the growing phase. From these results the authors concluded that Bio-Lac and Boviglo (natural feed additives) have the potential for an alternative to antimicrobial growth promoters in growing steers (Ran *et al.*, 2019).

2.2 Fenugreek.

2.2.1 Characteristics of Fenugreek.

Fenugreek (*Trigonella foenum-graecum L. Leguminosae*) is a historical medicinal plant that originated in India and Northern Africa (Basch *et al.*, 2003). Fenugreek is an annual legume plant growing to a height of 0.61 meter and producing 10 to 20 yellow coloured seeds in each pod (Blank *et al.*, 1997). These seeds, when toasted and grounded, is an essential ingredient in curry powders and other food products like artificial maple syrup, chutneys and pickles (Blank *et al.*, 1997). The leaves and seeds of the Fenugreek plant can be prepared in either powdered or oil form (Basch *et al.*, 2003).

This medicinal plant was used in ancient Egypt to preserve bodies from decay and is still used in Egypt today as a culinary additive (Basch *et al.*, 2003). The ancient Romans used this medicinal plant with woman who were in labour to help with the delivery of the child. The Fenugreek seeds contain the peptide hormone Oxytocin which causes the uterus to contract and help with childbirth (Basch *et al.*, 2003). In China fenugreek is used as a traditional medicine. Chinese culture have used fenugreek to improve a weak physique, treat and cure gout and also to improve weakness of the body (Bahmani *et al.*, 2016). In India, Fenugreek is used as a tonic for a healthy metabolism, to increase the production of milk while lactating and also as a culinary spice (Bahmani *et al.*, 2016). The fenugreek plant has long since found great value as traditional medicine and have also gained therapeutic value (Bahmani *et al.*, 2016).

Today fenugreek is cultivated in a few countries including India, Algeria, Saudi Arabia, Egypt, Pakistan, Turkey, Iran, Spain, Ukraine and Italy (Ahmad *et al.,* 2016).

Fenugreek plants contain a high protein content of 220-250 g/kg (DM) (Bahmani *et al.*, 2016). The seeds are further also rich in vitamins, carbohydrates, fibres, saponins and minerals (Altuntaş *et al.*, 2005). Table 2.3 indicate the nutritional content of the Fenugreek plant. The Fenugreek plant contains relative large amounts of diosgenin, a phytosteriod sapogenin, that increase the release of growth hormones from the pituitary gland (Singh *et al.*, 2013). Sapogenin is a sugar moiety which is glycosidically connected to a hydrophobic aglycone and may occur as a steroid or terpenoid (Jouany & Morgavi, 2007). Diosgenin is further a forerunner in the creation of numerous synthetic steroidal drugs in the pharmaceutical industry (Singh *et al.*, 2013). Many plants including lucerne and soya beans contain saponins and are commonly included in ruminant diets (Jouany & Morgavi, 2007). Fenugreek also contain steroidal saponins (Wina *et al.*, 2005). Saponins reduce ruminal protein degradation rate and increase microbial protein synthesis in the rumen (Makkar & Becker, 1996). According to Makkar & Becker (1996) these effects cause an increased flow of amino acids to the lower intestines and is responsible for higher growth rates observed (Makkar & Becker, 1996). Extracted saponin compounds from *Yucca Schidigera* and *Quillaja Saponaria* showed results of decreasing ruminal protozoa concentrations in an *in vivo* study done. These compounds also showed results in altering the ammonia-N, propionate concentration and the propionate-acetate concentration in the rumen which may enhance the utilization of N (Pen *et al.*, 2006). Fenugreek plant seeds are commonly use in animal feed and human consumption (Dronca *et al.*, 2018). The seeds of the Fenugreek plant is renowned for a bitter taste, but also adopts the taste of maple afterwards (Dronca *et al.*, 2018).

Table 2.1 Nutrient concentration of fenugreek plant adapted from Blumenthal *et al. (*1988)

Nutrient		Concentration
Carbohydrates	Mainly mucilaginous fibre (*galactomannans*)	45 – 60 %
Protein	High levels of lysine and tryptophan	20 – 30 %
Lipids	Fixed oils	5 – 10 %
Pyridine-type alkaloids	Trigonelline	Trigonelline: 0.2 – 0.36 %
	Choline	Choline: 0.5 %
	Gentianine	-
	Carpaine	
Flavonoids	Apigenin Luteolin Orientin Quercetin Vitexin Isovitexin	-
Free Amino Acids	4-Hydroxyisoleucine Arginine Histidine Lysine	4-hydroxyisoleucine: 0.09%
Saponins	Steroidal Saponins	0.6 – 1.7 %
Cholesterol and sitosterol	-	-
Vitamins	A, B1,C and nicotinic acid	-
Volatile oils	Nalkanes Sesquiterpenes	-

2.2.2 Fenugreek as a natural alternative component to animal feed.

The shoots and the seeds of the Fenugreek plant can be used as animal feed additives as these components of the plant are rich with quality bioactive components like proanthocyanins, polyphenols and flavonoids (Dronca *et al.*, 2018).

Fenugreek have been evaluated in a number of studies on broilers to enhance growth and performance birds (Adil *et al.*, 2015). A few studies where Fenugreek have been included as a nutritional additive have produced promising results towards increasing early weight gain, production parameters, dry matter and N-retention with broilers (Park & Kim, 2016).

Fenugreek encourages feed intake (FI) which has a positive impact on body condition (Williams, 2019) Compared to a control diet, broilers fed Fenugreek showed improved crypt depth, increase in villus height and width and a larger surface area for absorption in the small intestine (Abdel-Rahman *et al.*, 2014). The intestinal surface area, which cause the animal to utilize nutrients more efficiently, increase with the addition of Fenugreek compounds (Adil *et al.*, 2015).

Fenugreek with high protein levels and good *in vitro* digestibility can be used as an forage for ruminants (Mir *et al.*, 1997). Fenugreek contains a crude protein value of 179g/kg of DM at 19 weeks after seeding under irrigation conditions (Mir *et al.*, 1998). Mir *et al*. (1998) conducted a study to compare the nutritive value of lucerne and Fenugreek silage in the diets of growing steers. The Fenugreek was harvested after 17 weeks and yielded 14.1 tons per hectare of dry matter. Both the Fenugreek and lucerne was free of any moulds after 40 days in the silo and both remined free of mould after 16 days after being exposed to oxygen. Both silages had low pH values, 4.7 and 4.4 for Alfalfa and Fenugreek respectively, which indicated the two different silages to be of good quality. The Alfalfa silage had a DM% of 34.6% and the Fenugreek silage had a DM% of 38.4%. The two silages had similar acid detergent fiber (ADF) (34.9% of DM for Alfalfa and 35.1% of DM for Fenugreek) , crude protein (CP) (18.0 of DM% for Alfalfa and 17.9% of DM for Fenugreek), *in vitro* gas production and lignin contents (7.8% of DM for Alfalfa and 8.2% of DM for Fenugreek). The ADG, 0.82kg/animal per day for the Alfalfa diet and 0.84kg/animal per day for the Fenugreek diet,and average DMI, 6.4kg/animal per day for the Alfalfa diet and 6.2kg/animal per day for the Fenugreek diet, of both the diets (Fenugreek and lucerne) increased and the feed efficiency improved linearly with the increase of grains in the two diets. The performance parameters of the animals were similar when the two diets were compared. From the study Mir *et al*. (1998) concluded that Fenugreek silage is comparable to lucerne mid-bloom silage in terms of nutritive values. Fenugreek silage, which is a high dry matter yielding legume, can be used effectively(not proven) in a feedlot backgrounding diet (Mir *et al.*, 1998).

Alloui *et al.* (2012) studied the effects of Fenugreek seeds when supplemented as a natural additive to broiler diets. In the he authors compared a basal diet supplemented with antibiotics and a coccidiostat with a basal diet supplemented with fenugreek seeds at a rate of 3g of fenugreek seeds per kg of feed. In this study the researchers recorded live body weight (LBW) at week 3 and 6 of age, the daily DMI of the animals, mortality rate and feed convertion ratio (FCR). The chickens supplemented with fenugreek had significantly higher body weights at week 3 and 6 (Alloui *et al.*, 2012). The Fenugreek treatment group had higher DM ’s and the researchers also reported improved FCR of the fenugreek treatment group in the 6 weeks of the study. No significant differences in slaughter parameters or mortalities between treatments

were however observed (Alloui *et al.*, 2012). Alloui *et al.* (2012) concluded that supplementation of Fenugreek can indeed be benificialy be used as a natural additive. These authors strongly suggest that Fenugreek be used as a feed additive and an alternative to antobiotic growth promoters (Alloui *et al.*, 2012).

Park and Kim (2016) conducted a separate study with broilers with four treatment groups. Day-old Ross 308 male broiler chicks were divided into four dietary treatments with 12 replications, and 16 broilers per replication. Treatments consisted of a 2 x 2 factorial design, with two dietary energy levels (high Metabolizable Energy (ME) of low ME) and two levels of supplemental FSE (0% or 0.1%). The authors measured growth performance, total tract nutrient retention, blood profiles, excreta noxious gas emissions and meat quality. The results obtained from this study showed that the broilers supplemented with 0.1% Fenugreek seed extract (FSE) or high ME during the first 14 days showed improved BW gain, when this treatment was compared to the treatments that received low ME or 0% FSE respectively (Park & Kim, 2016). These results could be attributed to higher stress levels of the birds during the first 14 days. These results would suggest that when fenugreek is fed it can play an important role in mitigating stress in animal production systems.

Supplementing Dairy cows with fenugreek in the diet have showed promising improvement in production parameters (Biggs 2019). From the Fenugreek plant seeds, commercial products like Nutrifen® and NutrifenPLUS® are obtained which are used as a natural additive for animal feed (Williams, 2019).

Nutrifen® is a commercial product composed of fenugreek cotyledon extract (*Trigonella foenum Graecum*), while NutrifenPLUS® consists of 73% fenugreek cotyledon extract (*Trigonella foenum Graecum*), fennel seeds (*Foeniculum vulgane*), saw palmetto berries (*Serenoa repens*), brown kelp (*Laminariales*), a natural source of methylsulfonylmethane (MSM) and white distilled vinegar powder (Williams, 2019).

Smit (2014) studied the effects that Nutrifen® and NutrifenPLUS® (Fenugreek) on the digestibility of feed and the milk production of dairy goats, which included Saanen, Toggenburg and British Alpine goats. In the study, Smit (2014) used 144 lactating dairy goats which were divided into the three treatment groups: the control group, Nutrifen® group and the NutrifenPLUS® group. The goats that received Nutrifen® top dressed over the basal diet, had the highest daily milk yield of the three groups. The milk yield of the latter group differed significantly from the control group but not from the NutrifenPLUS® group. The Nutrifen® group reached a daily milk yield of 4.6 kg in comparison to the NutrifenPLUS® group that peaked at a daily milk yield of 4.3 kg and the control group that reached a daily milk yield of 4.2 kg. (Saanen, Alpine and Toggenburg). No significant differences between the three groups found

when digestibility was considered. The dairy goats digested the feed with fenugreek as efficiently as the goats that received the basal diet without any additives. The DMI for the two treatment groups were higher ($P \leq 0.05$) in this study, which supports the evidence of fenugreek enhancing appetite (Smit, 2014).

Background of beef production. In an article written in Our World in Data, it is stated that global meat production has increased four to five times since 1961 (Ritchie & Roser, 2017). According to these authors, Asia is the continent that produces the largest amount of meat globally (40-45%). Global beef production has doubled in volume since 1961 reaching 68 million tonnes worldwide in 2014 (Ritchie and Roser, 2017).

Globally, feedlot operations are rapidly expanding beef production meet the increased demand. Feedlot operations have significant to the growth in global beef production (Deblitz, 2012). It is predicted that more animals will have to be produced through feedlot systems in an environment of ever increasing grain prices and land shortages (Deblitz, 2012). Most feedlot systems require large amounts of grains and legumes as these represent most of the dietary ingredients (Steinfeld *et al.,* 2006). The demand for feed material (feed grains) has impacted the demand for arable land to use for livestock production and comprised up to 34% of the total arable land in 2006 (Steinfeld *et al.,* 2006).

The National Agricultural Statistic Service of the United States Department of Agriculture (USDA) calculated that 11.9 million animals are being fed in feedlots in the United States alone and that this number increases by 3.2% annually (USDA, 2018). A national total of 1.1 million cattle were fed in Australian feedlots in 2018 (Meat and Livestock Australia, 2018).

According to the South African Feedlot Association, the feedlot industry in South Africa gained popularity in the 1960's. Farmers in the grain producing areas of South Africa were forced to feed their cattle grain and potato by-products in pens due to limited grazing availability during certain times of the year (winter). These farmers utilized experience and technologies from the United States to improve their feedlot systems. The South African Feedlot Association was established in the early 1970's and their members produce about 75% of all the beef in South Africa today. South Africa produces approximately 1.35 million beef carcasses per annum through the feedlot industry (Red Meat Abattoir Association, 2019).

World beef consumption reached a peak of 587.4 million tonnes in 2016, with Uruguay as the largest per capita beef consumer globally at 56.3 kg (Cook, 2019). Argentina is the second largest consumer of beef at 54.5 kg/capita per annum followed by Hong Kong at 51.8 kg/capita per year (Cook, 2019). According to Cook (2019), the ten highest beef consuming countries all have an annual per capita consumption of more than 22.7 kg (2016). The ten highest

ranking beef consuming countries during 2016 were (from high to low): Uruguay, Argentina, Hong Kong, United States, Brazil, Paraguay, Australia, Canada, Kazakhstan and Chile (Cook, 2019). South Africa ranked as the 17th highest consumer of beef with a total national consumption of 2.6 thousand tonnes during 2016. The per capita beef consumption in South Africa reached a total of 16.4 kg/year during 2016 (Cook, 2019). China has seen a drastic development in their beef market between 1996 and 2017. The domestic beef consumption increased with 111% from 3.5 thousand tons of meat in 1996 to 7.3 thousand tons of meat in 2017 (Bunmee *et al.,* 2018).

Beef products are in high demand worldwide, despite uncertainty of the quality before purchasing in stores/supermarkets (Alfnes, 2004). Therefore, consumers buy beef based on factors like colour, fat content, freshness (packaging date), brand, place of purchase and origin of the beef to judge the quality (Alfnes, 2004). Consumers further buy meat according to beliefs, knowledge or experience and this creates variation in consumer preference (Alfnes, 2004). According to Becker (1999), country of origin is the major safety and quality indication amongst European consumers when choosing meat products. In Sweden, a 1984 report revealed that consumer confidence in meat safety declined after it became public that 30 tonnes of antibiotics had been used in feed for animal production worldwide every year. This prompted Sweden to become the first country to regulate the withdrawal of antibiotic growth promoters (AGPs) in feed for animal production in 1986 (Cogliani *et al.,* 2011). Numerous other countries followed suit and increasing public concern regarding the emergence of antibiotic-resistant bacteria and its role in antimicrobial resistance in humans, has led to the ban on the use of growth-promoting antibiotics, including ionophores, in animal feeds in the European Union (EU) as of January 2006 (Regulation No 1831/2003 of the European Parliament, 2003, Perreten, 2003). The main intention was to limit the non-essential use of antibiotics in animal production and to protect the efficacy of important human antibiotics (Perreten, 2003). All EU member states have banned all use of AGPs in 2006 (Pradella *et al.,* 2006).

Feedlots and other cattle production systems have to constantly guard against diseases, such as bovine respiratory disease, and mortality of newly received and weaned cattle (Galyean *et al.,* 1999). These cattle endure high levels of stress when being transported, on arrival at a feedlot or when being marketed (Galyean *et al.,* 1999). Optimum nutrition can aid to reduce these stressors and can alleviate a decrease in DMI that is associated with stress (Galyean *et al.*, 1999). Susceptibility to infections will increase with a decrease of nutrient intake as the immune system is compromised (Galyean *et al.,* 1999). Passive immunity via transfer of immunoglobulins from the cow to the calf is important to decrease the chances of infectious diseases in the calf (Weaver *et al.,* 2000). Stress free animals will consume sufficient amounts

of feed that will maintain adequate energy intake (Galyean *et al.,* 1999). New arrivals in a feedlot normally are subjected to a high stressed environment and often lead to lower net energy intake, resulting in a low capacity for protein deposition (Galyean *et al.,* 1999). Vitamin B supplementation to newly received feedlot or weaned calves enhanced their performance and decrease morbidity levels (Galyean *et al.,* 1999). Vitamin E also showed positive results with increasing performance of calves and lower morbidity levels (Galyean *et al.,* 1999).

The 10 most popular beef breeds in South Africa are listed as Bonsmara, Brahman, Nguni, Beefmaster, Simmentaler, Santa Gertrudis, Angus, Simbra, Drakensberger and the Afrikaner (Scholz *et al.,* 2008). Considering the commercial beef cattle industry of South Africa, commercial feedlots provide the formal sector with more than 70% of the total beef cattle slaughtered in South Africa. Scholtz *et al.* (2008) conducted a survey study in 2003 with 219 commercial feedlots and a total of 218 459 animals. The 5 most popular breeds found in the feedlot survey was listed as Bonsmara, Hereford, Simmentaler, Limousin and SA Angus (Scholz *et al.,* 2008). Bonsmara cattle contributed 15.9%, Hereford cattle 12.7% and Simmentaler 12.3% of the total animals in the feedlot survey respectively (Scholtz *et al.,* 2008).

2.4 ***Dry matter intake (DMI).***

DMI of cattle has a major effect on production (Shaver *et al.*, 1988). A dairy cow trial was done by Shaver *et al.*(1988) to determine particle size distributions of masticated forage, ruminal digesta, and faeces and to evaluate effects of forage physical form, feed intake, and forage fibre content on particle size reduction". The authors of the trial concluded that large amounts of forage in the diet can reduce DMI due to physical restriction of rumen fill. In this study, it was concluded that higher DMI of cows will only be possible if/when the rumen content was discarded quick enough through digestion (Shaver *et al.*, 1988). These authors further investigated the effect of forage chop lengths (particle size) to determine a critical size that would escape the rumen without increasing the retention time in the rumen. The authors experimented with different forage chop lengths and grain coarseness. The passage rate of small particles have an influence in the retention time, and this will have an influence on DMI (Shaver *et al.*, 1988). From these observations Shaver *et al*. (1988) determined a mean critical particle size of minimum 3.6mm for cattle

Natural feed additives are of interest for the effect they have on production parameters like DMI. Yang *et al.* (2010), performed a study on feedlot steers with the objective to evaluate the effects of supplementing the diet of feedlot cattle with cinnamaldehyde on DMI, growth performance, carcass characteristics and blood metabolites. The authors used 70 yearling steers and the animals were assigned to a randomized complete block design with five

treatment groups: control (no additives), monensin (330mg/steer per day), and 400, 800 or 1600 mg of cinnamaldehyde per steer per day. In the first week of the study, DMI declined relative to the DMI before the start of the trial by 27% for the control group, 11% for the medium cinnamaldehyde group, 10% for the high cinnamaldehyde group and 17% for the steers fed monensin. o reduction in DMI for the low cinnamaldehyde group was observed ($P = 0.25$). The DMI thereafter continuously increased ($P < 0.05$) up to week four of the trial, whereafter the DMI reached a plateau. The DMI had significantly ($P = 0.04$) increased for the group that was supplemented with 400mg monensin per steer per day when compared to the control group (Yang *et al.,* 2010).

Benchaar *et al.* (2006), studied the effects of monensin and increasing dose levels of a mixture of essential oil compounds on intake, digestion, and growth performance of beef cattle. The authors conducted two experiments in the study. In experiment one they used 20 heifers and 20 steers (Angus x Hereford) in a random block design. The animals were fed a TMR without supplementation (control), monensin (33mg/kg of DM) or essential oil (2 and 4 g/animal per day). In experiment two the authors used five steers (Angus x Hereford) in a 5 x 5 Latin square design and the animals were fed TMR without supplementation (control), monensin (33g/kg of DM) and essential oil (2, 3 and 4 g/animal per day). The DMI of the animals in experiment one was not affected by the increasing levels of essential oil ($P > 0.05$). In experiment two the DMI of the steers were significantly higher when fed essential oil ($P < 0.05$) when compared to the animals that had no supplementation (control). The DMI increased linearly with the increasing levels of essential oil ($P < 0.05$) (Benchaar *et al.,* 2006). From the study it was inconclusive to the effect of the particular essential oil on DMI (Benchaar *et al.,* 2006).

Grains and roughage are typically processed with a mechanical process to increase digestibility/availability of nutrients and handling and mixing of the ingredient in diets of beef cattle. Promotion of ruminal health and reduction of digestive upsets can be achieved through the inclusion of roughage in the diet of feedlot cattle. Increasing particle size of roughage may allow a decrease in roughage inclusion without sacrificing animal performance (Gentry *et al.,* 2016).

Finishing diets of feedlot cattle that contain high levels of concentrate with the inclusion of forage, may help maintain healthy rumen functions, reduce the risk of acidosis, possibly improve intake of dry matter, stimulate chewing and rumination, and may increase the passing rate of grain (Shain *et al.,* 1999). The physical form (qualitative) and the dietary concentration (quantitative) aspects of dietary fibre are necessary for healthy, normal rumen function (Shain *et al.,* 1999).

Dhiman *et al.* (2002) conducted a study to evaluate the effects of different types of maize processing (exposure of starch) and frequency of feeding on lactating dairy cow performance. No difference in DMI between finely ground maize and steam-flaked maize diets were reported (Dhiman *et al.* 2002). Steam-flaking involves the addition of moisture and heat over time to soften the grain before passing through rollers (Dehghan-banadaky *et al.,* 2007). Steam-flaking increased the digestibility of diets by 6 percent compared to coarsely ground maize and with 3 percent when compared to a finely ground maize diet (Dhiman *et al.* 2002). The cows that received the diets containing steam-flaked maize had a better protein utilization (Dhiman *et al.* 2002). The study also concluded that milk yield of these cows improved as the grain particle size decreased from coarsely ground particles to finely ground particles. No significant differences in DMI between two feeding frequencies (once per day or four times per day) were however found (Dhiman *et al.* 2002). It was, however, reported that with the increased feeding frequency, the Neutral Detergent Fibre (NDF) digestibility increased by 19% with the cows receiving the diets containing finely ground maize and steam-flaked maize (Dhiman *et al.* 2002).

Ruminants consuming forages (extensive production system) will spend 5-10 hours per day feeding and almost the same time ruminating (Baumont *et al.*, 2000). With intensive systems, the animals will receive their feed according to the farmer or manager of that system. According to Baumont *et al.* (2000), with systems, the DMI will reach a maximum when feed is delivered and slowly thereafter until “comfort” is reached. The animals learn from previous occurrences, given feed will stimulate nutritive and sensory recollection and motivate the animals to feed (Baumont *et al.*, 2000). Feed intake is defined as the total amount of feed the animal consume when it is provided *ad libitum* (Baumont *et al.*, 2000). The fill effect of a forage plant increases with the age (with increasing age, higher levels of lignin is formed in the plant, increased NDF content in the plant) and this leads to a decreased DMI (Baumont *et al.*, 2000). This phenomenon is due to increased NDF content resulting in lower NDF digestibility (Baumont *et al.*, 2000).

2.5 Average daily gain (ADG).

Increasing public concern about antibiotic residues and antimicrobial resistance have led to the evaluation of alternative natural feed additives like essential oils and essential oil blends to increase animal performance. Meschiatti *et al.* (2019), evaluated the performance response of finishing feedlot cattle to dietary addition of essential oils and exogenous enzymes. The study comprised of five treatment groups: (DM basis) sodium monensin (26mg/kg); blend of essential oils (90mg/kg); blend of essential oils with monensin (90mg/kg + 26mg/kg, respectively); blend of essential oils with exogenous α-amylase (90 mg/kg + 560 mg/kg,

respectively); and a blend of essential oils plus exogenous α-amylase and exogenous protease (90 mg/kg + 560 mg/kg + 840 mg/kg, respectively). The trial was aimed at the finishing period of a feedlot system and was conducted over a period of 93 days. The authors used 300 Nellore bulls in a randomized complete block design. All the animals that received the blend of essential oils had a significant higher DMI ($P < 0.001$) compared to the animals that just received monensin. The treatment group that received the blend of essential oils plus exogenous α-amylase resulted in 810g increased DMI ($P < 0.001$) and 190g greater ADG ($P < 0.004$) (Meschiatti *et al.,* 2019).

Geraci *et al*. (2012), studied the effects of a mixture of Cinnamaldehyde, Eugenol and Capsicum oleoresin on the performance of feedlot cattle in comparison with feedlot cattle receiving monensin as a control. The trial comprised of 24 Angus steers that were blocked by weight into four groups that were randomly allocated to eight pens of three steers each. The treatment groups were monensin (46.7 mg/kg dietary DM), plant extracts (266 mg/steer per day of Cinnamaldehyde and Eugenol plus 133 mg/steer per day of Capsicum oleoresin) which were added to a mineral mixture. The trial consisted of two periods, day 0-44 and day 45-84, with a total trial period of 84 days. The different diets were fed only once per day and these diets consisted of a maize-grain based concentrate with 200g of lucerne hay per steer/day. In this study DMI, ADG, FCR and rate of backfat deposition were determined throughout the duration of the trial. The second period of the trial yielded a significantly higher ADG ($P < 0.01$) for the treatment group who received the plant extract supplementation in comparison with the treatment group that only received monensin as supplementation (Geraci *et al*., 2012).

The essential oils and compounds that are extracted from specific plant species can exhibit antimicrobial properties. These essential oils can be considered as potential alternatives for antibiotic growth promotors (Lui *et al.,* 2020). Lui *et al.* (2020), evaluated an essential oil and prebiotic blend on the growth, development, and the health status of growing calves. The trial consisted of 40 Holstein new-born calves and the calves were locked by birth date and alternately assigned to one of two treatments. The two treatments comprised of a calf starter pellet which either included the essential oil and prebiotic blend (44.1 parts per million) or not (control). The calves had *ad libitum* access to the calf starter pellet from day three to the end of the 70-day experimental period. The calves also received two litres of whole milk twice daily to the age of 10 days, 3 litres twice daily up to the age of 35 days and then received 3 litres of whole milk only once daily up to the age of 42 days at which point weaning took place. The treatment group which received the essential oils and prebiotic combination yielded a significantly higher ($P < 0.05$) ADG (0.87 kg/day) in comparison with the control group that yielded a ADG of 0.78 kg/day (Lui *et al.,* 2020).

Place *et al.* (1998) investigated the effects of disease, management, and nutrition on ADG of dairy heifers. These authors reported that the amount of DMI of these heifers had a significant effect on the ADG. Results of this study confirmed a correlation of 1kg of DMI per heifer to 0.26kg ADG per heifer.

2.6 Cattle production parameters.

Increased profitability of the enterprise serves as motivation to feedlot operators to animal production. Profitability of any enterprise is dependent on cost of production and income (Pathak *et al*., 2004). Considering feedlots, the cost of feed is a major contributor to cost of production and is often volatile and difficult to manage (De Andrade *et al.,* 2020). Therefore, many feedlot operations focus on animal production to manage income and improved profitability. Profitability is increased when losses and excesses are reduced while income is increased (Pathak *et al.,* 2004; Nkrumah *et al.*, 2006). Genetic variation between beef breeds results in varied feedlot production response and profitability between breeds. Characteristics like average daily weight gain (ADG), birth weight, feed efficiency (FE), DMI, fat marbling and deposition, carcass and meat characteristics will be influenced by the breed of the animal (Cundiff *et al.*, 1986).

2.7 Nutrient requirement of beef cattle.

2.7.1 Energy requirement of beef cattle.

According to the National Research Council (NRC) (2000), the definition of energy is the potential to do work. Considering the discipline of animal nutrition and animal production systems, various approaches are used to explain and describe energy fractions (NRC, 2000).

The amount of available energy to the animal is defined as ME and this value can be used to evaluate the energy value of a feedstuff as well as expressing the energy requirement of animals (NRC, 2000).

Animal maintenance requirement can be defined as the amount of feed energy intake that will result in no net loss or gain of energy from the tissues of the animal body (NRC, 2000). Several factors influence animal maintenance requirements (Tylutki *et al.,* 2008):

- The regulation of body temperature.
- Essential metabolic processes of the body.
- Physical activity of the animal.

The energy required for maintenance is not necessarily equivalent to the energy required to maintain body fat, body protein and body growth (NRC, 2000). It is of value to not compare maintenance energy with the energy needed for production, but to consider these two values

separate from each other (NRC, 2000). Net Energy for maintenance (NE_m) can be calculated with the following equation (NRC, 2000):

$$\mathbf{NE_m = 0.322\ MJ/EBW^{0.75}}$$

Where: EBW = average empty metabolic body weight in kilograms.

Energy expenditure can be due to various reasons (NRC, 2000):

- breed or genotype
- sex
- age
- seasonality
- body weight
- previous feed provided
- temperature and other environmental conditions
- physical state

2.7.2 The Protein requirement of beef cattle.

Metabolizable protein considers the degradation of protein in the rumen and separate the protein requirement of the microorganisms within the rumen and the protein requirement of the animal itself (NRC, 2000). According to the NRC (2000) the definition for metabolizable protein is the "true protein that is absorbed in the intestine, supplied by microbial protein and undegraded intake protein". The metabolizable protein system also includes bacterial crude protein synthesised (NRC, 2000; Tylutki *et al*., 2008). Bacterial crude protein can supply beef cattle of all the metabolizable protein that is required, depending on the undegraded intake protein that is contained in the diet (NRC, 2000). Metabolizable protein requirement for maintenance has been studied by early researchers like Smuts (1935), and more recently by Wilkerson *et al*. (1993). Smuts (1935) calculated the metabolizable protein requirement for beef cattle to be 3.52 g MP/kg $BW^{0.75}$ (MP being metabolizable protein and $BW^{0.75}$ is metabolic body weight) (NRC, 2000). The metabolizable protein requirement was determined at a rate of 3.25 g MP/kg $BW^{0.75}$ (NRC, 2000). Wilkerson *et al*. (1993) focussed on the requirements of growth of calves. Growing calves weighing 253kg was used in the study and the metabolizable protein requirement of these calves was determined at 3.8 g MP/kg $BW^{0.75}$ (Wilkenson *et al.,* 1993).

2.8 Conclusion.

The increasing global demand for beef increases the number of cattle farmed and fed (USDA, 2020), while the trend of moving towards natural growth stimulants is growing. The future of animal nutrition is inevitable going to be influenced by the consumer which in turn will demand more natural production practices (Alfnes, 2004). It is therefore critical for animal scientists to

study and explore natural feed additives that can enhance animal production and efficiency while simultaneously comply with the increasing trend of using antibiotic free growth enhancers (Alfnes, 2004).

Some trial work suggests that Fenugreek and its extracts might be part of a new group of natural feed additives in the basket of products aimed at more natural feedlot production systems. Fenugreek plants contain a high protein content of 220-250 g/kg of DM (Bahmani *et al.*, 2016). The seeds are further also rich in vitamins, carbohydrates, fibres, saponins and minerals (Altuntaş *et al.*, 2005). Table 2.3. indicate the nutritional content of the Fenugreek plant. The Fenugreek plant contains relative large amounts of diosgenin, a phytosteriod sapogenin, that increase the release of growth hormones from the pituitary gland (Singh *et al.*, 2013)

Unfortunately, limited studies have been done on the effect that Fenugreek and its extracts have on the production parameters of beef cattle. For this reason, the current study was regarded as important in aiding the lack of information of the effect that Fenugreek may have on the production parameters of beef cattle.

2.9 References

Abdel-Rahman, H. A., Fathallah, S. I., Helal, M. A., Nafeaa, A. A. & Zahran, I. S. 2014. Effect of turmeric (*Curcuma Longa*), fenugreek (*Trigonella foenum-graecum L*) and / or bioflavonoid supplementation to broiler chicks diet and drinking water on the growth performance and intestinal morphometeric parameters. Glob. Vet. 12, 627–635 https://doi.org/10.5829/idosi.gv.2014.12.05.83148.

Adil, S., Qureshi, S. & Pattoo, R. A. 2015. A review on positive effects of fenugreek as feed additive in poultry production. Int. J. Poult. Sci. 14, 664–669 https://doi.org/10.3923/ijps.2015.664.669.

Ahmed, A. A., Bassuony, N. I., Awad, S. E. S., Aiad, A. M. & Mohamed, S. A. 2009. Adding natural juice of vegetables and fruitage to ruminant diets (B) nutrients utilization, microbial safety and immunity, effect of diets supplemented with lemon, onion and garlic juice fed to growing buffalo calves. World J. Agric. Sci. 5, 456–465.

Ahmad, A., Alghamdi, S. S., Mahmood, K., Afzal, M. 2016. Fenugreek a multipurpose crop: Potentialities and improvements. Saudi Journal of Biological Sciences. 23(2), 300-310. doi.org/10.1016/j.sjbs.2015.09.015.

Aiad, A. M. 2005. The replacement value of canola meal for soybean meal in growing buffalo calves ration. J. Agric. Sci. Mansoura Univ. 6, 3047–3058.

Alfnes, F. 2004. Stated preferences for imported and hormone-treated beef: application of a mixed logit model. Eur. Rev. Agric. Econ. 31, 19–37 https://doi.org/10.1093/erae/31.1.19.

Alloui, N., Aksa, S. B. E. N., Alloui, M. N. & Ibrir, F. 2012. Utilization of Fenugreek (*Trigonella Foenum-Graecum*) as Growth Promoter for Broiler Chickens. J. World's Poult. Res. 2, 25–27.

Altuntaş, E., Özgöz, E. & Taşer, Ö. F. 2005. Some physical properties of fenugreek (*Trigonella foenum-graceum L.*) seeds. J. Food Eng. 71, 37–43 https://doi.org/10.1016/j.jfoodeng.2004.10.015.

Andrade, T. S., Albertini, T. Z., Barioni, L. G., Medeiros, S. R., Millen, D. D., Santos, A. C. R., Goulart, R. S., & Lanna, D. P. D.2020. Perception of consultants, feedlot owners, and packers regarding the optimal economic slaughter endpoint in feedlots: a national survey in Brazil (Part I). Canad. J. Anim. Sci. 100(4), 745-758. https://doi.org/10.1139/cjas-2019-0219.

Bahmani, M., Shirzad, H., Mirhosseini, M., Mesripour, A. & Rafieian-Kopaei, M. 2016. A

Review on Ethnobotanical and Therapeutic Uses of Fenugreek (*Trigonella foenum-graceum L*). J. Evidence-Based Complement. Altern. Med. 21, 53–62 https://doi.org/10.1177/2156587215583405.

Basch, E., Ulbricht, C., Kuo, G., Szapary, P. & Smith, M. 2003. Therapeutic applications of Fenugreek. Altern. Med. Rev. 8, 20–27 https://doi.org/10.1007/978-1-60327-295-7.

Baumont, R., Prache, S., Meuret, M. & Morand-Fehr, P. 2000. How forage characteristics influence behaviour and intake in small ruminants: a review. Livest. Prod. Sci., 11–25 https://doi.org/10.1016/S0301-6226(00)00172-X.

Becker, T. 1999. Country of origin as a cue for quality and safety of fresh meat. Univ. Hohenheim - Inst. Agric. Policy Mark. 17, 188–208.

Benchaar, C., Calsamiglia, S., Chaves, A. V., Fraser, G. R., Colombatto, D., McAllister, T. A. & Beauchemin, K. A. 2008. A review of plant-derived essential oils in ruminant nutrition and production. Anim. Feed Sci. Technol. 145, 209–228 https://doi.org/10.1016/j.anifeedsci.2007.04.014.

Benchaar, C., Duynisveld, J. L. & Charmley, E. 2006. Effects of monensin and increasing dose levels of a mixture of essential oil compounds on intake, digestion and growth performance of beef cattle. Can. J. Anim. Sci. 86, 91–96.

Biggs, S. 2022. The effect of fenugreek seed cotyledon extract on milk yield and composition in Holstein cows. MSc Thesis, Department of Animal Sciences, Stellenbosch University.

Blank, I., Lin, J., Devaud, S., Fumeaux, R. & Fay, L. B. 1997. The Principal Flavor Components of Fenugreek (*Trigonella foenum-graecum L.).* Am. Chem. Soc., 12–28 https://doi.org/10.1021/bk-1997-0660.ch003.

Blumenthal, M., Busse, W. & Amp, R. 1988. Goldberg A.The Complete Commission Monograph: Therapeutic guide to herbal medicines.

Brent, B. E. 1976. Relationship of acidosis to other feedlot ailments. J. Anim. Sci. 43, 930–935 https://doi.org/10.2527/jas1976.434930x.

Britton, R.A. & Stock, R.A., 1987. Acidosis, rate of starch digestion and intake. Annual Report-Oklahoma Agricultural Experiment Station (USA).

Calsamiglia, S., Busquet, M., Cardozo, P. W., Castillejos, L. & Ferret, A. 2007. Invited review: Essential oils as modifiers of rumen microbial fermentation. J. Dairy Sci. 90, 2580–2595 https://doi.org/10.3168/jds.2006-644.

Cook, R. 2019. World beef consumption per capita (Ranking of countries). Beef2Live.

www.beef2live.com

Cogliani, C., Goossens, H. & Greko, C. 2011. Restricting antimicrobial use in food animals: Lessons from Europe. Microbe 6, 274–279 https://doi.org/10.1128/microbe.6.274.1.

Cundiff, L. V., Gregory, K. E., Koch, R. M. & Dickerson, G. E. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperature environment. 3rd World Congr. Genet. Appl. to Livest. Prod. 39, 271–282.

Dehghan-banadaky, M., R. Corbett, and M. Oba. 2007. Effects of barley grain processing on productivity of cattle. Anim. Feed Sci. Technol. 137: 1-24. DOI:10.1016/j.anifeedsci.2006.11.021.

De Oliveira Monteschio, J., de Souza, K. A., Vital, A. C. P., Guerrero, A., Valero, M. V., Kempinski, E. M. B. C., Barcelos, V. C., Nascimento, K. F. & do Prado, I. N. 2017. Clove and rosemary essential oils and encapsuled active principles (eugenol, thymol and vanillin blend) on meat quality of feedlot-finished heifers. Meat Sci. 130, 50–57 https://doi.org/10.1016/j.meatsci.2017.04.002.

Deblitz, C. 2012. Increasing cost of production – effects on commodity prices and the EU competitiveness A g. Agri Benchmark.

Dhiman, T. R., Zaman, M. S., MacQueen, I. S. & Boman, R. L. 2002. Influence of Corn Processing and Frequency of Feeding on Cow Performance,. J. Dairy Sci. 85, 217–226 https://doi.org/10.3168/jds.s0022-0302(02)74070-8.

Dronca, D., Pacala, N., Stef, L., Pet, I., Bencsik, I., Dumitrescu, G., Nicula, M., Marcu, A., Ciochina-petculescu, L., Caraba, V., Oprea, A. & Ahmadi, M. 2018. Fenugreek - a Dietary Alternative Component in Animal Feed., Anim. Sci. Biotechnol. 51, 6–11.

Fell, B.F. & Weekes, T.E.C., 1975. Food intake as a mediator of adaptation in the ruminal epithelium. Digestion and Metabolism in the Ruminant. 101-118.

Galyean, M. L., Perino, L. J. & Duff, G. C. 1999. Interaction of cattle health/immunity and nutrition. J. Anim. Sci. 77, 1120–1134.

Geraci, J. I., Garciarena, A. D., Gagliostro, G. A., Beauchemin, K. A. & Colombatto, D. 2012. Plant extracts containing cinnamaldehyde, eugenol and capsicum oleoresin added to feedlot cattle diets: Ruminal environment, short term intake pattern and animal performance. Anim. Feed Sci. Technol. 176, 123–130 https://doi.org/10.1016/j.anifeedsci.2012.07.015.

Gentry, W. W., Weiss, C. P., Meredith, C. M., Meyer, B. E., Cole, N. A., Tedeschi, L. O.,

McCollum, F. T. & Jennings, J. S. 2016. Effects of roughage inclusion and particle size on digestion and ruminal fermentation characteristics of beef steers. J. Anim. Sci. 94, 4759–4770 https://doi.org/10.2527/jas2016.1330.

Greathead, H. 2003. Plants and plant extracts for improving animal productivity. Proc. Nutr. Soc. 62, 279–290.

Griffin, S.G., Wyllie, S.G., Markham, J.L. & Leach, D.N., 1999. The role of structure and molecular properties of terpenoids in determining their antimicrobial activity. Flavour and Fragrance Journal, 14, 322-332.

Gupta, A., Dixit, A. K., Dixit, P., Mahajan, C. & Shrivastava, A. B. 2011. Incidence of gastro-intestinal parasites in wild ruminants around Jabalpur, India. J. Threat. Taxa 3, 2226–2228 https://doi.org/10.11609/jott.o2431.2226-8.

Gustafson, R. H. & Bowen, R. E. 1997. Antibiotic use in animal agriculture. J. Appl. Microbiol. 83, 531–541 https://doi.org/10.1046/j.1365-2672.1997.00280.x.

Ritchie, H. & Roser, M. 2017 - "Meat and Dairy Production". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/meat-production'

Hausmann, J., Deiner, C., Patra, A. K., Immig, I., Starke, A. & Aschenbach, J. R. 2018. Effects of a combination of plant bioactive lipid compounds and biotin compared with monensin on body condition, energy metabolism and milk performance in transition dairy cows. PLoS One 13, 1–20 https://doi.org/10.1371/journal.pone.0193685.

Jouany, J. P & Morgavi, D. P. 2007. Use of ‘natural’ products as alternatives to antibiotic feed additives in ruminant production. Animal 1, 1443–1466 https://doi.org/10.1017/S1751731107000742.

Krehbiel, C. R., Britton, R. A., Harmon, D. L., Wester, T. J. & Stock, R. A. 1995. The effects of ruminal acidosis on volatile fatty acid absorption and plasma activities of pancreatic enzymes in lambs. J. Anim. Sci. 73, 3111–3121 https://doi.org/10.2527/1995.73103111x.

Liu, T., Chen, H., Bai, Y., Wu, J., Cheng, S., He, B. & Casper, D. P. 2020. Calf starter containing a blend of essential oils and prebiotics affects the growth performance of Holstein calves. J. Dairy Sci. 103, 2315–2323 https://doi.org/10.3168/jds.2019-16647.

Makkar, H. P. S. & Becker, K. 1996. Nutrional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Anim. Feed Sci. Technol. 63, 211–228 https://doi.org/10.1016/S0377-8401(96)01023-1.

Meat and Livestock Australia. 2018. www.mla.com.au.

Meschiatti, M. A. P., Gouvêa, V. N., Pellarin, L. A., Batalha, C. D. A., Biehl, M. V., Acedo, T. S., Dórea, J. R. R., Tamassia, L. F. M., Owens, F. N. & Santos, F. A. P. 2019. Feeding the combination of essential oils and exogenous α-amylase increases performance and carcass production of finishing beef cattle. J. Anim. Sci. 97, 456–471 https://doi.org/10.1093/jas/sky415.

Mir, Z., Acharya, S. N., Mir, P. S., Taylor, W. G., Zaman, M. S., Mears, G. J. & Goonewardene, L. A. 1997. Nutrient composition, *in vitro* gas production and digestibility of fenugreek (*Trigonella foenum - graecum*) and alfalfa forages. Can. J. Anim. Sci. 77, 119–124 https://doi.org/10.4141/a96-061.

Mir, Z., Mir, P. S., Acharya, S. N., Zaman, M. S., Taylor, W. G., Mears, G. J., McAllister, T. A. & Goonewardene, L. A. 1998. Comparison of alfalfa and fenugreek (*Trigonella foenum-graecum*) silages supplemented with barley grain on performance of growing steers. Can. J. Anim. Sci. 78, 343–349 https://doi.org/10.4141/a97-087.

National Research Council 2000. Nutrient Requirements of Beef Cattle: Seventh Revised Edition: Update 2000. Washington, DC: The National Academies Press. https://doi.org/10.17226/9791.

Nkrumah, J. D., Okine, E. K., Mathison, G. W., Schmid, K., Li, C., Basarab, J. A., Price, M. A., Wang, Z. & Moore, S. S. 2006. Relationships of feedlot feed efficiency, performance, and feeding behavior with metabolic rate, methane production, and energy partitioning in beef cattle. J. Anim. Sci. 84, 145–153 https://doi.org/10.2527/2006.841145x.

Noori, G. R., Amanlou, H., Mahjoubi, E., Zahmatkesh, D., Mousavi, S. S. & Shahrami, E. 2013. Top-dressing of the different feed additives is effective to prevent lameness and to increase feedlot cattle performance during a short-term period. J. Appl. Anim. Res. 41, 263–268 https://doi.org/10.1080/09712119.2012.742441.

Ornaghi, M. G., Guerrero, A., Vital, A. C. P., de Souza, K. A., Passetti, R. A. C., Mottin, C., de Araújo Castilho, R., Sañudo, C. & do Prado, I. N. 2020. Improvements in the quality of meat from beef cattle fed natural additives. Meat Sci. 163, 108059 https://doi.org/10.1016/j.meatsci.2020.108059.

Park, J. H. & Kim, I. H. 2016. Interactive effects of fenugreek (*Trigonella foenum-graecum L.*) seed extract supplementation and dietary metabolisable energy levels on the growth performance, total tract digestibility, blood profiles, and excreta gas emission in broiler chickens. Anim. Prod. Sci. 56, 1677–1682 https://doi.org/10.1071/AN14834.

Pathak, S. D., Dilts, D. M. & Biswas, G. 2004. Simulating Growth Dynamics in Complex

Adaptive Supply Networks. Proc. 2004 Winter Simul. Conf.

Pen, B., Sar, C., Mwenya, B., Kuwaki, K., Morikawa, R. & Takahashi, J. 2006. Effects of *Yucca schidigera* and *Quillaja saponaria* extracts on *in vitro* ruminal fermentation and methane emission. Anim. Feed Sci. Technol. 129, 175–186 https://doi.org/10.1016/j.anifeedsci.2006.01.002.

Perreten, V. 2003. Use of antimicrobials in food-producing animals in Switzerland and the European Union (EU). Mitteilungen aus Leb. und Hyg. 94, 155–163.

Place, N. T., Heinrichs, A. J. & .Erb, H. . 1998. The Effects of Disease, Management, and Nutrition on Average Daily Gain of Dairy Heifers from Birth to Four Months. J. Dairy Sci. 81, 1004–1009.

Pradella, G., Anadon, A., Klose, V., Plail, R., Mohni, M., Schatzmayr, G., Spring, P., Montesissa, C. & Calini, F. 2006. Workshop III : 2006 EU Ban on Antibiotics as Feed Additives - Consequences and Perspectives. J. Vet. Pharmacol. Ther. 29, 41–46.

Ran, T., Gomaa, W. M. S., Shen, Y. Z., Saleem, A. M., Yang, W. Z. & McAllister, T. A. 2019. Use of naturally sourced feed additives (lactobacillus fermentation products and enzymes) in growing and finishing steers: Effects on performance, carcass characteristics and blood metabolites. Anim. Feed Sci. Technol. 254 https://doi.org/10.1016/j.anifeedsci.2019.05.013.

Red Meat Abattoir Association. 2019. South African Feedlot Associasion. www.rmaa.co.za.

Rivaroli, D. C., Guerrero, A., Velandia Valero, M., Zawadzki, F., Eiras, C. E., Campo, M. del M., Sañudo, C., Mendes Jorge, A. & Nunes do Prado, I. 2016. Effect of essential oils on meat and fat qualities of crossbred young bulls finished in feedlots. Meat Sci. 121, 278–284 https://doi.org/10.1016/j.meatsci.2016.06.017.

Scholtz, M. M., Bester, J., Mamabolo, J. M. & Ramsay, K. A. 2008. Results of the national cattle survey undertaken in South Africa, with emphasis on beef. Appl. Anim. Husb. Rural Develop. 1, 1-9. https://www.sasas.co.za/wp-content/uploads/2012/10/scholtzgaahrdvol1.08_0.pdf.

Shain, D. H., Stock, R. A., Klopfenstein, T. J. & Herold, D. W. 1999. The effect of forage source and particle size on finishing yearling steer performance and ruminal metabolism. J. Anim. Sci. 77, 1082–1092 https://doi.org/10.2527/1999.7751082x.

Shaver, R. D., Nytes, A. J., Satter, L. D. & Jorgensen, N. A. 1988. Influence of Feed Intake, Forage Physical Form, and Forage Fiber Content on Particle Size of Masticated Forage,

Ruminal Digesta, and Feces of Dairy Cows. J. Dairy Sci. 71, 1566–1572 https://doi.org/10.3168/jds.s0022-0302(88)79720-9.

Sikkema, J., De Bont, J. A. M. & Poolman, B. 1994. Interactions of cyclic hydrocarbons with biological membranes. J. Biol. Chem. 269, 8022–8028 https://doi.org/10.1016/s0021-9258(17)37154-5.

Singh, K. P., Nair, B., Jain, P. K., Naidu, A. K. & Paroha, S. 2013. Variability in the nutraceutical properties of fenugreek (*Trigonella foenum-graecum L.*) seeds. Rev. Colomb. Ciencias Hortícolas 7, 228–239 https://doi.org/10.17584/rcch.2013v7i2.2237.

Smith, H. J. 2014. The effect of a natural feed additive, Fenugreek, on feed digestibility and milk response in dairy goats. Thesis, Department of Animal Sciences, Stellenbosch University.

Smuts, D.B., 1935. The relation between the basal metabolism and the endogenous nitrogen metabolism, with particular reference to the estimation of the maintenance requirement of protein. Journal of Nutrition, 9, 403-433.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & De Haan, C. 2006. Livestock's long shadow: environmental issues and options. FAO. United Nations.

Tamminga, S. 1996. A Review on Environmental Impacts of Nutritional Strategies in Ruminants. J. Anim. Sci. 74, 3112–3124 https://doi.org/10.2527/1996.74123112x.

The National Agricultural Statistic Service of the United States Department of Agriculture (USDA), 2018. www.usda.gov.

Tylutki, T. P., Fox, D. G., Durbal, V. M., Tedeschi, L. O., Russell, J. B., Van Amburgh, M. E., Overton, T. R., Chase, L. E. & Pell, A. N. 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed Sci. Technol. 143, 174–202 https://doi.org/10.1016/j.anifeedsci.2007.05.010.

Van Nevel, C. J. & D. I. Demeyer. 1988. Manipulation of rumen fermentation. The Rumen Microbial Ecosystem. P. N. Hobson, ed. Elsevier Applied Science, New York, NY. 387–443

Vinceković, M., Viskić, M., Jurić, S., Giacometti, J., Bursać Kovačević, D., Putnik, P., Donsì, F., Barba, F. J. & Režek Jambrak, A. 2017. Innovative technologies for encapsulation of Mediterranean plants extracts. Trends Food Sci. Technol. 69, 1–12 https://doi.org/10.1016/j.tifs.2017.08.001.

Weaver, D. M., Tyler, J. W., VanMetre, D. C., Hostetler, D. E. & Barrington, G. M. 2000.

Passive Transfer of Colostral Immunoglobulins in Calves. J. Vet. Intern. Med. 14, 569–577 https://doi.org/10.1111/j.1939-1676.2000.tb02278.x.

Wilkerson, V., Klopfenstein T., Britton R., Stock R. & Miller P. 1993. Metabolizable protein and amino acid requirements of growing cattle. J. Anim. Sci. 71(10): 2777-2784.

Williams, C. A. 2019. The effect of Nutrifen® and Nutrifen Plus® in the diet of Hy-Line layers on egg production, egg quality and egg shelf life. MSc Thesis, Department of Animal Sciences, Stellenbosch University.

Wina, E., Muetzel, S. & Becker, K. 2005. The impact of saponins or saponin-containing plant materials on ruminant production - A review. J. Agric. Food Chem. 53, 8093–8105 https://doi.org/10.1021/jf048053d.

Yang, W. Z., Ametaj, B. N., Benchaar, C., He, M. L. & Beauchemin, K. A. 2010. Cinnamaldehyde in feedlot cattle diets: Intake, growth performance, carcass characteristics, and blood metabolites. J. Anim. Sci. 88, 1082–1092 https://doi.org/10.2527/jas.2008-1608.

CHAPTER 3: The effect of a dietary fenugreek cotyledon extract on the production and meat quality parameters of feedlot beef cattle

3.1 Abstract

Feedlot systems are rapidly expanding and being developed to produce more beef and keep up with the demand of the increasing human population globally. The World Health Organization (2019) encouraged farmers to use a more natural method of production using medicinal herbs and plants to replace or minimize the use of chemicals as additives to feed. This study evaluated the effect of a natural dietary additive, Fenugreek Cotyledon extract (FCE), on the production and meat quality of feedlot beef cattle Twenty-four Angus 10 months old bulls with a mean weight of 261± 39 kg were divided into two groups: Control without Fenugreek (C) and Fenugreek added (FCE). o significant differences were observed between the FCE and C treatments in any of the production phases regarding starting weight, final weight, total weight gain and feed conversion rate (FCR). The results indicated that FCE had no significant effect on final weight or FCR of the experimental animals in the starter, grower and finisher phases. A tendency (P = 0.07) towards tougher meat (higher shear force) was seen in the FCE group and a significant difference (P ≤ 0.05) was observed during the Finisher with Zilmax® phase where the total gain was negatively impacted with the addition of FCR.

3.2 Introduction

Global meat production has quadrupled since 1961 with Asia (40-45%) as the continent that produces the largest amount of meat globally (Ritchie & Roser, 2017) . Beef production alone has doubled since 1961 and in 2014 a total amount of 68 million tonnes of meat were produced worldwide (Ritchie & Roser, 2017).

Globally, feedlot systems are rapidly expanding and being developed to produce more beef and keep up with the demand. According to Agri Benchmark, feedlot systems are contributing significantly to the growth in global beef production (Deblitz, 2012). As grain commodity prices increase combined with an increase in land shortage, more animals will have to be produced through feedlot systems in future (Deblitz, 2012). Feedlot systems require large amounts of grain crops and legumes to effectively feed the animals. According to Steinfeld *et al.* (2006) these feedlots currently use approximately 34% of the global crop production land to produce beef and this number is predicted to linearly increase by 1.2% per annum in the future (FAO, 2019).

Beef products are in high demand worldwide. However, it is not possible for consumers to know the quality of the beef products before purchasing in stores and supermarkets (Alfnes, 2004). For this reason uneducated consumers rely on factors such as the colour, fat content, freshness (package date and expiry date), brand, place of purchase and origin of the beef to judge the quality of the product (Alfnes, 2004). Consumers will also buy meat according to their beliefs, knowledge or experiences and this preferences produces variation between consumer preferability (Alfnes, 2004). European consumers regard country of origin as the most important safety and quality indication to buy meat products (Becker, 1999). In first world countries, beef raised without growth promoting hormones is the preference when compared to beef that is produced with the use of growth promoting hormones (Alfnes, 2004). In Norway, 97% of all the beef purchased is produced without the use of any growth promoting hormones (Alfnes, 2004). Numerous other countries followed suit and increasing public concern regarding the emergence of antibiotic-resistant bacteria and its role in antimicrobial resistance in humans has led to the ban on the use of growth-promoting antibiotics, including ionophores, in animal feed in the European Union (EU) as of January 2006 (Regulation No 1831/2003 of the European Parliament, 2003).

Beef farmers are therefore encouraged to use more natural methods of beef production (Castanon, 2007). It supports the use of medicinal herbs and plants to replace or minimize the use of chemicals as feed additives. These include the use of effective natural additives to increase feed intake, feed utilization, rumen manipulators to improve the animals productivity and also eliminate harmful microorganisms (Ahmed *et al.*, 2009). Current public concern about the use of growth promoters and antibiotics in feeds to prevent diseases and increase feed efficiency have motivated scientists to do research on natural alternatives to growth promoters and antibiotics (Benchaar *et al.*, 2006). These underlying factors have created an interest in feed companies to use plant extracts as additives (Benchaar *et al.*, 2006).

Fenugreek (*Trigonella foenum-graecum L. Leguminosae*) is an historical medicinal plant originating from India and Northern Africa (Kakani & Anwer, 2012). Fenugreek is a legume plant growing to height of 60.1 cm. The leaves and seeds of the Fenugreek plant for medicinal uses can be prepared in either powdered or oil form (Basch *et al.*, 2003). Supplementing animals with Fenugreek products have also shown promising improvements in production parameters (higher milk yields) of dairy cows (Biggs, 2022). From the seeds of the fenugreek plant, commercial products, such as NutrifenPLUS® is obtained which is used as a natural additive in animal feeds (Williams, 2019).

The aims

- Evaluating the effect of dietary Fenugreek (NutrifenPLUS®) on production parameters in the starter, grower, and finisher with Zilpaterol Hydroxide phases of feedlot beef cattle.
- Evaluating the effect of Fenugreek (NutrifenPLUS®) on meat quality parameters in feedlot beef cattle.

3.3 Materials and Methods

3.3.1 Experimental location and climate

The trial was conducted at The Oaks Estate situated near Greyton, Western Cape Province of South Africa. The GPS coordinates for the farm are 19° 40' 50.67" E and 34° 6' 3.256" S with an altitude of 187 meter above sea level. The temperature in Greyton is warm and temperate with a predominantly winter rainfall The temperature varies from an average of 21.1°C during the warmest month (February) to 11.3°C during the coldest month (July). The trial started on the 1st of September 2019 and the cattle were transported to the abattoir on the 30th of November 2019. Greyton receives an average annual rainfall of 490mm. The driest month for Greyton is January with a mean precipitation of 20 mm, whereas August is the wettest month with a mean precipitation of 64 mm.

3.3.2 Experimental animals and husbandry during the feedlot trial

Ethical clearance was obtained from the Animal care and use ethical committee of Stellenbosch University (ACU-2019-9663). The experimental techniques and practices were in accordance with the regulations set out by the ethical committee and the code of conduct of South African Society for Animal Science (SASAS).

Twenty-four Angus bulls (10 months of age) were divided into two groups. Twelve animals were allocated to a control (CON) and twelve animals to the Fenugreek Cotyledon Extract (FCE) treatment, as indicated in Section 3.3.3. All animals were ranked according to starting weight and consecutive pairs were randomly allocated to treatment blocks prior to trial commencement. Both the FCE treatment and CON groups had the same mean body weight of 261 kg at commencement of the trial. The 24 animals used in the trial were selected from a group of 200 bulls to obtain similar breed, age and weight. The animals received a standard feedlot total mixed ration (TMR) daily, offered *ad libitum* and with free access to fresh water. The water troughs in the two camps were cleaned twice weekly, which was the standard farm procedure. Both feedlot camps had an area of 441 m^2 resulting in 36.75 m^2/animal. Both camps had a feed bunk space of 9 m per camp, resulting in 75 cm of feed bunk space per

animal in each camp. The animals were gradually introduced to the treatment supplementation over a 14-day adaptation period. All the animals were provided with a spacious environment and the animals received straw *ad libitum* for the first week to help with the adaptation and to serve as bedding.

3.3.3 Feedlot trial procedure with fenugreek

The control group received the standard farm TMR while the FCE treatment group received NutrifenPLUS® (Emerald seed products, Saskatchewan, Canada), which was mixed by hand into the standard TMR (Table 3.2.) For the first 3 days the FCE treatment animals received 80 g of NutrifenPLUS® per animal per day. From day 4 to day 90 the animals received 120 g of NutrifenPLUS® per animal per day as recommended by the suppliers. The NutrifenPLUS® was spread on top of the of TMR that the animals received daily and mixed into the feed by hand. Both groups began simultaneously on a starter diet fed for 14 days. The starter phase was followed by a grower phase for 14 days and a finisher phase for 28 days. When the animals reached an A2 classification (visual evaluation), both the treatment and control groups entered a finishing phase with Zilmax® (zilpaterol hydrochloride, Merck Animal Health, New Jersey, USA) for 28 days. After the Zilmax® finisher phase all 24 trial animals were fed the finishing diet (without Zilmax®) for a 48-hour withdrawal period before being slaughtered (see Table 3.1.). Zilmax® was fed at 86 g per ton mixed TMR as per standard farm procedure and according to supplier recommendation. All trial groups were fed twice daily at 08h00 and 15h00. Feed fed was recorded daily while weekly refusals allowed weekly average daily intake calculation.

The animals were weighed (full belly) biweekly with a Tru-Test scale (Datamars Livestock, Auckland, New Zealand) accurate to 1kg. At the end of the 90-day growth trial, all the final animal weights (full belly) were determined prior to being transported to the abattoir.

Warm and cold carcass weights as well as the warm and cold pH readings were recorded at the abattoir. Slaughter percentages were then calculated.

Table 3.1 Different diets and the duration the diets that were provided to the animals

Diet	Duration
Starter diet	Two weeks
Grower diet	Two weeks
Finisher diet	28 days (untill animal reach A2 classification)
Finisher diet with β-agonist	Four weeks
Finisher diet	At least 48 hours

3.3.4 Vaccinations and treatment of experimental animals

All the cattle that arrive on The Oaks farm receive the following medicine:
Animals arriving in the months April to September (dosage is dependent on the body weight):

- Bovitech iii® (Intervet (Pty) Ltd., South Africa) For the treatment of Bovine Virus Diarrhoea and Mannheimia haemoltica IRB (Infectious bovine rhinotracheitis)
- Covexin 10® (Cooper Veterinary Products, South Africa) Immunisation against type A, B, C and D *Clostridium perfringens*.
- Bothutrax® (Intervet (Pty) Ltd., South Africa) Immunity against anthrax and botulism.
- Delete All® spray on back of animals (Intervet (Pty) Ltd., South Africa) to help control ticks, variety of flies, mange mites and kills lice.
- Reverin® (Intervet (Pty) Ltd., South Africa) for the treatment of Heartwater and tick-borne gall sickness (anaplasmosis), pneumonia, navel ill, foot rot and joint ill.
- Gardal® (Intervet (Pty) Ltd., South Africa) Against roundworms, milk tapeworm.
  Revalor H® pill behind ear (Intervet (Pty) Ltd., South Africa) A slow releasing growth promotor (trenbolone acetate and oestradiol).

A follow up treatment 14 days after the first treatment was repeated with:

- Bovitech PI® (Intervet (Pty) Ltd., South Africa) to reduce the incidence of morbidity and mortality caused by undifferentiated bovine respiratory diseases (pasteurellosis) associated with *M. (Pasteurella) haemolytica* and BHV-1 (infectious bovine rhinotracheitis - IBR).
- Covexin 10® (Cooper Veterinary Products, South Africa) to ensure an active immunisation against type A, B, C and D *Clostridium perfringens*.

3.3.5 Animal diets during the different phases

Diets were formulated with AMTS.Cattle v 2.1.31 (AMTS LLC, Groton, NY, USA) and mixed on The Oaks farm using a mixer wagon (Seko Industries, Curtarolo, Italy). The respective diets and compositions are depicted in Table 3.2. Feed was delivered at a rate of 15 kg of feed per animal in each camp. Prior to mixing, ingredients were hammer milled (6mm sieve). NutrifenPLUS® powder was weighed out on a Scales Incorporated (JLC – ES) scale and stored in ziplock bags in a dry and safe place until use.

Table 3.2 Formulated ingredient (as is) and nutrient composition (% DM) of the experimental diets.

Item	Starter diet		Grower diet		Finisher diet		Zilmax® diet	
	Control	FCE	Control	FCE	Control	FCE	Control	FCE
Wheat hay	40	40	25	25	20	20	20	20
Hominy chop	395	392	410	407	415	412	415	412
Maize (milled)	70	69	70	69	80	79	80	79
Maize silage	250	248	250	248	240	238	240	238
Apple pomace (wet)	170	169	170	169	170	169	170	169
[1]Commercial [2]HPC	75	74	75	74	75	74	75	740
NutrifenPlus®	0	8	0	8	0	8	0	8
Zilmax®	0	0	0	0	0	0	0	0
Total (kg)	1000	1000	1000	1000	1000	1000	1000	1000
Nutritional values (% DM)								
Moisture (%)	7.4	4.5	3.9	5.2	5.3	5.2	5.7	5.6
Crude protein (%)	11.2	11.9	10.8	11.4	11.9	12.3	12.2	12.2
Crude fat (%)	4.9	5	4.8	5	5.2	5.3	5.7	5.4
NDF (%)	25.3	25.3	27.3	24.3	26.7	25.6	26.7	28.1
ADF (%)	10.4	11.3	13.3	11	15.2	10.5	11.8	12.1
Calcium (%)	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Phosphorous (%)	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ash (%)	4.9	6.1	58.9	5.3	5.4	5.2	5.7	5.8

[1]DM = 88%, CP = 48%, CF = 7,5%; [2]HPC = High Protein Concentrate.

3.3.6 Total mixed ration (TMR), diet sampling and proximate analyses

Samples of the TMR of both treatments and phases (starter, grower, finisher and Zimax finisher) were collected with a single random grab sample repeated 24 times. The grab samples were pooled and stored at 4^0C whereafter proximate analyses were performed at the Department of Animal Sciences, Stellenbosch University. Samples were milled through a standard laboratory mill (Scientec RSA Hammer mill Ser. Nr 372; Centrotec) to pass through a 2 mm screen. The clearly marked samples were stored at 4^0C in airtight Ziplock bags until further used.

Dry matter was determined by forced air oven drying at 100°C for twenty-four hours according to method 934.01 of the AOAC (Feldsine *et al.,* 2002). Crude protein content was determined with a Leco N analyser (model FP 528, St Joseph, Michigan, USA), according to method 990.03 of the AOAC (AOAC, 2002). Ash content was determined by incineration at 500°C for six hours according to method 942.05 of the AOAC (AOAC, 2002). Ether extract content was determined according to AOAC method 920.39 (AOAC, 2002). Neutral Detergent and Acid Detergent Fibre were determined with *an* Ankom^{220} Fiber Analyzer (ANKOM Technology, Fairport, NY, USA). All TMR samples were weighed in triplicate (300 +/- 10 µg) and heat-sealed in fibre filter bags (Ankom F57) of 25 µm porosity. The NDF content of the bag residues (Amok, 2016) was then determined using α-amylase and sodium sulphite (Na_2SO_3) as described by Van Soest *et al.* (1991).

3.3.6 Dressing percentage and carcass pH determination

All the animals were slaughtered at Tomis Abattoir (Hermon, Western Cape RSA). Cold and warm carcass weights were determined whereafter dressing percentages were calculated. Warm carcass pH and temperature data were recorded 15 min after death and a cold carcass pH and temperature recording was taken the following morning of all 24 carcasses. The pH and temperature of each carcass was measured using a Crison pH25 handheld portable pH meter (Lasec (PTY) Ltd, South Africa). Carcass classification was also determined at time of slaughter.

3.3.7 Sampling of meat and analyses

Meat samples were taken from the cold carcass the day after slaughter. A cut was made from the *Longissimus Dorsi (LD)* starting from the 12th rib and continuing 12 cm in length towards the 13th rib on the right-hand side of the loin. All the samples were packed in airtight bags and clearly marked. Prior to analysis the samples were trimmed of any visible connective tissue and fat. The following physical meat quality tests were performed:

3.3.7.1 Meat surface colour

A cut of the *LD* samples (2.5 cm thick) was made and left to bloom for 30 minutes (Honikel, 1998). To measure the meat surface colour, a handheld digital calibrated Colour-guide 45°/0° colorimeter (aperture size 11 mm; illuminant/observer of D65/10°) (BYK-Gardner GmbH, Gerestried, Germany) was used. Three measurements were taken on the bloomed surface of each meat sample to determine the CIE L* (lightness), a* (red-green range) and b* (blue-yellow range) values. The chroma (colour intensity) and hue angle (colour definition) were calculated using a* and b* values (Honikel, 1998):

$$\text{Hue } (°) = \tan\text{-}1\ (b^*/a^*)$$

$$\text{Chroma } (C^*) = ((a^*)2 + (b^*)2)\text{-}0.5$$

3.3.7.2 Cooking Loss

A cut of the *LD* samples (2.5 cm thick) was made to evaluate cooking loss. This sample was put in a polyethylene bag and placed into a hot water bath (80°C) to cook for 60 minutes. The bags were successively removed and any accumulated water in the bag was drained and removed. The samples were then placed in cold water to cool down for an hour followed by removal from the polyethylene bag and any water dried of the sample using a paper towel. The dried and cooled samples were successively weighed whereafter cooking loss was calculated as the difference in weight from uncooked to cooked and presented as a percentage (Honikel, 1998).

3.3.7.3 Shear force

The Warner-Bratzler shear force method (Honikel, 1998) was used to measure the shear-force of the cooked samples (section 3.3.8.2). Three cuts of the cooked *LD* samples were made from each sample with a 2.5 cm core and 1.27 cm in diameter. These cuts were made parallel to the fibres of the meat and an Instron universal testing instrument (Instron model 4444/H1028, Appollo Scientific cc, South Africa) fitted with a Warner-Bratzler attachment with a 1 mm thick triangular blade with a semi-circular cutting edge was used to cut the core sample perpendicular to the grain. The Instron instrument was set to operate with a load cell of 2.000 kN at a speed of 200 mm /min. The mean shear force values per sample obtained were then expressed in Newton (N).

3.3.7.4 Meat proximate analysis

For the chemical analysis, an uncooked sample of *LD* sample (4 cm thick) was homogenised. The same methods of analysis as described in section 3.3.5 were followed DM, CP and ash

determination. The total fat of the meat samples was measured using the Chloroform/Methanol method as described by Chong *et al*., 1996.

3.3.8 Statistical analysis

The animals in this study were randomly blocked within treatment. The data from the study was analysed using a mixed model analysis of variance (ANOVA) with RStudio (1.4.1103, 2021) (Nel, 2021, Centre for Statistical Analysis, Stellenbosch University). Because feed DMI was only determined per group, and as there was only one group per treatment, no statistical analyses could be done to determine treatment effect on feed intake. According to an ANOVA, it was established that the initial mean bodyweight of the groups did not differ significantly. Additionally, a Levene's test was done to determine whether the variances of the initial weights were also homogeneous (Schultz, 1985). Because the latter was confirmed, it was accepted that treatment was the only other factor that affected feed intake during the trial. Under such conditions it is valid to use individual body weights and group mean DMI to determine feed efficiency values per animal (Nel, 2021, Centre for Statistical Analysis, Stellenbosch University). These values were then analysed according to a Repeated Measures ANOVA (RMANOVA) over time. Significant differences between means were tested using a Bonferoni test (Samuels, 1989). A probability value of $P \leq 0.05$ statistically significant (5% level of significance) between treatments while tendencies were declared at $P \leq 0.10$.

3.4 Results and Discussion

3.4.1 Body weight and efficiency of feed conversion in different phases

Results of body weight changes and efficiency of feed conversion observed in the different phases are presented in Table 3.3.

No significant differences were observed between the Fenugreek (FCE) and the control (CON) treatments in any of the phases for starting weight, final weight, total weight gain, ADG and FCR. An exception was a higher total weight gain ($P = 0.04$) for the CON treatment in the Zilmax® phase (Table 3.3). These results indicate that NutrifenPLUS® had no significant effect on final weight, ADG nor FCR of the experimental animals in the starter, grower and finisher phases. A significant difference ($P \leq 0.05$) was observed during the Finisher with Zilmax® phase where the total gain was negatively impacted by the addition of FCE. The total gain observed in the CON and FCE treatments in the Zilmax phase were 68.7±5 and 58.2±15, respectively.

The absence of a difference in starting weight between the two treatments was to be expected as the animals were assigned to comparable treatment blocks as explained in section 3.3.2

and 3.3.3. Because it was established that the initial body weight of the two groups was homogenous (refer to the statistical analysis section), it was accepted that treatment would be the only other factor that would have affected feed intake during the trial. Therefore, individual body weights and group mean DMI values were used to determine the efficiency of feed conversion per animal. Mean DMI for the control treatment and the FCE treatment were calculated as 3.03 kg and 2.76 kg, respectively. Kirkubakaran *et al*. (2016) conducted a study on the influence of dietary fenugreek, garlic and black pepper on production parameters of broiler chickens. In the latter study, the fenugreek treatment resulted in lower DMI and body weight (Kirubakaran *et al.*, 2016). In a study by Abduljawad (2015) where obese rats were given a high fat diet containing high levels of protein and co-supplemented with Fenugreek seed, it was concluded that the treatment group which received a high fat diet with high protein levels and supplemented with Fenugreek seed powder showed a significant decrease in bodyweight gain and lower DMI in comparison with the control group. Studies by Kirkubakaran *et al.,* 2016 and Abduljawad, 2015 found results that are similar and support the results of the present study. See Table 3.3. These results are most likely due to Fenugreek that reduce absorption and remove carbohydrates from the body before the carbohydrates enter the bloodstream and finally result in weight loss of the animal (Petit *et al.*, 1995). Fenugreek seed contains high levels of soluble fibre which can form gelatinous structures and cause an increase in retention time or delayed gastric emptying (Hannan *et al.*, 2007), slowing down of digestion and absorption of nutrients and finally cause a feeling of fullness in the animals (Petit *et al.*, 1995). This may cause a decrease in DMI of the animals fed fenugreek seed (Petit *et al.*, 1995). Shah & Mir (2004) reported that DMI between two treatment groups, the control group that received a TMR and a Fenugreek treatment group received a TMR replacing 20% of the DM of the control TMR with crushed fenugreek seed (on DM basis) and the diets were fed three times daily, did not differ significantly.

Handa *et al.* (2005) speculated that Fenugreek seed extract can act as an anti-obesity agent in experimental mice. Fenugreek seed extract can also decrease adipose tissue while adipose tissue is considered to contribute to liveweight gain in animals. This may explain the non-significant difference in ADG between the treatment groups (Fiems *et al.*, 2000). Fenugreek further significantly decreased lipid accumulation in the liver of mice (Handa *et al.*, 2005). Notably, only the weight of lipidic tissue was decreased which indicates that Fenugreek seed extract reduced the body weight gain of animals by the inhibition of fat accumulating and not by the toxicity of the fenugreek extract (Handa *et al.*, 2005). Handa *et al.* (2005) suggested that the decrease in body weight was due to the reduction of plasma triglyceride gain by 4-hydroxyisoleucine. These results indicates that 4-hydroxyisoleucine is one of many active compounds found in the extract of Fenugreek seeds (Handa *et al.*, 2005). Fenugreek extract

possesses anti-proliferative actions and this inhibits the formation of new adipocytes in the muscles of the animals (Ghorbani *et al.*, 2014). To elucidate other active compounds, further studies should be done on the Fenugreek seed extract (Handa *et al.*, 2005). Zilmax® (β-adrenergic agonist) increases the growth of animals through the stimulation of protein synthesis (Mersmann, 1998). In contrast Zilpaterol increases lipolysis which leads to a decrease in accumulation of fat in the carcass of the animals (Mersmann, 1998). The effect of the Zilpaterol in combination with the fenugreek supplementation may explain the significant difference in total weight gain between the two treatments where the Fenugreek treatment group exhibited significantly less weight gained in that period of the present study. The results found are in accordance with the studies done by Kirkubakaran *et al.* (2016), Abduljawad (2015).

Table 3.3 The average (± standard error) starting weight, final weight, total weight gain, Feed Conversion Ratio (FCR) and Average Daily Gain (ADG) of the control and fenugreek treatments

Item	Starter			Grower			Finisher			Zilmax®		
	Control	FCE	*P* value	Control	FCE	*P* value	Control	FCE	*P* value	Control	FCE	*P* value
Start weight (kg)	261±22	261±25	**0.35**	310±30	305±30	**0.29**	342±32	338±32	**0.63**	396±29	395±35	**0.87**
Final weight (kg)	310±29	307±30	**0.71**	342±32	338±32	**0.63**	396±29	395±35	**0.87**	465±28	453±39	**0.42**
Total gain (kg)	47±12	46±22	**0.91**	32±10	34±10	**0.63**	54±7	57±11	**0.56**	69±5	58±15	**0.04***
DMI (kg)	9±0	8±0		10±0	9±0		11±0	10±0		13±0	12±0	
FCR (kg)	3.1±1.0	3.2±1.4	**0.87**	4.9±1.8	4.5±2.8	**0.72**	5.9±0.9	5.3±1.2	**0.21**	6.6±0.4	7.7±2.5	**0.18**
ADG (kg)	3.0±1.6	2.9±3.7	**0.73**	2.0±1.6	2.1±1.5	**0.5**	2.1±3.0	2.4±2.0	**0.37**	2.4±1.1	2.0±2.9	**0.13**

***P* value ≤ 0.05, which indicates a significant difference between the treatments for the Gain(kg) parameter.**

3.4.2 Parameters monitored over the duration of the feedlot trial

Results of body weight changes, feed conversion ratio, total intake and the different costs involved observed over the total period are presented in Table 3.4. No significant differences were observed between the FCE and the control treatments over the total feedlot period when starting weight, end weight, total weight gain, ADG, FCR, carcass classification, the weaner cost (R), carcass income (R) and the margin/head (R) were considered (see Table 3.4).

Table 3.4 The average (±standard error) start weight, final weight, total weight gain, total intake, FCR, carcass classification, weaner cost (R), carcass income (R) and the margin/head (R) of the control and FCE treatments over the total feedlot period

Item	Treatment		*P* value
	Control	FCE	
Start weight (kg)	263.4±23	261±12	**0.95**
Final weight (kg)	464.4±28	453.1±39	**0.42**
Total gain (kg)	201.3±17	191.3±38	**0.45**
FCR (kg)	4.7±0.4	4.9±1	**0.59**
ADG (kg)	2.3±0.2	2.2±0.4	**0.45**
Dressing %	56.6±7	57.0±10	**0.88**
Carcass classification	2.2±0.4	2.2±0.5	**0.93**
Weaner cost (R)	7466.4±647	7420.6±676	**0.95**
Carcass cost (R)	11244.2±798	10957.4±821	**0.42**
Margin/Head (R)	1282.8±840	1231.9±1084	**0.9**

These results indicate that FCE had no significant effect on any of the parameters. Notably over the total period of the present study there was not a significant difference in total weight gain irrespective of the difference observed during the Zilmax® finisher phase (as discussed and explained in the previous section). These results suggest that the combination of FCE and zilpaterol supplementation had a bigger effect than just FCE supplementation on the weight gained by the animals when compared to the Finisher phase results where no zilpaterol were present. The lack of difference at starting weight was already explained in the previous section and was expected due to the procedure followed when animals were allocated to the treatments. The final weight, total weight gain and ADG over the total period of the present study also did not differ. This result may be explained by the discussion in the previous section. The difference in average final weight between the control group and the FCE group was 11.3kg with the control group having the heavier final weight at the end of the trial. The control group gained an average of 10kg more than the FCE group over the total period. The average ADG for the control group over the total period of the trial was 2.37kg and the FCE had an

average of 2.35kg over the total period. These results are in accordance with South African feedlot figures and may be part of the better results recorded in the South African feedlots (Strydom, 2008). The lack of a significant difference in ADG in the current study is in accordance with a study done by Nasri *et al.* (2011), who fed saponin extract from *Quillaja Saponaria* to lambs and Fenugreek compounds are also rich in saponins (Sauvaire *et al.,* 1991; Arivalagan *et al.,* 2013). No significant differences in ADG was also reported between the lamb treatments when Fenugreek was compared to a control (Nasri *et al.*, 2011). As all the experimental animals in the current study originated from the same origin and was bought at the same time and were selected to be of the same weight, it is to be expected that no significant differences in weaner cost between the two treatments would exist. Carcass income and margin/head is a function of final weight, market price, dressing % and feed cost (Kluyts *et al.*, 2007). The lack of differences in these parameters will explain the lack of differences in income and margin between treatments. This indicates that the animals were purchased for almost the same price per treatment and the carcasses of the two treatments generated almost similar income. There were no significant differences in carcass classification between the two treatments and this helps to explain the lack of significant differences for carcass income and margin/head. The lack of significant differences in carcass classification and total weight gained contrasts with results of Abbas *et al.* (2012), who reported lower gut fat accumulation when Fenugreek was compared to a control.

3.4.3 Characterization of meat quality

Results of warm carcass, cold carcass, cooking loss %, meat colour (L), (a), (b), shear force (N), crude protein (%), crude fat (%), moisture (%) and ash (%) of the control and the FCE treatments observed over the total period are presented in Table 3.5. The results are comparable to those typically found in South African feedlots (Strydom, 2008). There were no significant differences observed between the FCE and the control treatments when meat parameters were taken into consideration. A tendency (P = 0.07) to a higher shear force was observed in the treatment. The FCE treatment shear force was ±12 N higher compared to that of the control. These results indicate that the use of dietary FCE may have to result in tougher meat when compared to meat originating from animals that did not receive any FCE in the diet. It was expected that both the control and FCE treatments will have elevated shear force values as it is well documented that dietary Zilpaterol addition lead to elevated shear force values (Lean *et al.,* 2014).

In the current study no significant differences were found between the two treatments for warm and cold carcass weight and these results is in accordance with the studies done by Abbas *et al.* (2012) and Salama *et al.* (2015). Abbas *et al.* (2012) weighed the cuts of meat after the

carcass had cooled down and found no significant difference in the weights of the different cuts of meat between when FCE was fed compared to a control. Similarly, the lack of significance with cooking loss between the two treatments is also in correspondence with the study done by Abbas *et al.* (2012).

The lack of differences of meat CP, moisture, intermuscular fat and ash content between the control and FCE treatment is supported by work of Salama *et al.* (2015) on the dietary effect of fenugreek on male goat kid meat quality. The FCE treatment group in the current study did show a numerically lower average fat content (Table 3.5) and this may be explained by a known inhibitory effect of fenugreek seed on carcass fat accumulation (Handa *et al.*, 2005). From Table 3.5 a tendency (P = 0.07) towards tougher meat (higher shear force) were observed. Work of Handa *et al.* (2005) and Ueda *et al*. (2007) supports the results of the current study.

Table 3.5 Average (±standard error) warm carcass, cold carcass, cooking loss %, meat colour (L), (a), (b), shear force (N), crude protein (%), crude fat (%), moisture (%) and ash (%) of the control and the FCE treatments

Item	Treatment		*P* value
	Control	FCE	
Warm Carcass (kg)	263.2±18	256.7±19	**0.43**
Cold Carcass (kg)	255.5±18	249.0±19	**0.42**
Cooking Loss %	64.0±7	67.5±6	**0.2**
Meat Colour (L)	40.2±4	40.4±2	**0.87**
Mear Colour (a)	11.5±3	10.1±1	**0.12**
Meat Colour (b)	12.5±3	11.6±1	**0.32**
Shear Force (N)	38.0±10	50.4±19	**0.07**
Protein %	98.3±1	97.7±2	**0.34**
Fat %	1.8±1	1.4±0.4	**0.13**
Moisture%	75.7±1	75.9±1	**0.7**
Ash %	1.1±0.2	1.2±0.1	**0.15**

The structure of intramuscular connective tissue and matrix metalloproteinases in the longissimus muscle is reported to be disrupted by adipose tissue deposits (Nishimura *et al.*, 1999) and in contrast adipocyte differentiation, which is suppressed by fenugreek extract (Ghorbani *et al.*, 2014), increased the tenderness of the meat (Phillips *et al.*, 2000; Bouloumié *et al.*, 2001). The results from these researchers could explain the tendency in the shear force results in the current study. There were no significant differences for meat colour (L), (a) and

(b) between the control and FCE carcasses as the animals were of similar age, sex, experienced the same environmental conditions, fed the same basal TMR diets, slaughtered the same day and experienced the same stress levels while being handled. These similarities therefor also led to the lack of differences in the average pH for warm and cold carcasses between the two treatments and was expected (Priolo *et al.*, 2001). These results may conclude that dietary FCE had a very limited effect on meat quality parameters when fed to beef cattle in a feedlot environment.

3.5 Conclusion

The results from the present study indicate that FCE (NutrifenPLUS®) at an inclusion level of 120g/animal per day had no significant effect on the growth parameters evaluated through the starter, grower, finisher, and finisher with Zilmax® phases, except for total weight gained during the finisher with the Zilmax® phase. The significant difference seen in total weight gained in the finisher with ZIlmax® phase of the study could be attributed to a combination of FCE and ZIlmax® and the combined effects these products have on fat accumulation. Although the meat fat content did not show any significant differences in the meat samples collected, gut fat accumulation could have been reduced by the combined effects of FCE and Zilmax®. It may be worthwhile for future studies to remove zilpaterol from the diet and study the effect of FCE without zilpaterol being present in the diet. With consumer resistance increasing against antibiotic use in animal production and possible law enforcement against the use of antibiotics in animal production, FCE may be a possible replacement for antibiotic growth promoters in the future. For this reason, further studies with FCE and other natural additives like FCE should continue. Future studies should include gut fat content measurement as well. NutrifenPLUS® had no positive or negative effects at the inclusion level of 120g/animal/day of NutrifenPLUS® on the meat quality of the animals. All the meat quality parameters evaluated, except shear force, in the study showed no significant effect between the control or treatment. Shear force showed a tendency towards tougher meat when FCE was fed compared to the control.

3.6 References

Abbas, S. F., El-ati, M. N. A. & Allam, F. M. 2012. Effect of Dietary Fenugreek Seeds on Growth and Carcass. Egypt. J. Nutr. Feed. 15, 91–101.

Abduljawad, S. H. 2015. The ameliorative effect of fenugreek (*Trigonella Foenum-graecum L.*) seeds on obese albino rats. Adv. Environ. Biol. 9, 26–32.

Ahmed, A. A., Bassuony, N. I., Awad, S. E. S., Aiad, A. M. & Mohamed, S. A. 2009. Adding natural juice of vegetables and fruitage to ruminant diets (B) nutrients utilization, microbial safety and immunity, effect of diets supplemented with lemon, onion and garlic juice fed to growing buffalo calves. World J. Agric. Sci. 5, 456–465.

Alfnes, F. 2004. Stated preferences for imported and hormone-treated beef: application of a mixed logit model. Eur. Rev. Agric. Econ. 31, 19–37 https://doi.org/10.1093/erae/31.1.19.

Arivalagan, M., Gangopadhyay, K. K., Kumar, G. 2013. Determination of Steroidal Saponins and Fixed Oil Content in Fenugreek (Trigonella foenum-graecum) Genotypes. Indian J Pharm Sci. 75(1), 110-3. doi: 10.4103/0250-474X.113542.

Basch, E., Ulbricht, C., Kuo, G., Szapary, P. & Smith, M. 2003. Therapeutic applications of Fenugreek. Altern. Med. Rev. 8, 20–27 https://doi.org/10.1007/978-1-60327-295-7.

Becker, T. 1999. Country of origin as a cue for quality and safety of fresh meat. Univ. Hohenheim - Inst. Agric. Policy Mark. 17, 188–208.

Benchaar, C., Calsamiglia, S., Chaves, A. V., Fraser, G. R., Colombatto, D., McAllister, T. A. & Beauchemin, K. A. 2008. A review of plant-derived essential oils in ruminant nutrition and production. Anim. Feed Sci. Technol. 145, 209–228 https://doi.org/10.1016/j.anifeedsci.2007.04.014.

Biggs, S. 2019. The effect of fenugreek seed cotyledon extract on milk yield and composition in Holstein cows. Thesis, Department of Animal Sciences, Stellenbosch University.

Bouloumié, A., Sengenès, C., Portolan, G., Galitzky, J. & Lafontan, M. 2001. Adipocyte Produces Matrix Metalloproteinases 2 and 9 Involvement in Adipose Differentiation. Diabetes 50, 2080–2086 https://doi.org/10.2337/diabetes.50.9.2080.

Castanon, J. I. R. 2007. History of the use of antibiotic as growth promoters in European poultry feeds. Poult. Sci. 86, 2466–2471 https://doi.org/10.3382/ps.2007-00249.

Chong, M. L., Belzahet, T. & Mayuree, C. 1996. A Simple and Rapid Solvent Extraction Method for Determining Total Lipids in Fish Tissue. J. AOAC Int. 79, 487–492.

Deblitz, C. 2012. Increasing cost of production – effects on commodity prices and the EU competitiveness A g. Agri Benchmark.

FAO. 2019. Climate change and the global dairy cattle sector - The role of the dairy sector in a low-carbon future. https://www.fao.org/3/CA2929EN/ca2929en.pdf.

Feldsine, P., Abeyta, C. & Andrews, W. H. 2002. AOAC International methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. J. AOAC Int. 85, 1187–1200 https://doi.org/10.1093/jaoac/85.5.1187.

Fiems, L. O., De Campeneere, S., De Smet, S., Van De Voorde, G., Vanacker, J. M. & Boucqué, C. V. 2000. Relationship between fat depots in carcasses of beef bulls and effect on meat colour and tenderness. Meat Sci. 56, 41–47 https://doi.org/10.1016/S0309-1740(00)00017-6.

Ghorbani, A., Hadjzadeh, M. A. R., Rajaei, Z. & Zendehbad, S. B. 2014. Effects of fenugreek seeds on adipogenesis and lipolysis in normal and diabetic rats. Pakistan J. Biol. Sci. 17, 523–528 https://doi.org/10.3923/pjbs.2014.523.528.

Handa, T., Yamaguchi, K., Sono, Y. & Yazawa, K. 2005. Effects of fenugreek seed extract in obese mice fed a high-fat diet. Biosci. Biotechnol. Biochem. 69, 1186–1188 https://doi.org/10.1271/bbb.69.1186.

Hannan, J. M. A., Ali, L., Rokeya, B., Khaleque, J., Akhter, M., Flatt, P. R. & Abdel-Wahab, Y. H. A. 2007. Soluble dietary fibre fraction of *Trigonella foenum-graecum* (fenugreek) seed improves glucose homeostasis in animal models of type 1 and type 2 diabetes by delaying carbohydrate digestion and absorption, and enhancing insulin action. Br. J. Nutr. 97, 514–521 https://doi.org/10.1017/S0007114507657869.

Honikel, K.O., 1998. Reference methods for the assessment of physical characteristics of meat. Meat science, 49(4), pp.447-457.

Kakani, R.K. & Anwer, M.M., 2012. Fenugreek. In Handbook of herbs and spices. 286-298. Woodhead Publishing.

Kirubakaran, A., Moorthy, M., Chitra, R. & Prabakar, G. 2016. Influence of combinations of fenugreek, garlic, and black pepper powder on production traits of the broilers. Vet. World 9, 470–474 https://doi.org/10.14202/vetworld.2016.470-474.

Kluyts, J. F., Neser, F. W. C. & Bradfield, M. J. 2007. Derivation of economic value for the Simmetaler breed in South Africa. S. Afr. J. Anim. Sci. 37, 107–121.

Lean, I. J., Thompson, J. M. & Dunshea, F. R. 2014. A meta-analysis of zilpaterol and ractopamine effects on feedlot performance, carcass traits and shear strength of meat in cattle. PloS one, 9(12), e115904. https://doi.org/10.1371/journal.pone.0115904.

Mersmann, H. J. 1998. Overview of the Effects of β-adrenergic Receptor Agonists on Animal Growth Including Mechanisms of Action 1 , 2 , 3 , 4. J. Anim. Sci. Sci. 76, 160–172.

Nasri, S., Ben Salem, H., Vasta, V., Abidi, S., Makkar, H. P. S. & Priolo, A. 2011. Effect of increasing levels of Quillaja saponaria on digestion, growth and meat quality of Barbarine lamb. Anim. Feed Sci. Technol. 164, 71–78 https://doi.org/10.1016/j.anifeedsci.2010.12.005.

Nel, D. 2012. Centre for Statistical Analysis, Stellenbosch University.

Nishimura, T., Hattori, A. & Takahashi, K. 1999. Structural changes in intramuscular connective tissue during the fattening of Japanese Black cattle: Effect of marbling on beef tenderization. J. Anim. Sci. 77, 93–104 https://doi.org/10.2527/1999.77193x.

Petit, P. R., Sauvaire, Y. D., Hillaire-Buys, D. M., Leconte, O. M., Baissac, Y. G., Ponsin, G. R. & Ribes, G. R. 1995. Steroid saponins from fenugreek seeds: Extraction, purification, and pharmacological investigation on feeding behavior and plasma cholesterol. Steroids 60, 674–680 https://doi.org/10.1016/0039-128X(95)00090-D.

Phillips, A. L., Means, W. J., Kalchayanand, N., McCormick, R. J. & Miller, K. W. 2000. Bovine placental protease specificity toward muscle connective tissue proteins. J. Anim. Sci. 78, 1861–1866 https://doi.org/10.2527/2000.7871861x.

Priolo, A., Micol, D. & Agabriel, J. 2001. Effects of grass feeding systems on ruminant meat colour and flavour. A review. Anim. Res. 50, 185–200 https://doi.org/10.1051/animres:2001125.

Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003R1831&rid=10.

Ritchie, H. & Roser, M. 2017. Meat and Dairy Production. Published online at OurWorldInData.org. https://ourworldindata.org/meat-production.

Salama, R., Found, S. M., El-Sysy, A. I. & Gomaa, A. S. 2015. Effect of adding Fenugreek seeds to goat rations and age at weaning on the fattening performance and carcass characteristics of Baladi male kids. Egypt. J. Nutr. Feed. 18, 55–63.

Samuels, M. L., 1989. Statistics for the Life Sciences. Collier MacMillan Publishers, London.

Sauvaire, Y., Ribes, G., Baccou, J. C. & Loubatieres-Mariani, M. M. 1991. Implication of steroid saponins and sapogenins in the hypocholesterolemic effect of fenugreek. Lipids 26, 191–197 https://doi.org/10.1007/BF02543970.Schultz, B.B., 1985. Levene's test for relative variation. Systematic Zoology, 34(4), pp.449-456.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & De Haan, C. 2006. Livestock's long shadow: environmental issues and options. 32-33.

Strydom, P. E. 2008. Do indigenous Southern African cattle breeds have the right genetics for commercial production of quality meat? Meat Sci. 80, 86–93 https://doi.org/10.1016/j.meatsci.2008.04.017.

Ueda, Y., Watanabe, A., Higuchi, M., Shingu, H., Kushibiki, S. & Shinoda, M. 2007. Effects of intramuscular fat deposition on the beef traits of Japanese Black steers (Wagyu). Anim. Sci. J. 78, 189–194 https://doi.org/10.1111/j.1740-0929.2007.00424.x.

Van Soest, P. J., Robertson, J. B. & Lewis, B. A. 1991. Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition. J. Dairy Sci. 74, 3583–3597 https://doi.org/10.3168/jds.S0022-0302(91)78551-2.

Williams, C. A. 2019. The effect of Nutrifen® and Nutrifen Plus® in the diet of Hy-Line layers on egg production, egg quality and egg shelf life. Thesis, Department of Animal Sciences, Stellenbosch University.

CHAPTER 4: The effect of supplements containing FCE on production and financial parameters of pasture fed beef bulls

4.1 Abstract

Large amounts of grains in the diets of beef animals raised in the conventional intensive production systems automatically lead to increased grain dependency. The agricultural sector provides food for over 7 billion people, however, could have negative effects on the environment through intensive production practice. The use of natural production systems like pasture fed systems may benefit human health, animal health and ethics and decrease the impact of environmental pollution. The effect of a natural dietary additive, Fenugreek, on the production of pasture fed beef cattle was evaluated in this study. Twenty-eight 10-month-old Brahman-cross bulls divided into two treatment groups were used fourteen animals were allocated to a control and fourteen animals to Fenugreek treatment. No significant production differences were observed between the Fenugreek and the control treatments over the total feed period for starting weight (kg), end weight (kg), gain(kg), total dry matter intake (kg), feed conversion rate (FCR) (kg), feed cost (R), weaner cost (R), carcass income (R) and the margin/head (R).

4.2 Introduction

Globally the conventional way of producing beef is through intensive feedlot production systems and this include large amounts of grains in the diets of the animals (Clancy, 2006). Grain producers need to supply the increasing demand for beef globally which could lead to water and air pollution (Clancy, 2006). Examples of air pollution would be from methane production due to the fermentation process in the rumen (Lusk, 1998). Water and ground pollution would be from the runoff of fertilizers, herbicides and pesticides used on the grain fields required to supply grain to the feedlots (Clancy, 2006).

With the use of antibiotics as growth promoters, there is an concerning risk of antibiotic resistance development in humans (Menkem *et al.,* 2018). As a consequence the European Union have banned the use of most antibiotic growth enhancers in animal nutrition (Demir *et al.,* 2005). Due to the banning of these antibiotics, there is pressure on the manufacturers of growth promoters and an increasing demand to find alternatives. Promising alternatives for antibiotic growth promoter use include natural growth promoters like the extracts or concentrated active components from plants (Demir *et al.*, 2005).

The use of more natural production systems like pasture rearing systems may increase human health, animal health and decrease the impact of environmental pollution (Stampa *et al.*, 2020). From a human health point of view, beef produced on diets that contain high grain levels have decreased levels of unsaturated fats that could contribute to human health (Hall, 2009). Beef animals fattened on pasture, produce lower levels of total fat, higher levels of omega-3 fatty acid alpha-linolenic acid, eicosapentaenoic acid and docosahexaenoic acid (Daley *et al.*, 2010). These fatty acids are also known as beneficial fatty acids as they have beneficial contributions to human health (Daley *et al.*, 2010). Beef animals that are reared on a well-managed pasture system will contribute to increased soil fertility, increase water quality, improve human and animal health (Abhishek *et al.*, 2014).

The Fenugreek plant is considered to be an excellent alternative forage to alfalfa and other legumes for ruminants (Basu *et al.*, 2008). If Fenugreek is cultivated under favourable conditions, it results in material that is rich in protein, vitamins, and amino acids (Altuntaş *et al.*, 2005). The Fenugreek plant contains relative large amounts of diosgenin, a phytosteriod sapogenin, that increase the release of growth hormones from the pituitary gland (Singh *et al.*, 2013). Sapogenin is a sugar moiety which is glycosidically connected to a hydrophobic aglycone and may occur as a steroid or terpenoid (Jouany & Morgavi, 2007). Diosgenin is further a forerunner in the creation of numerous synthetic steroidal drugs in the pharmaceutical industry (Singh *et al.*, 2013). Many plants including lucerne and soya beans, contain saponins and are commonly included in ruminant nutrition (Jouany & Morgavi, 2007). Fenugreek contain steroidal saponins (Wina *et al.*, 2005). Saponins reduce ruminal protein degradation rate and increase microbial protein synthesis in the rumen (Makkar & Becker, 1996). According to Makkar & Becker (1996) these effects cause an increased flow of amino acids to the lower intestines and is responsible for higher growth rates observed (Makkar & Becker, 1996). Supplementing animals with Fenugreek in the diet have also showed promising improvement in production parameters of dairy cows (Biggs, 2019). The nutritive values of the Fenugreek plant can be compared to the nutritive values of alfalfa in early-bloom and the effects on rumen conditions, weight gain by cattle and the digestibility of the material (Mir *et al.*, 1998). Fenugreek is a bloat free legume which is very desirable with cattle farming (Basu *et al.*, 2014). Cattle fed Fenugreek displayed increased efficiency of fermentation which leads to lower levels of methane gasses produced by these cattle (Goel *et al.*, 2008). Therefore cattle fed Fenugreek may be considered to be more environmental friendly (Goel *et al.*, 2008).

The aim

- Evaluating the effect of supplementing pasture fed beef cattle with natural Fenugreek Cotyledon Extract on the production and financial parameters of beef bulls.

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4.3 Materials and methods

4.3.1 Experimental location and climate

The trial was conducted at The Oaks Estate situated near Greyton, Western Cape province of South Africa. The GPS coordinates for the farm are 19° 40' 50.67" E and 34° 6' 3.256" S with an altitude of 187 meter above sea level. The temperature in Greyton is warm and temperate with predominantly winter rainfall. Greyton receives an average yearly rainfall of 490mm. The driest month for Greyton is January with a perception of 20mm average and August being the wettest month with an average perception of 64mm. The temperature varies from an average of 21.1°C which is in the warmest month, February, to 11.3°C in the coldest month July (Greyton climate, 2019). The trial started on the 1st of September 2019 and the cattle were transported to the abattoir on the 30 November 2019.

4.3.2 Experimental animals and husbandry during the pasture trial

Ethical clearance was obtained from the ethical committee of Stellenbosch University (ACU-2019-9663). The experimental techniques and practices were in accordance with the regulations set out by the ethical committee and the code of conduct of South African Society for Animal Science (SASAS).

Twenty-eight cross-Brahman bulls (10 months of age) were randomly allocated two groups. Fourteen animals were allocated to a control group and fourteen animals were allocated to a FCE (NutrifenPLUS®) (Emerald seed products, Saskatchewan, Canada) treatment. All the animals were blocked according to weight and randomly allocated to treatment prior to trial commencement. Both the FCE treatment and the control group animals started the trial on a mean weight of 276kg. The 28 animals used in the trial were selected from a group of 200 to be of similar breed, age, and weight. All the animals received supplementary feed at a total intake of 5kg/animal per day between 17h00 and 18h00 daily. The animals had *ad libitum* access to irrigated ryegrass (*Lolium perenne*) pastures daily and had *ad libitum* access to fresh clean water. The supplementary feed was provided in drainable troughs (to prevent urea poisoning) with ample space to allow a maximum of four animals to feed simultaneous. Six throughs were made available per treatment, resulting in 24 "feeding allowable spaces". This "oversupply of feed space" was done to prevent any chance of competition. The water throughs were cleaned every second day (farm procedure). All the animals had space (0.021ha/animal per day) to roam freely.

4.3.3 Trial procedure with fenugreek

The control group received the standard farm supplementary feed mix, used for the animals on pasture and the FCE treatment groups received NutrifenPLUS® hand mixed into the same formulated supplementary mix as the control (Table 4.1). The 28 animals were weighed and ranked blocked according to weight whereafter they were randomly allocated to treatment. The two experimental groups received similar (quantity and quality) *ad libitum* irrigated ryegrass (*Lolium perenne*) grazing. For the first 3 days the FCE treatment animals received 80g NutrifenPLUS® per animal per day. Day 4 to day 90 the animals received 120g NutrifenPLUS® per animal per day as recommended by the suppliers. The FCE was spread on top of the of supplementary feed the animals received daily and mixed in by hand. A 3.6 ha area was contained on the farm and divided into six camps per treatment group resulting in 12 equally sized camps in total that had an average size of 0.3 ha per camp. Irrigation poles were set up every 15m from each other, parallel and diagonal, for the 3.6 ha area. The layout of the camps ensured that the two treatment groups had access to the same amount and quality of pasture. As sufficient camps were available and the quality did not differ, the rotational grazing system therefore allowed the animals to be rotated to the alternative group's camps. Each camp was irrigated after the cattle were moved to a fresh camp or when the farm manager advised to do so. The cattle were rotated to fresh camps according to DM availability. The cattle were restricted within the camps to paddocks with the aid of electrical fencing (Agri 25km Solar Energizer, Nemtek, Randburg, South Africa) and rotated to fresh camps on a weekly basis using pasture DM yield to determine the rotation. The pasture DM yield was determined by determining the pasture height with a rising plate meter (RPM) (NZ Agriworks Ltd, Jenquip, New Zealand). All camps DM availability was determined before and after grazing.

4.3.3.1 Rising plate meter calibration and DM yield prediction

Prior to DM determination, a standard regression curve was established by calibration of the RPM. Thirty-five measurements were used for calibration. Measurements between 5 and 20 cm were used to calculate the regression before grazing and measurements between 6 and 11 cm were used to calculate the regression after grazing. A metal ring of the same known area (0.166 m^2) as the RPM was placed on random areas on the pasture (Earle & McGowan, 1979). The grass inside the metal ring was cut down to 3 cm and the grass were collected. The collected grass was placed in a bag and weighed to the nearest 1g by an Electronic Compact Scale (Adam Equipment S.A., Johannesburg, South Africa). Accurate digital moisture determination was done in duplicate at 120°C by a Radwag moisture analyser (NDC Technologies, Irwindale, California, USA. Model Max50/NH) to calculate the DM content of

the specific pasture. These DM values were fitted to a linear equation (Earle & McGowan, 1979) to predict pasture DM yield (kg/ha) per hectare:

$$Y = (a \times H) + b$$

Where: Y = DM yield (kg/ha)

a = gradient

H =recorded height of the RPM

b = intercept value

The standard regression curve established on the experimental pasture:

$$Y = 21.869x+768.81$$

This DM yield prediction linear equation was used to measure and record the DM availability of the camps and to ensure the animals have sufficient *ad libitum* pasture available to graze.

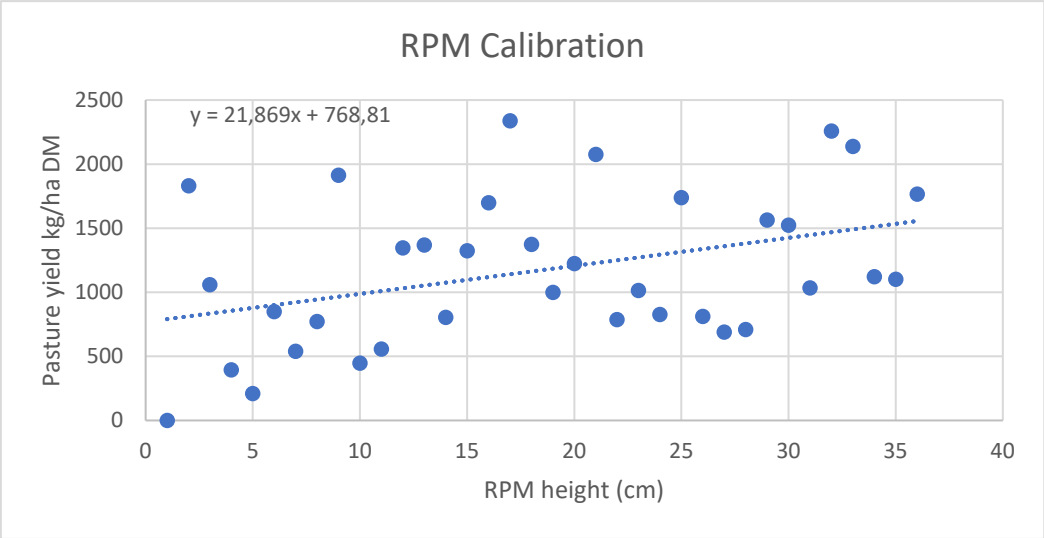

Figure 4.1 Scatter plot of measurements made to calibrate Rising Plate Meter (RPM) on experimental pasture (Earle & McGowan, 1979).

4.3.3.2 Pasture DM determination and management of animals

The RPM data was recorded weekly while the animals were grazing to calculate DM yield and DM availability. This was done by taking 70 readings per treatment paddock weekly (Swanepoel, 2020). The 70 readings were taken in a zig-zag pattern from the bottom of the paddock towards the top part of the paddock and each reading was taken approximately 10m from each other. Measurements were taken in the morning between 07h00 and 09h00. The after-grazing measurements were used as an indication of grazing DM availability and whether

it was necessary to move the treatment group to the new paddocks. In this study the animals were moved to the new paddock when a minimum pasture height of 6.21 ± 3.81cm was reached. Irvine *et al*. (2010) suggested an accepted after grazing pasture height of 5 to 6cm and the minimum in this study adheres to this value. According to the standard regression curve established on the experimental pasture, a minimum of 6.21cm in pasture height would calculate to an available pasture yield of 904.61kg/ha DM. The animals in the study were managed on a rotational grazing basis and this system was used to ensure sufficient regrowth during the resting periods to ensure high quality pasture yields. After the animals were removed from a grazed camp, it was fertilized with Urea Nitrogen (AmiPLUS +S, Yara International, Oslo, Norway) at a rate of 80kg of fertiliser per ha as per recommended by farmer and irrigated. Each camp received the fertilizer once, as the animals grazed each camp twice during the 90-day study allowing a minimum of 30 days for regrowth. After all the camps were grazed once, the treatment groups were switched between the camps so that the treatment groups would not graze the same camp twice during the study. Twenty-four grass grab samples were collected for proximate analysis (See Section 4.3.6.).

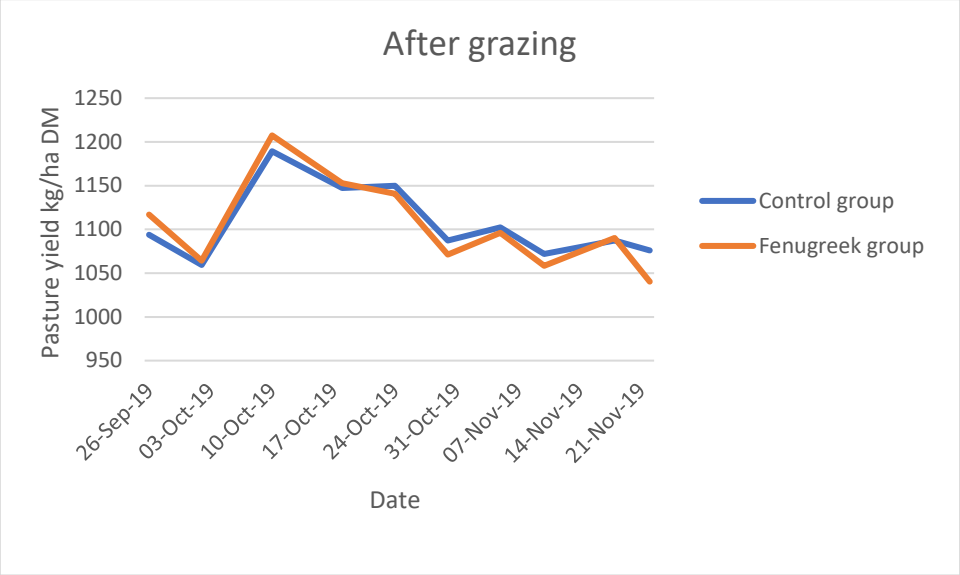

Figure 4.2 Pasture yield (kg DM/ha) after grazing over the experimental period.

The cattle were weighed (full belly) biweekly with a Tru-Test scale (Datamars Livestock, Auckland, New Zealand) accurate to ±1kg. At the end of the 90-day growth trial, all the final animal weights (full belly) were determined prior to being transported to the abattoir.

Warm and cold carcass weights and pH readings of the warm carcass were recorded at the abattoir. Slaughter percentages were then calculated.

4.3.4 Vaccinations and treatment of experimental animals

All cattle that arrived on The Oaks farm were processed as:
Animals arriving in the months April to September (dosage is dependent on the body weight):

- Bovitech iii® (Intervet (Pty) Ltd., South Africa) Prevention of Bovine Virus Diarrhoea and Mannheimia haemoltica IRB (Infectious bovine rhinotracheitis)
- Covexin 10® (Cooper Veterinary Products, South Africa) Immunisation against type A, B, C and D *Clostridium perfringens*.
- Bothutrax® (Intervet (Pty) Ltd., South Africa) Immunity against anthrax and botulism.
- Delete All® spray on back of animals (Intervet (Pty) Ltd., South Africa) to help control ticks, variety of flies, mange mites and kills lice.
- Reverin® (Intervet (Pty) Ltd., South Africa) for the treatment of Heartwater and tick-borne gall sickness (anaplasmosis), pneumonia, navel ill, foot rot and joint ill.
- Gardal® (Intervet (Pty) Ltd., South Africa) Against roundworms, milk tapeworm.
- Revalor H® pill behind ear (Intervet (Pty) Ltd., South Africa) A slow releasing growth promotor (trenbolone acetate and oestradiol).

A follow up treatment 14 days after the first treatment was repeated with:

- Bovitech PI® (Intervet (Pty) Ltd., South Africa) to reduce the incidence of morbidity and mortality caused by undifferentiated bovine respiratory diseases (pasteurellosis) associated with *M. (Pasteurella) haemolytica* and BHV-1 (infectious bovine rhinotracheitis - IBR).
- Covexin 10® (Cooper Veterinary Products, South Africa) immunisation against type A, B, C and D *Clostridium perfringens*.

4.3.5 Supplements and feed composition

Diets was formulated with the use of AMTS.Cattle v 2.1.31 (AMTS LLC, Groton, NY, USA) software and mixed on The Oaks farm using a mixer wagon (Seko Industries, Curtarolo, Italy). Prior to mixing all ingredients were hammer milled (6mm sieve). The NutrifenPLUS® powder was pre-weighed out on a Scales Incorporated (JLC – ES) scale and stored in Ziplock bags in a dry and safe place until use.

Table 4.1 Composition and analysed nutritional values of the supplements and pasture used in the trial

Ingredients	Unit	Treatments	
		Control	FCE
Wheat straw	kg	140	137
Hominy chop	kg	350	342
Maize (milled)	kg	200	195
[1]Commercial phosphate lick	kg	50	49
Molasses meal	kg	160	156
[2]Commercial HPC	kg	100	98
NutrifenPLUS®	kg	0	23
Total		1000	1000
Supplementary feed			
Moisture	%	5.4	5.4
Crude protein	%	12.8	12.8
Crude fat	%	4.0	4.0
NDF	%	25.7	25.7
ADF	%	11.8	11.8
Calcium	%	1.1	1.1
Phosphate	%	0.5	0.5
Ash	%	10.8	10.8
Pasture			
Moisture	%	9.4	9.4
Crude protein	%	19.5	19.5
Crude fat	%	2.8	2.8
NDF	%	52.3	52.3
ADF	%	25.9	25.9
Calcium	%	0.6	0.6
Phosphate	%	0.4	0.4
Ash	%	9.8	9.8

[1]DM=88%, Ca=20%, P=8%. [2]DM=88%, CP=48%, CF=7.5%; [2]High protein concentrate

4.3.6 Supplementary diet, pasture grass sampling and proximate analyses

Supplementary diet samples for both treatments were collected with single random grab samples repeated 12 times. The grab samples were pooled and stored at 4°C until proximate analyses were performed at the Department of Animal Science of the University of Stellenbosch. A total of 24 random grass grab samples were cut by hand at 3cm height throughout the duration of the study. The grass samples were taken from a fresh camp before the cattle were moved to the specific camp. Pre-evaluation analysis were performed on the

trial pasture to ensure that the pasture grazed by both the treatments groups were homogonous. The trial camps had homogonous pasture and for this reason the grass samples were pooled and stored at 4°C until proximate analyses were performed at the Department of Animal Science of the University of Stellenbosch.

4.3.7 Sample preparation and analysis

All samples were milled through a standard laboratory mill (Scientec RSA Hammer mill Ser. Nr 372; Centrotec) to pass through a 2 mm screen. The clearly marked samples were stored at 4°C airtight Ziplock bags.

Dry matter was determined by forced air oven drying at 100 °C for twenty-four hours according to method 934.01 of the AOAC (Feldsine *et al.,* 2002). Crude protein content was determined with a Leco N-analyser (model FP 528, St Joseph, Michigan, USA), according to method 990.03 of the AOAC. (AOAC, 2002). Ash content was determined by incineration at 500°C for six hours according to method 942.05 of the AOAC. (AOAC, 2002). Ether extract content was determined according to AOAC method 920.39 (AOAC, 2002).
All Neutral Detergent and Acid Detergent Fibre as well as crude fibre content was determined with an Ankom^{220} Fiber Analyzer (ANKOM Technology, Fairport, NY, USA). All TMR samples were weighed in triplicate (300 +/- 10 µg) and heat-sealed in fiber filter bags (Ankom F57) of 25 µm porosity. The NDF content of the bag residues (Amok, 2016) was then determined using α-amylase and sodium sulfite (Na_2SO_3) as described by Van Soest *et al.* (1991).

4.3.8 Dressing percentage of the animals

After 90 days of experimentation all the animals were transported and slaughtered at a registered commercial abattoir (Robertson, Western Cape, RSA). Cold and warm carcass weights were determined whereafter dressing percentages were calculated. Warm carcass pH and temperature data was recorded 15 min after death. The pH and temperature of each carcass was measured using a Crison pH25 handheld portable pH meter (Lasec (PTY) Ltd, South Africa). Carcass classification was also determined by an experienced and trained grader at slaughter.

4.3.9 Statistical Analysis

The animals in this study were randomly blocked within a treatment. The data from the study was analysed using a mixed model analysis of variance (ANOVA) with RStudio (1.4.1103, 2021). Because feed DMI was only determined per group, and as there was only one group per treatment, no statistical analyses could be done to determine treatment effect on DMI. The animals, however, were all the same breed, sex and age and weight. The animals were also

allocated per treatment to have similar mean initial weight between the groups (Section 4.3.2). According to an ANOVA done it was ensured that the mean bodyweight of the groups do not differ significantly. Additionally, a Levene's test was done to ensure that the variances of the initial weights were also homogeneous (Schultz, 1985). Due to the small variances of the bodyweight of the groups and the homogeneous at the start of the trial, it was accepted that treatment will be the only other factor that will affect feed intake. Under such conditions it can then be valid to use individual body weights and group mean DMI to determine feed efficiency per animal (Nel, 2021, Centre for Statistical Analysis, Stellenbosch University). The remainder of the parameters were subsequently analysed according to a RMANOVA over time.

Significant differences between means were tested using a Bonferroni test (Cabin & Michell, 2000). A probability value of $P \leq 0.05$ was considered statistically significant (5% level of significance) between treatments while tendencies were declared at $P \leq 0.10$.

4.4 Results and Discussion

Results of starting weight, end weight, gain, DMI, feed cost (R), weaner cost (R), carcass cost (R) and margin/head (R) of the control and FCE treatments observed over the total period are presented in Table 4.2. No significant differences were observed between the FCE and the control treatments for starting weight, final weight, total weight gain, total combined DM intake, FCR, feed cost (R), the weaner cost (R), carcass income (R) and the margin/head (R) when compared (see Table 4.2) over the total feed period. The total combined DMI consisted of the 5kg of supplementary feed per animal per day and *ad libitum* pasture. Pasture (C3 grass grazed in the mature state) intake was calculated at 2.8% of bodyweight (Cordova *et al.*, 1978). The absence of difference in start weight between the two treatments was to be expected as the animals were assigned to a treatment randomly as described in Section 4.3.2. In the current study no significant differences for final weight and total weight gain were observed between the two treatments. The FCE group however did show a numerical lower final weight and total weight gain in comparison with the control group. It has been shown that Fenugreek can inhibit absorption and remove carbohydrates from the body before the carbohydrates enter the bloodstream, finally resulting in slower weight gain of the animal (Petit *et al.*, 1995). The Fenugreek seeds containing high levels of soluble fibre can further promote gelatinous structures and cause an increase in retention time or delayed gastric emptying (Hannan *et al.*, 2007). This slowing down of digestion and absorption of nutrients can induce a sense of saturation in the animals leading to a decrease in DMI of pasture in the FCE fed animals (Petit *et al.*, 1995). The numerically lower DMI of the FCE treatment could possibly therefore be attributed to slower digestive rates. The lack of a significant difference of DMI between the two treatments in the present study correspond with results of a study of Shah &

Mir (2004) who provided dairy cows with 20% Fenugreek seed of the diet dry matter. In the latter study no significant differences for daily feed intake between the Fenugreek treatment group and the control group, were also reported. The lack of significance of total feed cost between treatments in the present study was expected as DMI also did not differ. As expected, there was no significant difference in weaner cost between the two treatments as the weaner cost per kg was similar (Table 4.2) and the animals were allocated to treatments to be as homogenous as possible. The lack of a significant difference in carcass income and margin/head between the two treatments can be explained by a similar beef price (due to similar classification) and final weights being similar (Table 4.2.). These results indicates that the animals were purchased for almost the same price per treatment and the carcasses of the two treatments resulted in similar income per kilogram because of the similar final weights.

Table 4.2 The average (±standard error) start weight, end weight, gain, DMI, feed cost (R), weaner cost (R), carcass cost (R) and margin/head (R) of the control and FCE treatments

	Treatment		
Item	**Control**	**FCE**	***P* value**
Start weight (kg)	278±7	276.4.8±12	**0.91**
End weight (kg)	418.7±21	411.8±21	**0.38**
Total gain (kg)	140.7±20	135.4±15	**0.42**
Total DMI (kg)	858.3±29	847.9±38	**0.42**
Feed Cost (R)	2472.1±72	2446.1±95	**0.42**
Weaner Cost (R)	7881.3±193	7836.8±340	**0.91**
Carcass Cost (R)	10811.2±530	10563.5±647	**0.28**
Margin/Head (R)	307.8±454	130.7±515.6	**0.34**

4.5 Conclusion

The results from the present study indicate that FCE (NutrifenPLUS®) at an inclusion level of 120g/animal per day had no significant effect on the growth or financial parameters evaluated. Different rates of FCE might however affect the results of the current study and should be studied in future pasture to examine at which inclusion level FCE may have positive or negative growth results on grazing ruminants. Different pasture grass at different qualities may be considered as well as different environments and different types of supplemental feed can be considered in future studies.

4.6 References

Abhishek, R., Manoj, K. J. & Pratap, T. 2014. Cow dung for eco-friendly and sustainable productive farming. Philos. Trans. R. Soc. B Biol. Sci. 3, 201–202 https://doi.org/10.1098/rstb.2007.2189.

Altuntaş, E., Özgöz, E. & Taşer, Ö. F. 2005. Some physical properties of fenugreek (*Trigonella foenum-graceum L.*) seeds. J. Food Eng. 71, 37–43 https://doi.org/10.1016/j.jfoodeng.2004.10.015.

Basu, S. K., Acharya, S. & Thomas, J. 2008. Genetic improvement of fenugreek (*Trigonella foenum-graecum L.*) through EMS induced mutation breeding for higher seed yield under western Canada prairie conditions. Euphytica 160, 249–258 https://doi.org/10.1007/s10681-007-9545-9.

Basu, A., Basu, S. K., Kumar, A., Sharma, M., Hedi, A., Solorio-sánchez, F., Oladimeji, M., Hafez, E. E. & Cetzal-ix, W. 2014. Fenugreek (*Trigonella Foenum-Graecum L.*), A Potential New Crop for Latin America. Am. J. Soc. Issues Humanit. 4, 145–162.

Biggs, S. 2019. The effect of fenugreek seed cotyledon extract on milk yield and composition in Holstein cows. Thesis, Department of Animal Sciences, Stellenbosch University.

Cabin, R. & Mitchell, R. 2000. To Bonferroni or Not to Bonferroni: When and How Are the Questions. Bulletin of the Ecological Society of America. 81, 246-248. doi.org/10.2307/20168454.

Clancy, K. 2006. Greener Pastures How grass-fed beef and milk contribute to healthy eating. Union Concerned Sci. Food Environ. Program., 1–4.

Cordova, F. J., Wallace, J. D. & Pieper, R. D. 1978. Forage Intake by Grazing Livestock: A Review. J. Range Manag. 31, 430 https://doi.org/10.2307/3897201.

Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A. & Larson, S. 2010. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr. J. 9, 1–12 https://doi.org/10.1186/1475-2891-9-10.

Demir, E., Sarica, Ş., Özcan, M. A. & Suiçmez, M. 2005. The use of natural feed additives as alternative to an antibiotic growth promoter in broiler diets. Arch.Geflügelk 69, 110–116.

Earle, D. F. & McGowan, A. A. 1979. Evaluation and calibration of an automated rising plate meter for estimating dry matter yield of pasture. Aust. J. Exp. Agric. Anim. Husb. 19, 337–343.

Goel, G., Makkar, H. P. S. & Becker, K. 2008. Effects of *Sesbania Sesban* and Carduus *Pycnocephalus* leaves and Fenugreek (*Trigonella foenum-graecum L.*) seeds and their extracts on partitioning of nutrients from roughage- and concentrate-based feeds to methane. Anim. Feed Sci. Technol. 147, 72–89 https://doi.org/10.1016/j.anifeedsci.2007.09.010.

Greyton climate. 2019. https://en.climate-data.org/.

Hall, W. L. 2009. Dietary saturated and unsaturated fats as determinants of blood pressure and vascular function. Nutr. Res. Rev. 22, 18–38 https://doi.org/10.1017/S095442240925846X.

Hannan, J. M. A., Ali, L., Rokeya, B., Khaleque, J., Akhter, M., Flatt, P. R. & Abdel-Wahab, Y. H. A. 2007. Soluble dietary fibre fraction of *Trigonella foenum-graecum L.* (fenugreek) seed improves glucose homeostasis in animal models of type 1 and type 2 diabetes by delaying carbohydrate digestion and enhancing insulin action. Br. J. Nutr. 97, 514–521 https://doi.org/10.1017/S0007114507657869.

Irvine, L. D., Freeman, M. J. & Rawnsley, R. P. 2010. The effect of grazing residual control methods on cow intake and milk production in late spring. Proc. 4 th Australas. Dairy Sci. Symp., 195–198.

Jouany, J. P. & Morgavi, D. P. 2007. Use of 'natural' products as alternatives to antibiotic feed additives in ruminant production. Animal 1, 1443–1466. https://doi.org/10.1017/S1751731107000742.

Levy, S. B. 1987. Antibiotic use for growth promotion in animals: Ecologic and public health consequences. J. Food Prot. 50, 616–620 https://doi.org/10.4315/0362-028x-50.7.616.

Makkar, H. P. S. & Becker, K. 1996. Nutrional value and antinutritional components of whole and ethanol extracted *Moringa Oleifera* leaves. Anim. Feed Sci. Technol. 63, 211–228 https://doi.org/10.1016/S0377-8401(96)01023-1.

Menkem, Z. E., Ngangom, B. L., Tamunjoh, S. S. A. & Boyom, F. F. 2018. Antibiotic residues in food animals: Public health concern. Acta Ecol. Sin. 39, 411–415 https://doi.org/10.1016/j.chnaes.2018.10.004.

Mir, Z., Mir, R. S., Acharya, S. N., Zaman, M. S., Taylor, W. G., Mears, G. J., McAllister, T. A. & Goonewardene, L. A. 1998. Comparison of alfalfa and fenugreek (*Trigonella foenum-graecum*) silages supplemented with barley grain on performance of growing steers. Can. J. Anim. Sci. 78, 343–349 https://doi.org/10.4141/A97-087.

Nel, D. 2012. Centre for Statistical Analysis, Stellenbosch University.

Petit, P. R., Sauvaire, Y. D., Hillaire-Buys, D. M., Leconte, O. M., Baissac, Y. G., Ponsin, G. R. & Ribes, G. R. 1995. Steroid saponins from fenugreek seeds: Extraction, purification, and pharmacological investigation on feeding behavior and plasma cholesterol. Steroids 60, 674–680 https://doi.org/10.1016/0039-128X(95)00090-D.

Shah, M. A. & Mir, P. S. 2004. Effect of dietary fenugreek seed on dairy cow performance and milk characteristics. Can. J. Anim. Sci. 84, 725–729 https://doi.org/10.4141/A04-027.

Schultz, B.B., 1985. Levene's test for relative variation. Systematic Zoology, 34(4). 449-456.

Singh, K. P., Nair, B., Jain, P. K., Naidu, A. K. & Paroha, S. 2013. Variability in the nutraceutical properties of fenugreek (*Trigonella foenum-graecum L.*) seeds. Rev. Colomb. Ciencias Hortícolas 7, 228–239 https://doi.org/10.17584/rcch.2013v7i2.2237.

Stampa, E., Schipmann-Schwarze, C. & Hamm, U. 2020. Consumer perceptions, preferences, and behaviour regarding pasture-raised livestock products. Food Qual. Prefer. 82, 103872 https://doi.org/10.1016/j.foodqual.2020.103872.

Swanepoel, P. 2021. Department of Agronomy, Stellenbosch University.

Wina, E., Muetzel, S. & Becker, K. 2005. The impact of saponins or saponin-containing plant materials on ruminant production - A review. J. Agric. Food Chem. 53, 8093–8105 https://doi.org/10.1021/jf048053d.

CHAPTER 5: Conclusion and Recommendations

The aim of this study was to evaluate a natural alternative growth promoter, FCE. Effects of dietary FCE on beef cattle performance and carcass characteristics in an intensive feedlot system and on extensive pasture based grazing system were determined.

Intensive Feedlot system

The first aim of this study was to determine the effects that natural dietary FCE had on beef cattle in a feedlot production system. The FCE treatment received the recommended amount of FCE powder spread over the TMR. Starting weight, final weight, total weight gain, FCR, ADG (kg) and beef characteristics were compared between the two treatments. The results in Chapter 3 indicate that FCE had no significant effect on final weight, ADG (kg) nor FCR (kg) of the experimental animals in the starter, grower, and finisher phases. A significant difference ($P \leq 0.05$) was observed during the Finisher with Zilmax® phase where the total gain was negatively impacted with the addition of FCE.

Secondly in effects of FCE characterisation was determined and resulted in no significant differences between the FCE and the control treatments. It can therefore be concluded that FCE had no effect on any of the beef parameters evaluated in the current study. A tendency ($P = 0.07$) to differ was however seen in the shear force between the two treatments. This could however not be explained.

Future studies should also compare FCE without zilpaterol as a treatment The role of FCE on fat deposition could lead to interesting applications regarding consumer preference and health perceptions relating to beef consumption. Different results may be concluded in studies with different basal TMR diets and under different environments.

Future studies may find different results if gut fat accumulation is determined, and gut content is measured. Future studies with more experimental animals could also be considered, as more than 12 animals per treatment may have a higher possibility to obtain significant differences.

Pasture Study

This study determined the effects of natural dietary FCE on growth of pasture fed beef cattle. The FCE powder was spread over the supplementary feed and mixed in by hand. The two treatments were supplied daily. Starting weights, end weights, gain, total intake, FCR, feed cost (R), the weaner cost (R), carcass cost (R) and the margin/head (R) were compared. The

results reported in Chapter 4, did not show any significant differences between the FCE and the control treatments. These results indicates that FCE had no significant effect on final weights and income

Different inclusion rates can be included in future pasture studies to examine at which inclusion level FCE may have positive or negative growth results on grazing ruminants. Future studies with more experimental animals could also be considered, as more than 14 animals per treatment may have a higher possibility to obtain significant differences when compared. Different pasture grass with different quality can be considered for future studies. Animals can be housed/kept under different environmental circumstances and different types of supplemental feed can be considered for future studies.

In both these studies, at the recommended inclusion level of the FCE supplier, no significant advantage of using Fenugreek Cotyledon Extract could be determined on any of the parameters evaluated.