

**Effects of baobab oil seed cake on growth performance and enteric methane emissions in
Savannah × Boer crossbreed yearling goats**

By

Saho Samkelo

(201302860)



University of Fort Hare
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A Dissertation submitted in fulfillment of the requirements for the degree of

Master's in Agriculture - Animal Science



Department of Livestock and Pasture Science

University of Fort Hare
Together in Excellence
University of Fort Hare

P/Bag X1314

Alice, 5700

South Africa

Supervisor : Dr Mpendulo, Conference Thando

Co-supervisor: Professor Mupangwa, John Fisher

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Declaration

I, Samkelo Saho, declare that this thesis has not been submitted to any other University; it is my original work conducted under the supervision of Dr. C.T. Mpendulo and Prof. J. Mupangwa. All assistance towards producing this research work and all the references contained herein has been fully acknowledged.



14 February 2020

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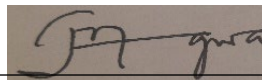
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Approved as to style and content by:

Dr C.T. Mpendulo



Professor J.F. Mupangwa



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Abstract

The study was conducted to investigate the effects of feeding graded levels of baobab oil seed cake (BOSC) on growth performance and enteric methane emissions of Savannah × Boer goats at yearling age. A total of 24 goats weighing 16.63 ± 3.639 kg were used in a completely randomized block design. The study was conducted for 70 days, where the adaptation period was 14 days. The baobab oil seed cake was included in the diets at 0% (control diet), 15%, 30%, and 45 % on a mass basis. The experimental diets were iso-nitrogenous and iso-caloric. In experiment 1, the parameters measured include the average daily feed intake (ADFI), body weight gain (BWG), and average daily gain (ADG), feed conversion ratio (FCR), and enteric methane emissions (EME). On weeks and treatment interaction, the ADG and the BWG were higher in goats fed on diets with 15%, 30%, and 45% BOSC than those fed on the control diet (0% BOSC). Highest ADG was observed on goats that fed on a diet with 30% BOSC. The inclusion of baobab oilseed cake (15%, 30%, and 45% BOSC) goats' diets significantly increased ($P < 0.05$) (ADFI). Females in the current study gained more weight than males. It was observed that goats fed diets with 0% baobab oil cake emitted higher methane output ($P < 0.05$). Methane emission decreased as the baobab inclusion levels in the diet increase ($P < 0.05$). Female Savannah × Boer goat emitted more methane than male ($P < 0.05$). It was noted that the interaction between animal sex and baobab oil seed cake inclusion levels significantly ($P < 0.05$) influenced methane emission. It was concluded that baobab oil seed cake can be strategically used as animal feed ingredient to influence growth performance and to modulate rumen fermentation in goats.. However, it will be necessary to investigate the effect of baobab seeds on meat quality and the fatty acid composition of goats in future research.

Keywords: Feed intake, methane gas emissions, baobab oilseed cake, goats

Dedication

This thesis is dedicated to my late brother Sonwabo Saho. You supported my education when I was still a young boy, and may your soul continue to rest in peace. Also, special dedication to my late father, Mr. Ziphathe Gadile Saho, may your soul continue to rest in peace. To my family, this is my gift to you; thank you for your endless support may this be something you take pride in forever.



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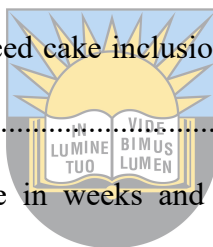
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List of abbreviations

ADFI- Average Daily Feed Intake

ADG- Average Daily Gain

AOAC – Association of Official Analytical Chemistry

BOSC- Baobab Oil Seed Cake

BWG- Body Weight Gain

CH₄- Methane

DAFF – Department of Agriculture Forestry and Fisheries

DM- Dry Matter

DMI- Dry Matter Intake

FAO- Food and Agriculture Organisation of the United Nations

FAOSTAT- Food and Agriculture Organisation Corporate Statistical Database

FBW- Final Body Weight

FCR- Feed Conversion Ratio

FI- Feed Intake

G-Grams

GHG-Greenhouse Gases

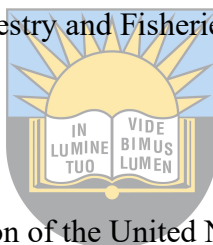
IBW-Initial Body Weight

Kg- Kilograms

L S Means- Least Square Means

LMD- Laser Methane Detector

MOC – Macadamia oil cake



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NRC- National Research Council

NS- Not Significant

PPM- Parts per million

SAS- Statistical Analysis System

SBM- Soy Bean Meal

SEM- Standard Error of Means

VFA-Volatile Fatty Acids



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Chapter 1: General Introduction

11. Background

The world number of goats has grown drastically by 75%, from approximately 589 million goats in 1990 to 1034 million in 2017 (Visser, 2019). The highest numbers were reported in Asia and Africa, with about 59.8%, 35%, respectively, making up to 94.8% out of the world's total goat numbers (Prescilla *et al.*, 2015a). South African numbers of goats have grown from 4.8 million in 2002 to about 6.5 million goats in 2009 (Roux and West, 2014; Mpendulo *et al.*, 2017), constituting about 55% of the total goats found in Southern Africa (Visser, 2019). In South Africa, the Eastern Cape Province contributes about 37% in goat production (Prescilla *et al.*, 2015b). In the Eastern Cape Province, indigenous goats such as Boar, Savannah, and Xhosa ear-lobbed goat breeds are found. This is mainly due to the agro ecological conditions in the province. Goats require low inputs but are more profitable to keep (Casey and Webb, 2010).

Goat farmers experience significant challenges of feed for their goats, which leads to underfeeding or malnutrition in goats. This might be due to the conditions of the natural pastures and the quality of browse species that goats consume. In communal farms, the feed quality and availability are significant constraints due to complete dependency on natural feed sources (Webb, 2002). Therefore, it is important to look for alternative protein sources to supplement livestock during dry season. Baobab oil seed cake due to its good quality protein ranging from 20% to 36% CP and energy levels ranging from 7941.232 to 18681.56 kJ/kg can be used to feed goats during the dry season when feed is limited (Murray *et al.*, 2001). Also, it was noted that baobab seed cake is rich in vitamin C, fiber, and amino acids such as lysine and methionine, which may play an integral role in the growth performance of goats.

It is critical to evaluate the potential of nonconventional feed sources like *Vaschellia karroo* and *Adansonia digitata* for use in communal farming systems where resources to improve goat nutrition is limited. Mendieta-araica *et al.* (2011) pointed out that wild pasture grasses in the Eastern Cape Province have a low nutritional value. Dominant grass species are *Themeda triandra*, *Cymbopogon plurinodis*. These species have low nutritive value (2% crude protein), especially during the dry season; hence they fail to supply the nutritional requirements of goats for maintenance and production. Hence, farmers and researchers need to put more effort into exposing nonconventional feed sources that are cost-effective with adequate nutritive value.

Webb (2002) reported that malnutrition is the possible cause of the low productivity of goats kept under communal production systems. Lack of feed with good nutritional value, such as high protein content, might lead to poor productivity. In goats, a poor growth rate can lead to a poor growth performance. Feed remains of the major constraint that communal goat farmers are facing in the world and other parts of South Africa and Africa at large. Therefore, goat farmers need to opt for alternative feed sources, which they need to counter feed shortages. One of which is the Baobab oil seed cake. Due to its high nutritive value, Baobab seed cake can enhance productivity, because the baobab seeds contain tannins, they can improve growth and reduce methane emissions.

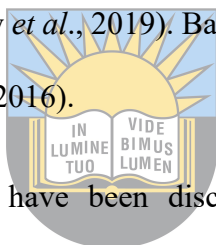
The Baobab is a multipurpose deciduous tree that originated in dry central Africa (Edwin, 2005). The baobab tree is found in the semi-arid and sub-humid parts of Sub-Saharan Africa, as well as western Madagascar. The Baobab tree is a drought-tolerant tree which can resist extremely high temperatures. In most areas worldwide, it is mainly grown for its sour fruits and leaves (Osman, 2016). The baobab oil seed cake has good quality protein, vitamins, and minerals and is a drought-tolerant tree. Forage quality and availability vary greatly from season to season, which also adversely affect the production of the animals (Ogunbosoye and Babayemi, 2016). Goats fed

baobab oilseed cake may have health benefits such as antioxidants, analgesics, and anti-inflammatory properties; also baobab is a good source of minerals and energy (Ogunbosoye and Babayemi, 2016).

Apart from the fact that feed is more important to growing animals and has become a limiting factor in animal productivity, there is also a rising concern of greenhouse gas (GHG) emission globally. The focus of the study will also be the effect of baobab oil seed cake on enteric methane emissions, during ruminal fermentation in ruminants. Hook *et al.* (2010) noted that methane (CH₄) emissions through enteric fermentation are becoming a significant concern worldwide. This is related to the influence and growth of atmospheric GHGs, as well as the loss of 2-15 % of the animal's gross energy intake (Getabalew *et al.*, 2019). Baobab native tree of Zimbabwe and South Africa (Mwale *et al.*, 2008; Darr *et al.*, 2016).

Various secondary plant metabolites have been discovered to have antimicrobial activity (Compean, 2014), leading to changes in ruminal fermentation to improve efficient utilization of energy feed, thereby suppressing methane production. According to Piñeiro-vázquez *et al.* (2018) condensed tannins from *Lespedeza cuneata* decreased up to 57%. Based on findings by Adejoro *et al.* (2019), it was concluded that methane was reduced by 13% per kg DM on sheep fed 41g of tannin-containing *Acacia mearnsii* as compared to those that were given normal forage. Due to their tanniforous characteristics, which are below levels which might be toxic to animals, and it is expected that feed with Baobab oilseed cake inclusion levels of 15%, 30%, and 45% should produce less methane as compared to 0% baobab oilseed cake inclusion level with soya bean meal.

Commercial feed sources such as soybean cake used to formulate diets are predicted to be in short supply soon due to high demand (Chimvuramahwe *et al.*, 2011). Due to an increase in competition



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with human requirements and increasing intensive animal production, an additional increase in conventional feed sources' prices, especially during the dry season when supply is low (Kusina and Bhebhe, 2018). Therefore, inadequate supply of high-quality feed sources, especially during the dry season, is a significant problem affecting livestock production (commercial and smallholder farmers) in sub-Saharan Africa (Chakeredza *et al.*, 2008).

1.1. Problem Statement

There are limited studies conducted on baobab oil seed cake as a protein supplement in goats. Hence researchers have to put more effort into exposing its nutritional composition and the potential benefits of using it in livestock production. The most essential and non-essential amino acids have been found in African baobab seeds, making them an excellent source of protein (Chisoro *et al.*, 2017). According to previous studies, for livestock, baobab seed cake could be a low-cost, locally available protein source (Chimvuramahwe *et al.*, 2011). Hence the current study evaluates potential benefits of using baobab oil seed cake in goat production. Because of its accessibility and affordability, cooperative farmers may use it to feed their goats. This is beneficial not only to those living in baobab-growing regions but also those living in other provinces.

Due to their genetic excellence for meat production, Boer goats and Savannah goats has successfully enhanced other indigenous breeds' productive performance through crossbreeding (Maynard *et al.*, 2016). Both Boer goats and Savannah goats are heat resistant. They also tolerate tannins, effective fiber digestion, adaptable to a variety of environments, and a decreased water turnover rate (Thomas, 2015). Due to the attributes mentioned above, goat farmers have decided to crossbreed Boer and Savannah goats. The crossbreed (Savannah × Boer goat) has now become favourites to South African goat farmers, especially in Eastern Cape, South Africa (Visser, 2014). Goat production is one of the primary sources of income for farmers living in arid and semi-arid

regions; however, goats kept in these areas are faced with nutritional deficiency due to drought, which aggravates the disease and low productive performances (Haji Baba *et al.*, 1998). This research will also look into the role of baobab oil seed cake in enteric methane emissions. Since goats are immune to anti-nutritional influences, the presence of tannins in baobab seeds will positively impact their ability to suppress methane emissions.

The Baobab oil seed cake (BOSC) is one of the low-cost and locally available protein sources used to feed goats. Nonetheless, many plants can produce high-quality yields of biomass, but they are not utilized for the improvement of livestock production due to a lack of information on their nutrient composition. Baobab oilseed cake can also play an integral part in methane mitigation due to tannins (2-12%) in Baobab seeds known to reduce methane gas production when fed to ruminants (Igboeli *et al.*, 1997). Therefore, there is a need for researchers to pay more attention at exposing and investigating methane mitigation strategies that are cost-effective and in line with animal ethics and environmentally sustainable. According to (Kim *et al.*, 2012), tannins are the safest and inexpensive ways to suppress CH₄ emissions in ruminants due to their ability to modify rumen fermentation. The Baobab oil cake contains 2-12% tannin (Igboeli *et al.*, 1997). Therefore, the current study aims at investigating the potential of BOSC on methane gas reduction.

1.3. Justification

This current research project investigates the potential benefits of using BOSC as a protein source in goats. BOSC contains high protein and energy content (Mwale *et al.*, 2008). Therefore, utilization of BOSC in feeding goats will enhance growth performance parameters such as ADG, BWG, and FCR. There will be an expected increase in feed intake on goats fed BOSC due to good

aromatic characteristics in baobab seed cake. Thus, ADG, BWG, and FCR will be improved. There will also be an added advantage of methane gas mitigation when supplementing goats with baobab oil seed cake due to the presence of tannins (2-12%) that are below toxic level (Igboeli *et al.*, 1997). Evaluating locally available and inexpensive protein sources such as baobab oil seed cake will help farmers (more especially resource-limited farmers) to be able to produce goats efficiently using cost-effective nonconventional baobab oil seed cake.

1.4. Objectives

1.4.1. Main objective

The study's main objective was to evaluate the effects of Baobab oil seed cake on feed intake, growth performance, and enteric methane emission of Savannah × Boer cross breed yearling goats.

1.4.2. Specific objectives are to:

- ✓ Determine the effects of Baobab oil seed cake on feed intake and growth performance of Savannah × Boer cross breed yearling goats.
- ✓ Determine the effects of Baobab oil seed cake on Savannah × Boer cross breed yearling goats on enteric methane emissions.

1.5. Hypotheses

Null hypothesis (H₀):

- ✓ Baobab oil seed cake has no effects on feed intake and growth performance of Savannah × Boer cross breed yearling goats.
- ✓ Baobab oil seed cake has no effects on methane emission in Savannah × Boer cross breed yearling goats.



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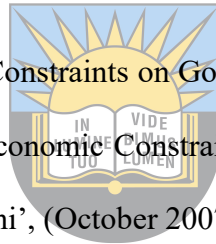
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Chapter two: Literature Review

2.1. Introduction

Feed remains a significant constraint in goat production, owing to its cost, which accounts for over 70% of total production (Ekiti, 2013). Shortage of feed in developing countries is aggravated by its competition with an ever-expanding human population and intensive animal production. This has led to a rise in the prices of conventional protein sources (Chimvurahwe *et al.*, 2011). One alternative way to counteract this problem is to perhaps opt for nonconventional protein sources to supplement goats. Nampanzira *et al.* (2015) noted that poor quality of pastures in goat farming systems contributes to low productivity. This is attributed to the fact that rearing practice in goats is mainly based on natural pastures; hence the grazing system is inefficient (Sharma *et al.*, 1998; Gwaze *et al.*, 2009). Baobab oil seed cake contains high protein (18-36% CP) content as reported by Salami and Okezie (1994); and, Murray *et al.* (2001). Therefore, they can be utilized to supply livestock with protein. Therefore, enhancing feeding and nutrition by utilizing the available nonconventional feed resources should be prioritized in goats' production. Adequate nutrition, therefore, remains an essential factor that determines the performance of animals. This review chapter will cover taxonomic classification and morphological description of the baobab tree, proximate analyses of nonconventional oil cakes used in livestock feeding, such as Macadamia oil cake and Baobab seed cake. In addition, amino acids profiles and fatty acid profiles of conventional oil cakes, Macadamia oil cake and baobab oil seed cake will be covered. The effects of Macadamia oil cake (MOC) and Baobab seed cake (BSC) on feed intake and growth performance of ruminants will also be discussed,

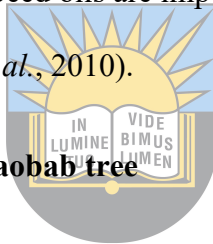
2.2. Taxonomic classification and morphological description of the baobab tree

Kingdom: Plantae; Phylum: Tracheophyta; Class: Magnoliopsida; Order: Malvales; Family: Malvaceae; Genus: *Adansonia*; Species: *digitata*; Botanical name: *A. digitata*; English name: Baobab (Lock *et al.*, 2004). Synonyms: *Adansonia bahobab* L, *Adansonia* baobab Gaert, *A. digitata* var. *congolensis* A. Chev, *Adansonia somalensis* Chiov, *Adansonia sphaerocarpa* A. Chevall, *Adansonia sulcata* A. Chevalier, *Baobabus digitata* Kuntze (Wickens, 2007) .

Adansonia digitata grows into a massive deciduous tree with a stem diameter of 2-10 m and a height of 20-30 m (Sidibe and Williams, 2002). The trunk is smooth, reddish-brown to grey in colour, velvety, and with longitudinal fibers running through it, the bark is smooth. The lateral root system of *Adansonia digitata* stretches 50 meters from the trunk (Rahul et al., 2015). Tubers are typically formed by the tips of the roots. The main roots of old trees, on the other hand, are shallow and rarely extend beyond 2 m depth. As a result, they are particularly vulnerable to severe winds and can be uprooted by a storm (Sidibe and Williams, 2002).

Young tree leaves are often simple. On adult trees, simple leaves appear first, followed by 2-3-leaflet leaves and mature leaves (20 cm diameter with 5 to 9 leaflets). Baobab inflorescences are made up of a single flower that blooms in the axils of leaves towards the tips of reproductive branches. White, large, pendulous, solitary or paired on leaf axils, and stunning flowers (Rahul and colleagues, 2015). Flowering occurs about the same time as the first leaves appear, usually near the end of the dry season or shortly before the first rains. The blossoms appear late in the afternoon and fade before daybreak the next day. Bats are attracted to the flowers because of their sulphur fragrance, which serves as a pollinator (Wickens, 2007). The pulp of the baobab tree is high in vitamin C. Interest in pulp usage may improve if the pulp is given added value by increasing its handling quality and storage stability via the use of appropriate technologies.

Currently, pulp preservation is out of the population's control, resulting in unfavourable pulp losses. To preserve pulp's nutritional value and sensory characteristics, it's vital to overcome challenges in extending its shelf life. Bioavailability studies are necessary to acquire a better understanding of the contribution to human health because the human body can never fully use food intake (Chadare, 2010). The vitamin C content of the fruit pulp is nearly 10 times that of oranges. It has a lot of pectin and sugars. The *Adansonia digitata* seeds are uniformed and entrenched in the pulp, with smooth testa and a dark brown to reddish black colour. They're eaten raw, dried, or ground, and they're also utilized in cooking. Kernels have an energy value of 1803 KJ/100 g, which is around 50% more than leaves (Rahul *et al.*, 2015). The crop is high in phosphorus, calcium, and magnesium. Seed oils are important dietary oils that are also employed in industry and medications (Nzikou *et al.*, 2010).



2.3. Ecology and distribution of the baobab tree

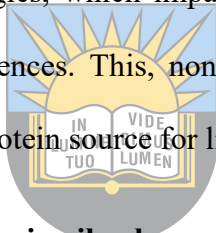
Baobabs are commonly considered as an African icon and can be found across tropical Africa's hotter, drier regions, primarily south of the Sahara (Gebauer *et al.*, 2002). The tree can be found in Namibia's mature forests and northern South Africa's savannah habitats, Zimbabwe's eastern and western regions, and the ecosystems of Angola (Venter *et al.*, 2017). The tree can only grow frost free areas (Mpofu *et al.*, 2012). It grows well in desert climates and can resist fire (Sidibe and Williams, 2002). The *Adansonia digitata* grows on free-draining sandy-textured soils, with the exception of deep sand, where it can obtain sufficient moisture or anchorage (Mpofu *et al.*, 2012). Baobab trees can withstand shallow lateritic soils and are unaffected by pH. They're also common on rocky hilltops, calcareous soils, and run-off places (Sidibe and Williams, 2002).

2.3. Chemical composition of other nonconventional oil cakes

Nonconventional oil cakes/meals have been used as protein or energy supplements for livestock due to the unavailability and high costs of conventional oil cakes/meals such as soybean meal, sunflower oil cake, and cotton seed meals. The Marula seed cake, a by-product left over after oil extraction from marula nuts, had a high dry matter (DM) content of 901g/kg, ether extract (EE) content of 394g/kg DM, crude protein (CP) content of 470g/kg DM, and lower values of neutral detergent fiber (NDF) (194 g/kg DM) and acid detergent fiber (ADF) content (131 g/kg DM) (Mlambo *et al.*, 2011). (Mthiyane and Mhlanga, 2017) found similar DM values in Marula seed cake, with EE content ranging from 289 to 343.5 g/kg DM, CP content ranging from 470.0 to 472.1 g/kg DM, crude fiber (CF) content ranging from 47.9 to 58.2 g/kg DM, and ADF content of 147 g/kg DM. Watermelon seed cake has a dry matter chemical composition of 92.5 - 95.5 % DM, 20.62 - 27.18 percent CP, 7.84 – 10.8 % EE, and 21.4 - 27.4 percent CF (Olayinka and Etejere, 2018). Watermelon seed cake has a high DM and medium CP content, making it a potential protein supplement for livestock, nonetheless its high fiber content may limit its use in non-ruminant animals such as birds (Elhag *et al.*, 2007). Low EE content in watermelon seed cakes suggests that it can be included at higher levels in ruminant rations. Uncultivated Rubber seed meal contains 14.1 % moisture and 10.3 % CP, while cultivated Rubber seed meal contains 2.6 % moisture and 21.9 % CP (Oyewusi *et al.*, 2007). Fresh, boiled, and toasted Rubber seed meals contain DM (percent) of 96.91, 85.40, and 93.63, respectively; CP (%) of 23.31, 24.60, 21.08; EE (%) of 38.47 as reported by (Udo *et al.*, 2018). The chemical compositions of these cakes vary due to various factors, including organisms and manufacturing methods. Rubber seed meals with a crude protein content of at least 20% can be considered as possible livestock protein supplements.

2.4. Nutritional composition of conventional oil cakes

According to Stein *et al.* (2015), the chemical composition of soybean meal ranged from 89.8 to 90 percent for DM, CP, EE, NDF, and ADF, and from 45.4 to 47.7 percent for DM, CP, EE, NDF, and ADF, respectively. Muya *et al.* (2020) reported similar findings on the chemical composition of soybean meals because their values fell within the ranges obtained by (Stein *et al.*, 2015) and (Alves *et al.*, 2016). The similarities suggest that soybean meals have a consistent chemical composition, which may benefit farmers by eliminating the need to analyse these meals for nutrient content. Onzález *et al.* (2003), on the other hand, examined specific varieties of soybeans and discovered that they contained CP (percent) ranging from 49 to 54, Stein *et al.*, (2015), Alves *et al.*, (2016), and Muya *et al.*, (2016) all observed a greater CP (2020). Variances in climatic conditions and oil extraction technologies, which impact the nutritional makeup of plant feed ingredients, could explain these differences. This, nonetheless, does not change the fact that Soybean meal is a high and excellent protein source for livestock.



2.5. Chemical composition of macadamia oil cake and baobab oil seed cake

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Several researchers studied the chemical composition of Macadamia oil cake, and their findings were somehow contradictory Tiwari and Jha (2017); Van Ryssen *et al.* (2014); and Skenjana *et al.* (2006). Tiwari and Jha (2017) reported that, on a dry matter basis, macadamia nut cake (MNC) contains 91.2 % DM, 25.5 percent CP, 3.7 % ash, 11.9 percent EE, 25.2 % CF, 28.0 ADF, and 35.8 % NDF. According to Van Ryssen *et al.* (2014), who determined the chemical composition of MOC on an as-fed basis, MOC contains 94 percent DM, 28 % ash, and 13.2 percent CP.

The Macadamia oil cake has a DM content of 93.8 %, an ash content of 2.8 percent, a CP content of 19.5 %, a CF content of 24.9 %, and an EE content of 10.4 % (Mikasi *et al.*, 2019). The differences in Macadamia oil residues can be attributed to different extraction methods and the

addition of soybean hulls during MOC production. In contrast to the oil extracted Macadamia residue used in the studies by Acheampong-Boateng *et al.* (2017); Skenjana *et al.* (2006); Van Ryssen *et al.* (2014), and Tu *et al.* (2021) used roasted Macadamia nuts and reported that they contain 98.6 % DM, 1.4 % ash, 9.9 % CP, 70 % EE, and 9.2 % CF. The chemical compositions of these Macadamia oil cakes and roasted Macadamia nuts differ due to differences in processing methods. Several studies on the proximate analysis of baobab oil seed cake have been conducted across the African continent (Saulawa *et al.*, 2014); (Babiker, 2012), with only a few studies conducted in South Africa (Chisoro *et al.*, 2018). Some of the proximate analyses of BOSC findings are contradictory, while others are similar. The BOSC contains 90.6 %DM, 4.57 % ash, 16.9 % CP, 5.26 % EE, and 25.61 % CF (Madzimure *et al.*, 2011), which is comparable to Babiker (2012) 's findings, who noted 15 % CP, 25.99 % CF, 3.97 % EE, and 9.38 % ash. Ezeagu (2008) CP and ash content of BOSC are similar to the values reported by by Madzimure *et al.* (2011); and Babiker (2012). However, In contrast to the findings of the authors mentioned above, (Saulawa *et al.*, 2014) reported the CP ranged from 18.68 – 28.85 %, CF (7.84 – 10.78 %), EE (2.19 – 4.41 %), and ash (5.84 – 8.92 %). BOSC's CP content (22.86 % DM) falls within the 18.85 – 28.85 % DM range as observed by (Chisoro *et al.*, 2018); and (Saulawa *et al.*, 2014). The nutritional value of baobab oil seed cake reported by Nkafamiya *et al.* (2007), and Oyesiji *et al.* (2020) are within the ranges reported by Saulawa *et al.* (2014). These differences in findings on the nutritional composition of baobab oil seed cake could be ascribed to climatic conditions as well as different the extraction methods.

According to the literature, MOC has higher NDF and ADF values than MNC and BSC. The high fiber content of MOC could be implied to the inclusion of Soyabean hulls during the oil extraction process. Soybean hulls serve as a layer covering the Soybean seed and are high in fiber, which

accounts for MOC's high fiber content. This scribes that BOSC might be more digestible than MOC mainly due to high lignin in the Soyabean hulls. Nevertheless, it is of great significance to note that the CP of BOSC content appears to decrease with oil extraction, although the CP content of Baobab seeds is higher than that of their residual cakes. This incidence dispute the expected increase in CP of residues after oil extraction from seeds.

2.7. Mineral composition of Macadamia oil cake and Baobab oil seed cake

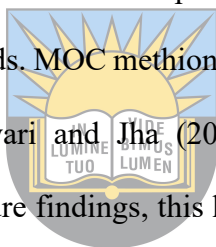
The Macadamia oil cake contains 0.16 - 0.24 % calcium (Ca) and 0.23 - 0.24 % phosphorus (P) Acheampong-Boateng *et al.* (2017); Van Ryssen *et al.* (2014), which is comparable to MOC's 0.33 % Ca and 0.30 % P observed by (Skenjana *et al.*, 2006). The feed-grade Macadamia nuts contain 0.1 percent Ca and 0.25 percent P as noted by (Sherrod and Isi-iizaki, 1966), which is within the ranges observed by (Acheampong-Boateng *et al.*, 2017) and (Van Ryssen *et al.*, 2014). Because feed grade Macadamia nuts were produced and roasted in Hawaii, whereas MOC was produced and oil extracted mechanically in South Africa, the similarities imply that neither environmental conditions nor processing methods have a significant influence on the Ca and P content of Macadamia nuts.

Calcium and Phosphorus levels in BOSC range from 0.12 to 0.3 % and from 0.13 to 0.24 %, respectively (Nkafamiya *et al.*, 2007); (Madzimure *et al.*, 2011). The BOSC contains 0.21 % Ca and 0.93 % P (Ezeagu, 2008), which are comparable to the Ca and P ranges reported by Nkafamiya *et al.* (2007) and Madzimure *et al.* (2007). The Ca content of boiled and soaked BSM (Saulawa *et al.*, 2014) is comparable to (Nkafamiya *et al.*, 2007) and (Madzimure *et al.*, 2011), but differs from untreated (raw), toasted, soaked, and boiled BSM (Saulawa *et al.*, 2014). The differences could be attributed to different processing methods. Based on literature findings, the Ca and P

contents of MOC and BOSC are comparable, except for the P content of BOSC, which is a bit higher than that of MOC.

2.8. Amino acids profiles of Macadamia oil cake and Baobab seed cake

Skenjana *et al.* (2006) reported that macadamia oil cake has lower amino acid profile values for lysine, methionine, threonine, tryptophan, phenylalanine, histidine, valine, isoleucine, leucine, arginine, cysteine, proline, glutamic acid, and tyrosine than MNC (Tiwari and Jha, 2017). The differences in amino acid values between MOC and MNC range from 1 to 3 g/kg, which may be ascribed to differences in cake processing methods. This is because MOC contains Soyabean hulls, whereas MNC does not. These Macadamia residues reported by several authors, on the other hand, appear to be good sources of Amino acids. MOC methionine (Skenjana *et al.*, 2006) is comparable to MNC methionine reported by Tiwari and Jha (2017) with values of 0.24 and 0.34 %, respectively. According to these literature findings, this now concludes MOC and MNC are both poor sources of methionine.



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The chemical composition of Baobab seeds disclosed that its protein contains an adequate amount of essential Amino acid profiles for lysine, methionine, cysteine, isoleucine, leucine, phenylalanine, tyrosine, threonine, tryptophan, valine, and histidine, with 1.25 percent methionine being the lowest and 6.54 % leucine being the highest (Ezeagu, 2008). According to the literature, baobab seeds are low in methionine and high in leucine, implying that methionine may be the first limiting amino acid when baobab seeds are fed to non-ruminants as a protein supplement. The amino acid profile for lysine, methionine, cysteine, isoleucine, leucine, phenylalanine, tyrosine, threonine, tryptophan, valine and histidine, threonine, serine, glutamine, glycine, alanine,

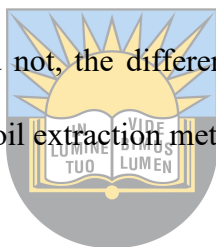
phenylalanine, histidine, arginine, and proline contains 0.19 % methionine as the lowest and 2.92 (Babiker, 2012).



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2.9. Fatty acids profile of Macadamia oil cake and Baobab oil seed cake

MOC's fatty acid composition includes 20.16 % monounsaturated fatty acids, 75.96 % polyunsaturated fatty acids, and 0.82 % polyunsaturated fatty acids: saturated fatty acids ratio, with oleic acid (C18:1n9c) accounting for 51.9 % of total fatty acids (Skenjana *et al.*, 2006). MOC's linoleic and linolenic acids account for 2.69 and 0.49 % of total fatty acids, respectively (Skenjana *et al.*, 2006). The MNC contains 16.18 % saturated fatty acids, 79.84 % monounsaturated fatty acids, 2.75 % polyunsaturated fatty acids, and 0.17 % polyunsaturated fatty acids: saturated fatty acids ratio, with oleic acid accounting for 57.43 % of total fatty acids (Tiwari and Jha, 2017). Linoleic and linolenic acids are found in lower concentrations in MNC oil. Because the MOC had soybean hulls added and the MNC did not, the difference in fatty acid compositions could be attributed to differences in Macadamia oil extraction methods.



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BOSC oil is high in oleic and linoleic fatty acids and low in polyunsaturated/saturated fatty acid ratio (Ezeagu, 2008). BOSC oil contains a low percentage of free fatty acids (oleic acid = 0.45 %) (Nkafamiya *et al.*, 2007), which contradicts Ezeagu's findings (2008). The variations could be attributed to environmental factors and processing methods. The seed contains a significant amount of oil (29.7 % on a dry weight basis) (Nnam and Obiakor, 2003). The baobab seeds are classified as both protein- and oil-rich. The seed oil contains a high concentration of mono- and polyunsaturated fatty acids (Osman, 2004). According to (Gebauer *et al.*, 2002), 26.89 % of all fatty acids are saturated, while 73.11 % are unsaturated. The seed oil contains high levels of oleic and linoleic acid and linolenic and palmitic acid (Ezeagu, 2008). According to (De Caluwé *et al.*, 2021), the key fatty acids in baobab oil are oleic (26.07 %) and linoleic (39.42 %).

2.10. Anti-nutritional factors

Anti-nutritional factors such as phytate, protease inhibitors, tannins, amylase inhibitors, phytic acid, oxalate, trypsin inhibitors, and alkaloids, according to Igboeli *et al.* (1997) and Oyeleke (2012), hinder the optimal usage and acceptability of baobab seeds as a source protein. They can be deactivated or removed using a variety of processing techniques such as heating with boiled water (Chadare *et al.*, 2009). Anti-nutritional elements found in baobab seeds, according to Osman (2004), include phytic acid (73 mg/100 g), a Trypsin Inhibitor Activity (5.7 TIU/mg sample), and catechin equivalent of tannin (23 %). The tannin content in baobab seeds can be affected by cold and hot water treatments, as well as acid and hot alkali treatments (Igboeli *et al.*, 1997).

Dehulling is another option, but it does not considerably reduce tannin levels. Dehulling, hot alkali treatments, and cold water treatments, on the other hand, greatly lower amylase inhibitor action (Chadare *et al.*, 2009). Furthermore, Nnam and Obiakor (2003) observed that fermenting baobab seeds reduces phytate and tannins. According to Chisoro *et al.* (2017), the most promising approach for creating nutritious feed products from baobab seeds is 6-day fermentation. On the other hand, Nkafamiya *et al.* (2007), argued that the amount of ant-nutrients present in baobab are below toxic levels. Baobab seed cake used in the current study is rich in tannins, as reported by (Makkar, 2003). It has been reported on several occasions that baobab oil cake contains 2-12 % tannins (Mwale *et al.*, 2008); (Amlan *et al.*, 2011) as a result, secondary plant metabolites like tannins have been shown to suppress enteric methane production in ruminants, so feeding goats with baobab oil seed cake would help to promote adequate nutrition while also lowering methane emissions.

Table 2.1: Shows phytochemical content of baobab seeds

Anti-nutrients	Baobab seed
Tannin, mg/g	0.30
Phytate, g/100g	1.21
Phytate-phosphorus	0.33
Phytate-P as % total P	1.10
Trypsin inhibitor, TIU/mg	Not Detected
Haemagglutinins, HU/mg	0.251
Cyanide, mg/100g	0.26
Total oxalate, mg/100g	42.00
Water soluble Oxalate	26.01
Soluble oxalate as % of total oxalate	61.90
Nitrate, mg/g	19.46
Nitrite, mg/g	0.104
Source: (Osman, 2004)	



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Table 2.2: Proximate analysis (%) of conventional and nonconventional feed

Feed	DM	CP	Ash	EE	GE*	NDF	ADF	References
Conventional								
Soybean meal	89.2	46	8.4	1.4	-	9.5	6.1	(Landero <i>et al.</i> , 2013)
Groundnut meal	94	23	26	9.3	-	-	-	(Mustafa and Alamin, 2012)
Sunflower meal	-	27	4.8	31	-	-	-	(Nkosi <i>et al.</i> , 2011)
Cottonseed meal	91	45	7.1	1.6	-	-	17	(Phenya and Nkosi, 2018)
Canola seed meal	94	26	6.1	19.5	-	-	-	(Webster and Lim, 2015)
Non-conventional								
Marula seed meal	90	47	5.6	39	-	19	13	(Mlambo, Dlamini, <i>et al.</i> , 2011)
Macadamia seed oilcake	94	20	2.8	10	-	52	42	(Acheampong-Boateng <i>et al.</i> , 2017)
Baobab seed oilcake	91	23	4.6	8	18	42	36	(Chisoro <i>et al.</i> , 2017)
Jatropha meal	-	36	9.4	9.3	18	4.3	-	(Makkar and Becker, 1999)
Castor bean cake	93	29	-	10.3	-	57	40	(Alves <i>et al.</i> , 2016)
Rubber seed meal	96	17.4	3.0	69	-	-	-	(Eka <i>et al.</i> , 2010)

*= MJ/kg DM, DM = dry matter, CP = crude protein, EE = ether extract, GE = gross

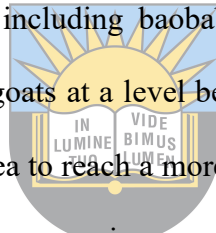
energy, NDF = neutral detergent fibre, ADF = acid detergent fibre.

2.11. Effect of Macadamia oil cake (MOC) and Baobab seed cake (BOSC) on feed intake and growth performance of ruminants

According to Hayirli *et al.* (2002), DM intake can be affected by various factors, including the feed's fiber (NDF) and fat content. Maynard (2018) argued that an animal's daily feed consumption positively impacts its daily production. The use of MOC as a protein supplement in feedlot cattle diets up to 20% to fully replace soybean meal has no effect on daily feed intake and enhances the animals' growth efficiency (Acheampong-Boateng *et al.*, 2017). The addition of MOC to lambs' diets as a protein supplement up to 20% of the total diet does not affect feed intake or growth efficiency (Acheampong-Boateng *et al.*, 2017). Both studies conducted by (Acheampong-Boateng *et al.*, 2008 and 2017) it is reported that MOC can substitute soybean meal as a protein supplement in ruminant diets without affecting feed intake or growth when it is added to make up 10% of the total diet. The addition of 12 % feed-grade Macadamia nuts to sheep's diets in replacing maize grains without affecting feed intake or growth efficiency (Sherrod and Isi-iizaki, 1966). However, Tikam *et al.* (2013) suggested that feed-grade Macadamia nuts could be used in ruminant rations to replace certain grains as long as the crude fat content of the ration does not exceed 10%, as this could interfere with feed digestibility and energy utilization. The differences observed in the studies mentioned above may be due to the lower oil content of the latter's feeds compared to (Sherrod and Isi-iizaki, 1966)'s findings. The diets of lambs in Sherrod and Isi-iizaki (1966) research included oil-rich items like soybean meal and macadamia nuts, which may cause the diets' high oil content Belewu and Olajide (2010). When included in the diets of lambs at 12.5 % of total diets, the BOSC can partially substitute Soyabean meal without negatively affecting daily feed intake or growth output of the animals. Feed intake and growth output were decreased when BOSC was used in excess of 12.5 % of the total diet to partially replace Soyabean (Tikam *et al.*, 2013).

BSC should be included in the diets of lactating cows up to 15% of their diet (Madzimure *et al.*, 2011). Feed intake and growth output were decreased when BOSC was used in excess of 12.5 percent of the total diet to partially replace soybean meal (Okoro *et al.*, 2017). The use of BOSC in the diets of lactating cows to partially replace Cotton seed cake as a protein supplement, up to 15% of the total diet, increases daily feed intake but decreases milk quality and quantity (Madzimure *et al.*, 2011). The animal performance differences between Madzimure *et al.* (2011) and Okoro *et al.* (2017) can be attributed to the animal species and BOSC processing system.

Whole Baobab fruit meal decreased daily feed intake, but at a 10% inclusion stage, whole Baobab meal had no effect on goat body weight gain (Ilori *et al.*, 2013). According to the reports of Okoro *et al.* (2017) and Ilori *et al.* (2013), including baobab fruit products (meal/cake) as protein supplements in the diets of sheep and goats at a level below 15% may yield satisfactory results, but further research is needed in this area to reach a more definitive conclusion. However, BOSC should not be used in the diets of lactating cows in amounts greater than 10% because it decreases milk quality and quantity.



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2.11. Effects of feeding ruminants with other oil cakes as protein supplements on growth performance

2.11.1 Feed intake

Dietary protein sources can affect DM intake because they affect the rumen's ability to retain ruminal contents (Bandyk *et al.*, 2001). High fiber content, such as that found in Sunflower meals, has a negative impact on animal efficiency by reducing intake and digestibility (Khalid *et al.*, 2012). Feedlot weaners TMR diet with 13% cold press Soybean oil cake showed an improved feed consumption (Chipa *et al.*, 2010). The addition of Marula seed cake (MSC) to feedlot cattle

diets does not affect feed intake (Mlambo *et al.*, 2011). The MSC supplementation of lactating dairy cows as a sole protein supplement or as a partial replacement for Soybean meal as a protein supplement does not affect feed intake (Mdziniso *et al.*, 2016). These findings by Luginbuhl *et al.* (2000) support the hypothesis that feeds with a higher oil content have a negative impact on animal feed intake.

Bulls fed a sunflower cake diet consumed more feed (DM) with an average of 8.45 kg/day, followed by bulls fed cottonseed and groundnut cakes, respectively, and bulls fed Guar meal diets consumed less feed (6.92 kg/day) (Sharif *et al.*, 2014). Rubber seed cake can be used at a 20% inclusion level in goat fattening diets with no adverse effects on feed intake (Chanjula *et al.*, 2011). Palm kernel cake can be used as a protein substitute for ruminant animals in fattening diets without compromising feed intake (Abdeltawab and Khattab, 2018). Feeding increased Palm kernel cake levels up to 30% of the diet did not affect feed intake, but feeding increased rubber seed kernel levels (>20%) resulted in significantly lower feed intake than goats fed 0% and 20% Rubber seed kernel (Chanjul *et al.*, 2011). Incorporating Licury cake into the diets of growing goats increased fiber content while having no effect on DM or OM intake (Borja *et al.*, 2010). The average DM consumption of cottonseed meal-supplemented goats was higher (651.9 g/day) than that of non-supplemented goats (482.0 g/day) (Solomon *et al.*, 2008).

2.11.2. Body weight gain and feed conversion efficiency of ruminant animals

The term "feed efficiency" refers to the amount of animal product produced per unit of feed consumed (Khalid *et al.*, 2012). Improved feed efficiency can result in better animal results (Kabir *et al.*, 2004). Compared to lambs fed the control diet, lambs fed grass silage-based diets supplemented with fish meal, canola meal, and heat-treated canola meal had a 32.4 % increase in

feed production (Plaisance *et al.*, 1997). When lambs were fed a Sunflower meal-based diet, their feed performance was lower than when they were fed a Soybean meal-based diet (Irshaid *et al.*, 2003).

This indicates that the type of oil cake has a significant impact on nutrient utilization in diets that include a protein supplement. Donadelli *et al.* (2019) reported that lambs fed canola meal had better weight gain and feed efficiency than lambs fed cotton seed meal, proving that species type and protein content do affect animal performance and diet utilization. Supplementing high-concentrate diets with sunflower seeds increased lamb feed conversion ratios (Ivan *et al.*, 2004). Lambs fed diets containing soybean meal and canola meal had higher feed consumption efficiency than those fed cotton seed meal, with values of 8.98, 8.58, and 9.79, respectively (Khalid *et al.*, 2012). Feeding full-fat canola seed diets to South African Mutton Merino lambs lowered feed conversion ratio by 21% (Brand *et al.*, 2001). According to Ivan *et al.* (2004), high oil content and likely higher fiber can have a negative impact on animal feed quality. (Khalid *et al.*, 2012) found that lambs fed canola meal-based diets gained substantially more weight and had a higher feed conversion ratio than lambs fed cotton seed meal, corn gluten meal, or sunflower meal-based diets. Supplementing Ogaden bulls on a hay diet with a groundnut cake-based concentrate increased average daily body weight gain, according to (Mekasha *et al.*, 2011). Weaning calves fed diets containing 6% and 13% cold press soybean oil cake had higher average daily gains and feed conversion efficiencies (Chipa *et al.*, 2010). Compared to lambs fed soybean meal, adding 10 and 20% sesame oil cake to the diet increased average daily gains and feed conversion performance (Omar, 2002). Differences in soybean meal may be due to the species and methods of oil extraction. It is observed that lambs gained more weight when cotton seed meal and corn gluten meal were added to their diets (Chakeredza *et al.*, 2001). Supplementing crossbred lambs with

protein sources such as canola meal and soybean meal resulted in a substantial increase in weight gain (Ponnampalam *et al.*, 2005). Lambs fed a diet based on fish meal gained more weight than lambs fed a sunflower-based diet (Nsahlai *et al.*, 2002). The high quality of the protein in fish meal, as well as the fact that sunflower meal is less digestible due to its high fiber content, can explain the increased weight gain in lambs fed fish meal diets. Groundnut meal can be supplemented with decorticated sunflower meal in the diets of Sudanese desert lambs at a rate of 0, 50, or 100 percent without affecting the final body weight or daily weight gain. The high fiber content of the two cakes can explain the similar animal responses when fed groundnut meal or sunflower meal, as fiber may affect feed material digestion. The weight gain of lambs fed either cotton seed meal or sunflower meal is identical (Kandylis *et al.*, 1999).

When the whole cottonseed is added to hay-based diets, the average daily gain of increasing male goats decreases linearly (Luginbuhl *et al.*, 2000). When young lambs and goats are fed heat-processed soybean meal, their live-weight gain increases (Al Jassim *et al.*, 1991). In comparison to lambs fed maize stover supplemented with browse leaf meals, supplementing goats' diets with cotton seed cake as a protein source increases body weight gain (Asaolu *et al.*, 2012). Cottonseed meal supplementation resulted in higher daily body weight gain (65.3 g/day) in Sidama goats than goats eating the control diet (10.2 g/day) (Matiwos *et al.*, 2008). Cottonseed cake supplementation, on the other hand, reduces the feed conversion efficiency of goats (13.7) compared to animals (47.9) in the control diet. Bulls fed oilseed cakes gained 1181 grams of live weight, 1113 grams on groundnut cake, 1077 grams on sunflower cake, and 1056 grams on sesame cake (Sharif *et al.*, 2014).

2.12. Methane emissions in livestock

According to Brouček (2015), roughly 11 % of global anthropogenic greenhouse gases (GHG) is produced by agriculture. The largest part of it (approximately 80%) is from livestock production (Stackhouse *et al.*, 2011). This results from enteric fermentation and manure handling (Kristensen *et al.*, 2011). According to Alemu *et al.* (2011), CH₄ is a major GHG that is emitted during ruminal fermentation. Methane contributes vigorously to global warming; it influences the degradation of the ozone layer (Huarte *et al.*, 2010). Agriculture contributes about 47% -56% in total anthropogenic methane emissions (Beach *et al.*, 2008). According to Moss *et al.* (2000), about 12%- 37% of this amount is from the enteric fermentation of ruminants. Approximately 10% to 15% of the methane produced by ruminants is from manure handling and storage (Beach *et al.*, 2008). Hook *et al.* (2010) reported that ruminants are the primary producers of methane among other animals mainly due to the fact that they have got a big-sized fore stomach with good metabolic processes. Rumen large part (70%) of the total stomach capacity and its volume is 15 L in small ruminants and 100 – 150 in cattle. According to Kristensen *et al.* (2011) production of methane begins from fermentation by microbes of hydrolysed CO₂ in the rumen, which results in a loss of energy for the animals (host). Other contributors in enteric methane production include; feed intake, quality of feed, type of feeds, energy consumption, size of the animal, growth rate, and level of production, breed, and thermal conditions.

2.12.1. Enteric methane formation

Recent studies have revealed that careful attention should be paid to measuring methane emissions from enteric fermentation (Knapp *et al.*, 2014). Enteric methane (CH₄) is released as a secondary product during fermentation in the rumen through methanogenic microorganisms in a process called biometanation (Knapp *et al.*, 2014). Salivation, chewing, and digesta kinetics are the major factors

influencing the type and rate of fermentation (Bell *et al.*, 2014). According to (Monteiro *et al.*, 2018), cattle produce seven times CH₄ more than sheep and nine times more methane than goats. Approximately 87% to 90% enteric CH₄ is produced in the rumen, while only 10% to 13% is produced in the large intestines (Bell *et al.*, 2014). Chagunda *et al.* (2013) reported that enteric methane is then released by an animal into the atmosphere through exhalation. Out of CH₄ discharged during biomethanation in the forestomach 95% is expelled by belching, and of the CH₄ emitted in the hindgut, 89 % is excreted through breath and 11% through the anus (Chagunda *et al.*, 2009). The rumen ecosystem degrades plant material at a much faster rate than other aerobic ecosystems like wetlands and estuaries, which is related to the fact that it is an anaerobic environment (Brouek, 2015).

The digestion of feed components by microorganisms such as bacteria, protozoa, and fungus produces volatile fatty acids such as acetate, propionate, and butyrate acid, which are then utilised as a source of energy by the animal (Li *et al.*, 2018). Gases are generated during this process, according to Cassandro *et al.*, (2013), and their production is removed through eructation. Gases are generated during this process, according to Cassandro *et al.*, (2013), and their production is removed through eructation. Methane is produced by combining carbon dioxide and hydrogen, therefore metabolic H₂ produced by microbial metabolism is reduced (Cassandro *et al.*, 2013). Methanogenic Archaea, a microbial group different from Eubacteria, utilise hydrogen to convert CO₂ to CH₄ as soon as it is created. Ruminant enteric methane represents a loss of feed energy from the diet and indicates inadequate feed utilization (Chagunda *et al.*, 2009). According to Boadi *et al.* (2004), ruminant methanogenesis results in a loss of 2 to 12 percent of gross energy intake.

2.12.2. Effect of feed on methane emissions

Ramin and Huhtanen (2013) provide evidence that that feed intake is the major contributing factor in enteric methane emission. This is aligned with (Getabalew *et al*, 2019) , who reported that the amount of enteric CH₄ is mainly related to the type and amount of feed that the animal takes per given period of time. Consequently (Getabalew *et al.*, 2019)’s interpretation indicates that as the daily feed intake increases, enteric methane production generally increases. Grainger *et al.* (2007) also believe that dry matter intake (DMI) is the main driving factor of daily methane production. Despite the fact that methane production per kilogram of DMI decreases with increasing feeding levels and diet digestibility, as well as with increasing proportions of concentrates or lipids in the diet. Grainger *et al.* (2007) also believe that dry matter intake (DMI) is the main driving factor of daily methane production. Methane generation in ruminants is also influenced by the type of feed and its composition.



According to Moss *et al.* (2000), microbial activity influences ruminal digestion, which requires energy, nitrogen, and minerals. As a result, the quality of forages has an impact on rumen microbial activity. Ruminant methane generation is further affected by species, processing methods, the amount of forage in the diet, and the grain supply (Moss *et al.*, 2000). Furthermore, it was discovered that when the protein level of feed increases, methane generation decreases and increases as the fiber content of feed increases. Chianese *et al.* (2009) implied that CH₄ emission is positively correlated to digestibility of the die but inversely proportional to fat concentration of the diet, while carbohydrate composition of the diet has minor effect. Additionally, Van Haarlem *et al.* (2008) reported that there is a substantial negative impact of CH₄ production on animal productivity, which then results in 2% to 12% energy loss in the animal’s gastrointestinal tract.

2.13. Effects of plant secondary metabolites in mitigating methane emissions

Despite nutritional deficiencies, recently, there are rising concerns of greenhouse gas emissions, particularly methane gas, which is produced by livestock during ruminal fermentation. Therefore, plant secondary metabolites such as tannins have been used to mitigate methane gas production. Plant secondary compounds present in forages and plant extracts have been established as potential inhibitors of methane in the rumen (Patra, 2011). This has corresponded with the research findings of Pal *et al.* (2015), who noted that various forage plants are rich in tannins. Hence they can contribute significantly to the reduction of enteric CH₄ gas production (Li *et al.*, 2013). This occurs when tannins inhibit methanogenic bacteria and also by indirectly reducing hydrogen production due to decreased fiber digestion and ruminal protozoal population (Pal *et al.*, 2015). Additionally, leguminous plants are considered to possess plant secondary compounds such as phenols, tannins and saponins. These secondary metabolites play an essential role in ruminant feeding as a methane mitigatory strategy because they exist naturally in plants (Wanapat *et al.*, 2015). Further research findings reveal that there are potential anti-methanogenic activities for both condensed tannins and hydrolysable tannins (Wanapat *et al.*, 2015).



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Baobab seed cake used in the present study is also rich in tannins, as reported by (Makkar, 2003). It been observed severally that baobab oil cake contains 2-12% tannins (Mwale *et al.*, 2008; Patra and Saxena, 2011), which means baobab seed cake does not only improve growth but can also be a suitable tool to mitigate methane gas emissions. Additionally, based on findings by Lockett *et al.* (2000), there is an added advantage of reduced ruminal methane emissions when feeding plant oils to the livestock, this might be attributed to the bio-hydrogenation of unsaturated fatty acids. This corresponds with findings by (Jordan *et al.*, 2014), who noted that there was a 40% decreased in enteric methane emissions without any detrimental impact on feed intake when soybean oil was added to the diet. This might be a similar case with baobab seed cake since it contains an equal

amount of fatty acid composition. Washaya *et al.* (2018) reported that Legume forages (*Vigna unguiculata* and *Lablab purpureus*) reduce enteric methane production from goats. This might be possibly ascribed to the action of tannins in these forages as reported by (Waghorn and Hegarty (2011), forage legumes can be used to influence rumen environment to suppress methane emission significantly. This could be attributed to the fact that legumes possess less structural carbohydrates and more condensed tannins than grass.

2.14. Summery

South African goats' production is dominated by many indigenous goats. However, its profitability and productivity being affected by various factors such as diseases and parasites, use of inappropriate breeding methods, and primarily limited forage availability. Among the aforementioned factors, feed remains a major limiting factor in goats' production. Firstly, the commercial feed sources such as sunflower oil, Soybean meal, which usually supply nutrient needs for livestock, have become too expensive recently, and also there is a competition between intensive animal production and an ever-increasing human population for commercial feed sources. Therefore, non-conventional feed products with high protein or energy content have the ability to be used as nutrient supplements to substitute the most widely used and often costly sources of these nutrients for more profitable livestock production.

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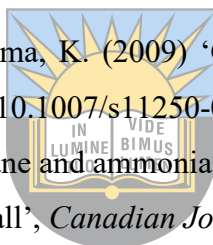
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Chapter Three

Experiment 1: Influence of baobab oil seed cake graded levels on growth performance in Savannah × Boer goats

(Submitted to Journal translational Animal Science, manuscript ID: TAS-2021-0843)

Abstract

The study was conducted to investigate the effect of feeding graded levels of baobab oil seed cake (BOSC) on feed intake and growth performance of Savannah× Boer goats at yearling age. A total of 24 goats weighing 16.63 ± 3.639 kg were used in a completely randomized block design. The experimental diets were iso-nitrogenous and iso-caloric. On weeks and treatment interaction, the average daily gain (ADG) and the body weight gain (BWG) were higher in goats fed on diets with 15%,30%, and 45% BOSC compared with those fed on a diet containing soya bean meal-based diet (control). The highest average daily gain (0.20 ± 0.015) was observed on goats that were fed on a diet with 30% BOSC ($P < 0.05$). Average daily feed intake (ADFI) was consistent with time, as the time changes from week 1 to week 9 also ADFI increased. Females in the current study gained more weight than males ($P < 0.05$). Therefore, BOSC can therefore be a valuable ingredient in goats' diets at 15 to 45 % inclusion levels without causing any detrimental effects on the goats' well-being.

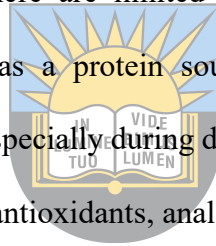
Keywords: Baobab oil seed cake, growth performance, goats, feeding

3.1. Introduction

In recent years, there has been a rapid growth in the human population in developing countries which has resulted in an increased demand for animal protein (Ahamefule *et al.*, 2019). This necessitates the need for the rapid increase in animal production. Hence, an increase in the production of sheep and goats could be part of the solution to this problem. This is, however, hindered by the increased cost of feed, which comprises approximately 70% of the total production (Ekiti, 2013). Additionally, meeting the animal protein demand by the teeming human population can be realized by enhancing the production of local goat breeds such as Savannah goats, Boer goats, and the Xhosa ear-lopped goats. Both Savannah and Boer goat breeds are able to survive in harsh environmental conditions such as high thermal conditions and are also disease resistant. This has made them favourites of South African goat farmers more especially in the Eastern Cape, South Africa (Visser, 2014). Goat production is the primary source of income for farmers living in arid and semiarid regions; however, goats that are kept in these areas are faced with nutritional deficiency due to drought, which aggravates the disease and low productive Performances (Salem, 2014).

Due to the above-mentioned reasons, it can therefore be anticipated that goat farmers in Baobab growing regions of South Africa and other parts of the world can benefit from the use of baobab oil seed cake to replace expensive commercial protein sources such as cotton seed meal, soybean meal and sunflower oil cake (Chimvurahwe *et al.*, 2011). Gadzirayi *et al.* (2012) noted that prices of commercial protein sources such as soybean meals are on the increase. Chisoro *et al.* (2018) reported that prices of commercial protein sources had increased rapidly lately from 2011

to 2018, and thus, using them in ruminant feeds such as goat feed might not be profitable due to increased production costs. The baobab tree is distributed in most sub-Saharan Africa's semi-arid and sub-humid regions and in western Madagascar. It is commonly grown in the Limpopo province of South Africa. The Baobab tree is a drought-tolerant tree that survives in extremely high-temperature places of the world. It is mainly grown for its sour fruits and leaves (Caluwé and Damme, 2010). Baobab seeds (*Adansonia digitata*) are very rich in protein, energy, vitamins and minerals (Chimvuramahwe *et al.*, 2011). Baobab seed cake contains high crude protein (18% to 38%) value, make it to be a good protein source for supplementation (Chimvuramahwe *et al.*, 2011). Goats' farmers in baobab growing regions use baobab seed cake to feed goats more especially during dry season when there are limited and poor-quality feed sources. Use of *Adansonia digitata*, more especially as a protein source may help to improve the growth performance and quality of goat meat especially during dry season. Feeding *Adansonia digitata* to goats has some health benefits such as antioxidants, analgesics, and anti-inflammatory and serves as a good source of micronutrients and energy (Caluwé and Damme, 2010).



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Inadequate feed supply remains a significant hindrance in goat production (Louis *et al.*, 2015). This has made rural goat farmers to change their supplementary strategy to such an extent that they now supplement their animals with crop and crop residues, more especially in the rural areas of Eastern Cape Province of South Africa (Gxasheka *et al.*, 2017). These regions experience a lot of rainfall seasonality and scarcity, resulting in a low fodder potential (Ben-Salem, 2010). Feeding baobab oil seed cake in goats may improve growth performance. The pleasing aroma in Baobab oil seed cake might increase palatability and acceptability in goats, thus improving body weight gain and feed conversion ratio. Therefore, the study's objective is to evaluate the potential effects of baobab oil seed cake on feed intake and growth performance of Savannah and Boer crossbreed

goats at yearling age. It was hypothesized that baobab oil seed cake will not improve the feed intake and growth performance of Savannah and Boer goat's crossbreed at yearling age.

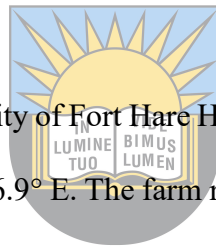
3.2. Methods and materials

3.2.1. Ethical approval

The feeding trial was conducted between November 2018 and January 2019. Prior the commencement of the study, the University of Fort Hare Research Ethics Committee granted the commencement of the study with the permission to use animals in this trial (with animal ethics No: MPE011SSAH01).

3.2.3. Study site

The study was conducted at the University of Fort Hare Honeydale Farm. The farm is 520 m above sea level and is located at 32.8° S and 26.9° E. The farm receives an average annual rainfall of 480 mm and has a mean annual temperature range of 7.22°C to 32°C. The farm is located in the False Thornveld of the Eastern Cape (Ngambu *et al.*, 2013).

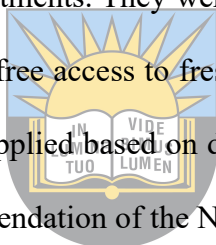


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3.2.4. Animal management, diets, feeding, and experimental design

A total of 24 yearling goats (12 females and 12 castrates), weighing 16.63 ± 3.639 kg, were used in the current study. All 24 goats were ear-tagged according to their respective treatments. The goats were de-wormed against internal parasites with Valbazen (manufactured by Zoetis™, dosage rate: 5ml for animals weighing 30kg body mass, containing Albendazole 1.9% m/v active ingredient). The goats were vaccinated against anthrax, pasteurellosis, and pulpy kidney using Hi-tet 120 (manufactured by Bayer (Pty) Ltd animal health care, dosage rate: 2ml for animals with 30 kg body mass, the composition of Oxtetracycline Hydrochloride 120 mg/ml as an active

ingredient). The goats were kept in well-ventilated individual pens in the animal house equipped with watering and feeding troughs. The experiment was conducted in a randomized complete block design (RCBD) where sex was a blocking factor. The goats were assigned to four different dietary treatments as follows: Treatment 1 (the control with 0% baobab oil seed cake but had soya bean meal (SBM) as source of protein, Treatment 2 (15% baobab oil seed cake), Treatment 3 (30% baobab oil seed cake) and Treatment 4 (45% baobab oil seed cake). Table 3.3 showed the constituents of the diets. The goats were given 14 days to adapt to the treatment diets, experimental pens, as well as human handling and presence before the commencement of the feeding trial that lasted for 70 days. The goats were given 1.2 kg (was split into two halves) of feed twice a day (8:00 am and 16h00 pm) across all treatments. They were kept in well-ventilated individual 124 pens that are 1.5m ×1.5m square, with free access to fresh and clean water *ad libitum* daily. The amounts of protein and energy were supplied based on daily energy and protein requirements of animals in accordance with the recommendation of the National Research Council (NRC, 2007).



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3. 2.5. Diet composition

Proximate analysis was done on the baobab oil seed cake (Table 3.3) using the methods of the Association of Official Analytical Chemists (method 920.85; AOAC, 2005) at ARC-AP nutrition laboratory, in Pretoria, Gauteng Province of South Africa. Proximate composition of the experimental diets (Table 3.2) was done using the methods of the Association of Official Analytical Chemists (method 920.85; AOAC, 2005) at the Department of Agriculture and Rural Development nutrition laboratory, in Kwa Zulu Natal Province of South Africa. Four experimental diets consisted of molasses, soya bean meal yellow maize, limestone, salt, Mono-Calcium phosphate, vitamin, and mineral premix) to which baobab oil seed cake (BOSC) was added at graded levels of 0%, 15%, 30%, and 45% (soya bean cake were not included in the treatments that

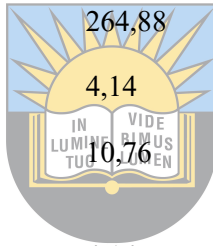
contain baobab seed oil cake). Also, teff (*Eragrostis teff*) grass hay was used as a source fiber (Table 3.1). Feed ingredients were bought from Monti Feeds (East London, South Africa). The mixing of rations was done at the Monti Feeds as guided by the recipe on the formulation sheet.



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Table 3.1: Quantity of feed per ingredient (in kg)

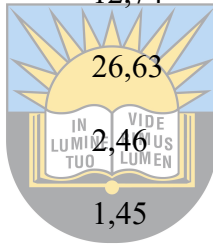
Ingredients	ACTUAL			
	D1 (0% BSOC)	D2 (15% BSOC)	D3 (30% BSOC)	D4 (45% BSOC)
Molasses Meal	38,27	37,25	36,02	35,07
Soyabean Meal 45%	170,07	140,72	112,07	85,72
Yellow Maize Meal	493,20	480,09	420,27	413,00
BSOC	0,00	48,92	94,62	138,16
<i>Teff Grass Hay</i>	280,61	264,88	288,18	272,73
<i>Limestone</i>	4,25	4,14	4,00	3,90
<i>Canola Oil</i>	0,00	10,76	32,02	38,96
Mono-Dicalcium Phosphate (Kynofos 21 Elite)	4,25	4,14	4,00	3,90
Salt	4,25	4,14	4,00	3,90
Vit/Mineral premix	5,10	4,97	4,80	4,68
Total	1000,00	1000,00	1000,00	1000,00



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Table 3.2: Proximate analysis of the diets

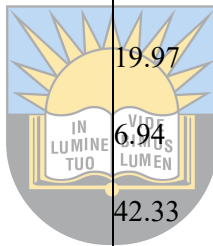
Component	Treatments			
	BOSC (0%)	BOSC (15%)	BOSC (30%)	BOSC (45%)
DM %	87,96	90,54	93,91	96,62
ME (MJ/kg DM)	12,10	12,03	12,16	12,04
Fat (EE) %	2,86	4,28	6,78	7,97
CP%	14,32	14,25	14,13	14,10
CF %	12,18	12,74	14,74	15,31
NDF %	25,30	26,63	29,59	30,99
ADF %	0,81	2,46	4,11	5,75
Ash %	1,37	1,45	1,53	1,61
Ca %	0,44	0,45	0,46	0,46
P %	0,37	0,39	0,40	0,42
Na %	0,16	0,16	0,16	0,16
Cl %	0,28	0,27	0,27	0,27
K	0,15	0,15	0,13	0,13
S	0,07	0,07	0,07	0,07



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Table 3.3: Chemical composition of Baobab oil seed cake used in the study on (% DM basis)

Component	Percentage Content (%)
Dry Matter(DM)	90.86
Moisture	9.14
Ash	4.57
Crude protein(CP) N × 6.25	22.86
Fat(ether extraction)	8.13
Crude fibre (CF)	19.97
Total non-structural carbohydrates	6.94
Neutral detergent fibre (NDF)	42.33
Acid detergent fibre(ADF)	35.93
Acid detergent lignin(ADL)	17.16
Calcium (Ca)	0.24
Phosphorus(P)	0.66
Energy(MJ/Kg)	0.18



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3.2.6. Baobab oil seed cake preparation

Baobab oil seed cake was bought from Eco-Products Company that processes the baobab seeds for its oils, situated in Limpopo. The seeds were extracted from the fruit pulp then separated from fruit pulp. The seeds were first decorticated, and then the kernels were put into a screw press (Screw Oil Press Machine, Model: SL-1685, Zhengzhou, China). The screw press then expelled the oil from the kernel. The expelling process produced the oil and the seed oil cake (by-product). The seed oil cake was then ground into a fine powder to pass through a 0.15 mm sieve. It was then tightly packed in polythene plastic bags, sealed, and kept at room temperatures (Chisoro *et al.*, 2018).



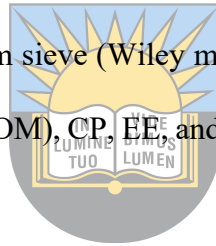
3.2.7. Measurements

3.2.7.1. Average daily feed intake

The feed intake (FI) was determined by subtracting the total amount of refused feed weekly from the feed supplied weekly. Rejected feed from feeding troughs was weighed. The amount of feed that disappeared was considered the feed consumed by the goats. Sacs were placed under all feeding troughs to collect feed spillages. Feed spillages and rejected feed were sun-dried, weighed, recorded, and then discarded. Weights of feed refusals and spillages were subtracted from the total weight of the feed offered to each goat weekly and divided by 7 to determine average daily feed intake (ADFI) (Mpendulo *et al.*, 2017).

3.2.7.2. Average daily weight gain

Body weight gain (BWG) was determined by weighing goats weekly using 11040-LS4 Electronic scale, Model TT 40 (Theuns Mulder Street Brits, Industrial Area) Ranging from 0-2000kg. Body mass (in kg) was then determined using the formula; Weight gain = Weight in the current week - weight in the previous week. Then average daily gain (ADG) was measured by weighing the goats every week across the whole experiment. The difference in weight of goats at the beginning and end of each week divided by 7 determined the ADG (Mpendulo *et al.*, 2017). Samples of feeds offered and orts were oven-dried at 65 °C until constant weight to determine DM concentration and then ground to pass through a 1-mm sieve (Wiley mill; Thomas Scientific, Philadelphia, PA, USA) and analyzed for organic matter (OM), CP, EE, and CF by the procedures described (Ikusika and Okoh, 2019).



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3.2.7.3. Feed conversion ratio

The feed conversion ratio was calculated from average daily feed intake divided by average daily weight gain. The following formula was used: Feed conversion ratio = Feed intake/Weight gain.

3.2.8. Statistical analysis

The PROC MIXED procedure of SAS (2010) for repeated measures was used to test for significance of baobab oil seed cake graded levels and time in a week on average daily feed intake (ADFI), and growth performance (ADG, BWG, and FCR). Differences between least-square

means were tested using the PDIFF option of SAS (2010). The Procedures of General Linear Model of the Statistical Analysis System package (SAS) software, Version 9.2. (SAS Institute Inc., Cary, NC, USA) was used to analyze the data on sex and treatment effects on growth performance parameters (ADFI, ADG, BWG, and FCR). The data were presented as Mean $\pm$ SE, with 5% significance level.

Linear Model: Model: $Y_{ij} = \mu + T_i + S_j + W_k + (T*S)_{is} + (T*W)_{ik} + (T*S*W)_{isk} + e_{ij}$.

Where:

Y_{ij} = response variable (feed intake, feed conversion ratio, average daily gain, body weight gain); μ = overall treatment means;

T_i = effect of treatment i^{th} (0%, 15%, 30%, and 45% BOSC);

S_j = effect of sex j^{th} (Males, and Females),

W_k = effect of week and

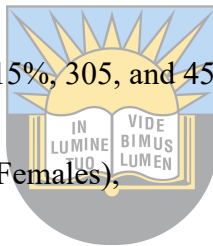
$T*S_{is}$ = Interaction between treatment and sex

$T*W_{ik}$ = Interaction between treatment and Week of successive feeding

$T*S*W_{isk}$ = 3 way interaction between treatment, Sex, and Week of successive feeding

e_{ij} = random error

The PROC REG of SAS (2010) was used to determine the relationships between baobab oil seed cake graded levels and time in a week on average daily feed intake (ADFI) and growth performance (ADG, BWG, and FCR).



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3.3. Results

3.3.1. Growth performance

The relationships between goats' growth performance (ADFI, ADG, BWG, and FCR), time in weeks, and inclusion levels of baobab oil seed cake are shown in (Table 3.4 and Figure 3.1) As the level of the test diet increases, the average daily feed intake generally increased from 1 to week 9 across all treatment diets (Table 3.4 and Figure 3.1). Feed conversion ratio in T1 (control diet) decreased linearly ($P<0.05$) with an increase in time (from week1 to week 9). There was a positive quadratic relationship ($P<0.05$) between time (in weeks), FCR, and BOSC inclusion levels between T2 (15% BOSC) and T4 (45% BOSC). There were no significant differences ($P>0.05$) observed on both average daily gains and body weight gains across all treatments. However, the results in table 3.4 show that goats, amongst all treatments, goats continued to gain body mass linearly from week 1 to week 9 (Figures, 3.2 and 3.3). Table 3.5 shows the results on the effect of graded levels of baobab oil seed cake (BOSC), sex, and treatment and sex interaction on average daily feed intake (ADFI). Baobab oil seed cake significantly affected ($P<0.05$) ADFI, with goats that were fed 30% BOSC diet were notably having higher ADFI (2.10 ± 0.020) than all other treatments. Sex did not significantly ($P>0.05$) affect ADFI. Treatment and sex interaction significantly ($P<0.05$) affected ADFI. Treatment, sex, treatment, and sex interaction did not significantly ($P>0.05$) affect the average daily gain. The highest average daily gain (0.20 ± 0.015) was observed on goats that were fed on a diet with 30% BOSC. Females had higher ADG (0.21 ± 0.015) than females with ADG (0.18 ± 0.015). Inclusion of baobab oil seed cake in goats' diet did not significantly ($P>0.05$) affect body weight gain, sex, treatment, and sex interaction significantly ($P<0.05$) affected body weight gain in goats across all treatments. The highest BWG (1.39 ± 0.123) was observed in goats that were fed 30% BOSC diet. The highest BWG (1.46 ± 0.087)

was observed on female goats, while male goats were observed to have the lowest BWG (1.11 ± 0.087). Incorporation of baobab oil seed cake in goats' diet did not significantly ($P > 0.05$) affect feed conversion ratio. Also the treatment and sex interaction had no significant effect ($P > 0.05$) on feed conversion ratio, but sex significantly ($P < 0.01$) affected feed conversion ratio, with female goats notably having higher FCR (20.16 ± 1.340) than males with FCR (15.38 ± 1.340).



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Table 3.4: LS means of baobab oil seed cake inclusion levels and time in weeks on growth performance parameters of goats

Parameter	Trt	Week									SEM	Regression Coefficient		R-Square	Sig
		1	2	3	4	5	6	7	8	9		Linear	Quadratic		
ADFI	1	0.58	1.22	1.70	1.73	1.80	1.82	2.15	2.25	2.28	0.060	0.474	-0.027	0.762	**
	2	0.87	1.27	1.32	1.38	1.43	1.47	1.52	1.60	1.74	0.060	0.70	-0.013	0.786	**
	3	0.89	1.38	1.44	1.53	1.61	1.66	1.68	2.20	2.27	0.060	0.549	-0.037	0.612	**
	4	0.89	1.03	1.12	1.14	1.18	1.23	1.28	1.33	1.36	0.060	0.245		0.802	**
ADG	1	0.029	0.12	0.13	0.18	0.18	0.19	0.22	0.24	0.25	0.053			0.014	NS
	2	0.07	0.11	0.16	0.17	0.18	0.18	0.19	0.23	0.27	0.053			0.003	NS
	3	0.09	0.12	0.15	0.15	0.17	0.17	0.17	0.25	0.23	0.053			0.015	NS
	4	0.18	0.21	0.23	0.30	0.30	0.31	0.32	0.34	0.35	0.053			0.097	NS
BWG	1	0.84	0.85	0.88	1.24	1.25	1.25	1.54	1.68	1.92	0.368			0.009	NS
	2	0.50	0.78	1.08	1.18	1.23	1.27	1.34	1.58	1.74	0.368			0.020	NS
	3	0.65	0.89	1.03	1.08	1.20	1.20	1.20	1.78	2.08	0.368			0.014	NS
	4	1.27	1.45	1.63	2.08	2.08	2.18	2.24	2.36	2.45	0.368			0.037	NS
FCR	1	20.00	10.17	13.08	9.61	10.00	9.58	9.77	9.38	9.12	12.08	2.494		0.164	*
	2	12.43	11.55	8.25	8.18	7.95	8.17	8.00	6.96	6.45	12.08	-5.538	0.861	0.196	**
	3	9.89	11.50	9.60	10.2	9.47	9.76	9.88	8.80	9.87	12.08			0.315	NS
	4	4.95	4.90	4.87	3.80	3.93	3.97	4.00	3.91	3.89	12.08		0.018	0.120	*

NS: not significant ($P > 0.05$); * significant ($P < 0.05$); ** significant ($P < 0.01$); SEM: standard error of the means; Trt: Treatment; Sig: Significance; ADFI: Average daily feed intake; ADG: Average daily gain; BWG: Body weight gain; and FCR: Feed conversion ratio

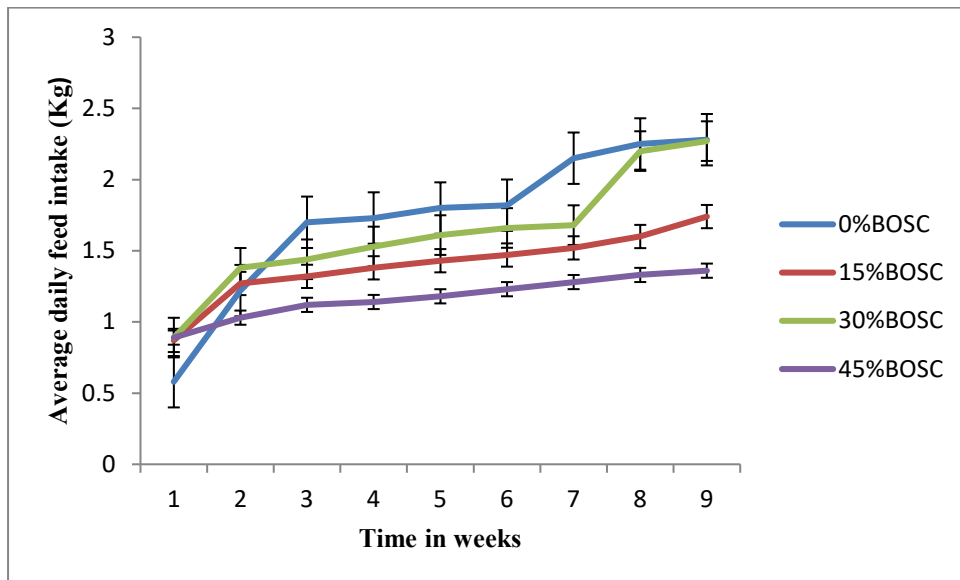


Figure 3.1: The effects of baobab oil seed cake inclusion levels and weeks on average daily feed intake

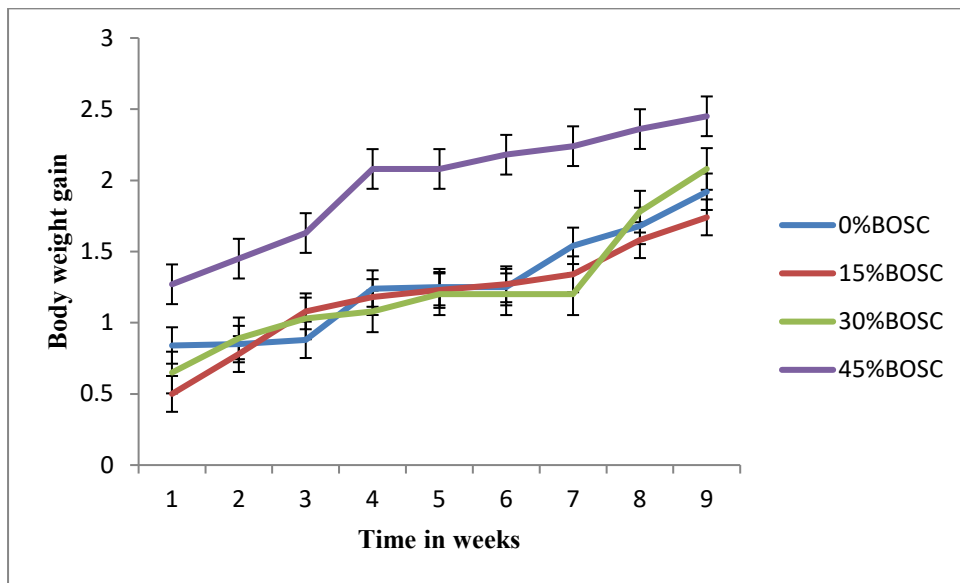


Figure 3.2: The effects of baobab oil seed cake inclusion levels and weeks on average daily gain



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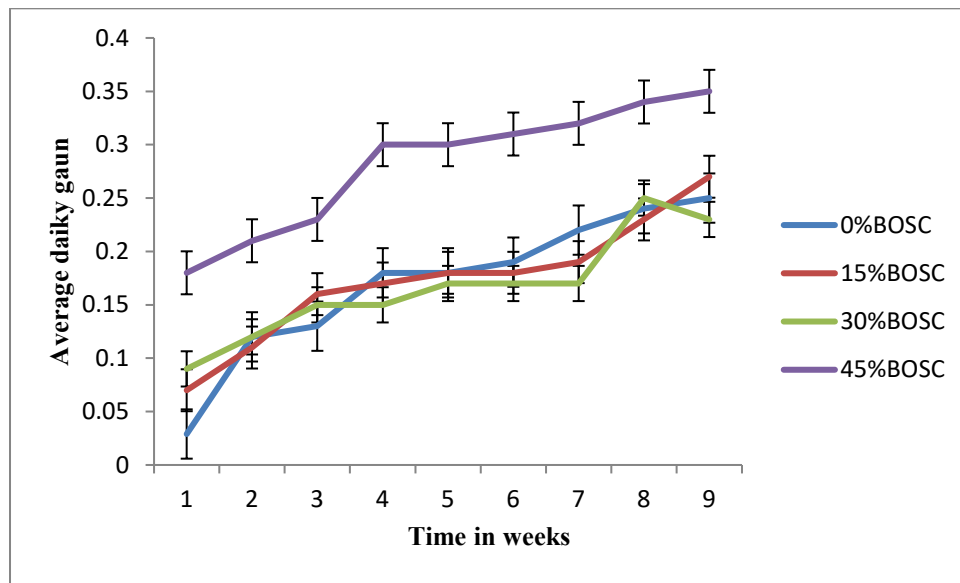


Figure 3.3: The effects of baobab oil seed cake inclusion levels and weeks on body weight gain



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Table3. 5: Effect of treatment, Sex, and Treatment and Sex interaction on feed intake and growth performance parameters

Parameter	Treatment				Sex		P-values		
	T1	T2	T 3	T4	M	F	T	S	T×S
IBW (kg)	14.23±1.485	14.82±1.485	15.19±1.485	16.30±1.8485	16.13±1.050	17.13±1.050	0.073	0.513	0.617
FBW(kg)	21.85±1.503	21.10±1.503	21.85±1.503	21.25±1.503	22.89±1.063	22.58±1.063	0.741	0.838	0.453
ADFI (kg)	1.89 ^a ±0.020	1.82 ^a ±0.020	2.10 ^b ±0.020	1.85 ^a ±0.020	1.90 ^a ±0.014	1.93 ^a ±0.014	<0.0001	0.115	0.002
ADG(kg)	0.19 ^a ±0.022	0.22 ^a ±0.022	0.020 ^a ±0.022	0.18 ^a ±0.022	0.18 ^a ±0.015	0.21 ^a ±0.015	0.623	0.193	0.074
BWG(kg)	1.16 ^a ±0.123	1.35 ^a ±0.123	1.39 ^a ±0.123	1.25 ^a ±0.123	1.11 ^a ±0.087	1.46 ^b ±0.087	0.563	0.005	0.009
FCR	16.98 ^a ±1.923	19.46 ^a ±1.923	18.84 ^a ±1.923	15.80 ^a ±1.923	20.16 ^a ±1.340	15.38 ^b ±1.340	0.514	0.014	0.335

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abcde LS Means in the same row with different superscripts differ significantly (P<0.05); Means with same superscript in the same raw are not significantly different (P>0.05) SEM: standard error of the mean. ADFI: Average daily feed intake; ADG: Average daily gain; BWG: Body weight gain; and FCR: Feed conversion ratio; T: treatment; S: Sex; T*S: Treatment and Sex interaction.

3.4. Discussion

Although baobab oil seed cake is rich in nutrients, it has anti-nutritional factors (Nkafamiya, Osemeahon, *et al.*, 2007). In spite of the fact that anti-nutritional factors can diminish protein digestion and amino acid absorption in animals, they might not have similar effects in ruminants due to the fact that they are degraded in the rumen through the process called microbial detoxification and are so not a concern (Mlambo *et al.*, 2015).

Feed intake and growth performance parameters (ADG, BWG, and FCR)

Significantly ($P < 0.05$) higher ADFI in treatment groups could indicate the palatability of the concentrate (soybean meal-based diet) and the baobab oil seed cake-based diet. This is consistent with Belewu (2007)'s finding that young goats fed a diet containing 40% baobab leaf meal had higher dry matter intake when compared to other leaves such as *Blighia sapida* and *Entada africana*. This could be attributable to an increase in food palatability (Edwin, 2005). Palatability could be caused by aromatic attributes of baobab oil seed cake, as described by Edwin (Chimvurahwe *et al.*, 2011). The good aroma in Baobab oilseed cake might also be attributed to the presence of vitamin C (134.4 mg, which is 15 times than that of orange) (Caluwé and Damme, 2010). Hence it can provide a good smell and can act as an appetizer. As noted by State (2014) this pattern could potentially be a reflection of relative acceptability and palatability. State and State (2018) reported that, significantly increased concentrate consumption in treatment groups on West African Dwarf goats ($P < 0.05$) could be an indication of the concentrate's palatability with fermented baobab inclusion. In this study, an increase in ADFI was associated to the quality of

protein (22.86 % CP) in baobab oilseed cake, which was greater than the minimum of 70g/kg DM CP required to promote optimal rumen microbial activity (Edwards *et al.*, 2010). This is in line with the findings of Tadesse *et al.* (2016), who reported that supplementing high-protein feed with nitrogen increases nitrogen availability in the rumen, resulting in faster feed degradation and utilization. The fact that goats acclimated to the diet over time (in a week) could explain the findings on the increase in ADFI with increasing time (in a week).

Non- significant ($P>0.05$) body weight changes reported in the current study contradict that of Odunola (2012), who reported a significant difference in the daily gain in WAD rams fed 25% baobab bark inclusion in the diet. This could be attributed to the species differences and the differences in nutritive value that is found in different baobab components. The results obtained in the trial align with Belewu and Olajide (2010), who reported that, when included in the diets of lambs at 12.5 % of total diets, the BOSC can partially substitute Soyabean meal without detrimentally affecting daily feed intake or growth performance of the animals. An increase in body weight gains with change in time might be an indication of goats' adaption to the treatment diets and experimental pens. The results observed on ADG in the current study were above the acceptable range of 29 to 51 g/day reported for Small East African goats (Wallie *et al.*, 2012). Growth rates between 36- 53 g/day (Mengistu, 2007), and 42-65 g/day reported by (Alemu *et al.*, 2010). The growth rate in the current study is higher than in other studies. This might be due to the differences in body sizes of goats as well as breeds. The differences in ADG could also be ascribed to the quality of the feed and differences in nutritional composition. Female goats in the current study were superior in body weight gain than male goats

There are few research studies to back up or refute the findings on weekly feed intake variations and growth performance indicators. Several research concentrate on treatment benefits, however

the feed conversion ratio is often inversely proportional to body weight. A decrease in feed conversion ratio is caused by an increase in body weight (FCR). Thus, the lower FCR indicates that the animals were able to get the most out of their food. The comparable trend seen on ADFI, ADG, and BWG can be used to back up the FCR findings. This means that when the goats became larger on a weekly basis, their feed consumption and growth rate increased as well. The results on FCR are consistent with Odunola (2012) who did not observe any significant differences when WAD rams were fed up to 25 % baobab bark in their diet. However, Inayat and Salim (2005) reported contradicting results that there was a lower FCR in diet with 10% baobab seed meal (BSM) inclusion level and higher FCR at 15% BSM inclusion level.



3.5. Conclusion

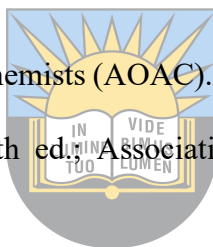
The incorporation of BOSC in the goats' diet improved the growth performance of goats. It can be concluded that BOSC is an excellent source of nutrients that could be used to replace commercial protein sources such as soybean meals. The sex of the goats also affected the average ADFI and growth performance of goats. This study also suggests that BOSC can be incorporated in the goats' diet up to 45% without causing any detrimental effects on the growth performance and well-being of goats.

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Chapter four

Experiment 2: Enteric methane emissions on Savannah × Boer crossbreed goats fed graded levels of baobab oil seed cake (*Submitted to Journal translational Animal Science, manuscript ID: TAS-2021-0843*)

Abstract

The effect of feeding graded levels of baobab oilseed cake on enteric methane emissions of Savannah and Boer crossbreed goats (12 Castrates and 12 females) at yearling age was evaluated. A total of 24 Savannah and Boer crossbreed goats (six goats per treatment: three females and three castrates) at yearling age, weighing 16.63 ± 3.639 kg, were used in the study. A completely randomized block design with four dietary treatments was used. The baobab oil seed cake was included in the diets at 0% (control diet, with soya bean meal), 15%, 30% and 45 % on a mass basis. The experimental diets were iso-nitrogenous and iso-caloric. It was observed that goats fed on a diet with 0% baobab oil cake emitted higher methane than those fed with baobab oil cake supplemented diets ($P < 0.05$). Methane emission decreased as the baobab inclusion levels in the diet increase ($P < 0.05$). Female Savannah × Boer goat emitted more methane than male ($P < 0.05$). Both sex and baobab oil cake inclusion levels contributed significantly to CH₄ emissions individually and interactively. Therefore, it could be concluded that the inclusion of Baobab oil seed cake in the diet of Savannah × Boer goat up to 45% could be used as a mitigating strategy against methane production through small stock, especially goat.

Keywords: Goats, rumen fermentation, enteric methane emissions, baobab oil seed cake

4.1. Introduction

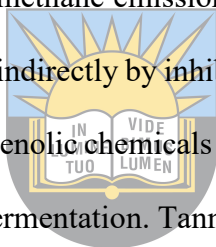
Ruminant livestock emits a significant amount of methane (CH_4), which adds to global anthropogenic greenhouse gas (GHG) emissions (Brown, 2014). Furthermore, methane emissions account for nearly 12% of the nutritional energy used by ruminants (Wang *et al.*, 2016). As a result, livestock-related greenhouse gas emissions (GGE) have become a major global concern. According to FAO (2006), the livestock sub-sector of agriculture contributes about 18 percent of global greenhouse gas (GHG) emissions each year (Masson-Delmotte *et al.*, 2018). As a result, lowering methane emissions has piqued interest as a means of maintaining the long-term viability of ruminant agriculture (Tavendale *et al.*, 2005). As a result, methods for reducing ruminant methane emissions benefit the environment while also potentially improving feed use. Currently, information on enteric methane emissions from Savannah and Boer crossbreed goat of South Africa varies from limited to non-existent. The increase in the population of Savannah and Boer crossbreed goat across Southern African region call for the reasons to estimate their greenhouse gasses contribution to global warming.

Several approaches for measuring intestinal methane emissions in ruminant animals have been developed (Patra, 2016). The respiration chamber technique is the gold standard method for measuring ruminant animals' methane emission. However, because chamber measurements are taken in a controlled environment, the results cannot be applied to grazing ruminants (Storm *et al.*, 2012).

The portable laser methane detector (LMD) technique may be a viable solution because it allows for the detection of CH_4 from animals in their natural environment while causing no interference with their behaviour (Ricci *et al.*, 2014); (Grobler *et al.*, 2014). The LMD could be utilized in field-based measurements for CH_4 output detection, such as screening animals for breeding programs

or evaluating different management practices (Hegarty, 2013). The LMD is a non-invasive technology that allows for individual animal CH₄ measurements and may have advantages over other field-scale methods like the SF₆ tracer, polyethylene, tunnel, or breathe sample methods (Pickering *et al.*, 2015). The LMD is a portable gas detector that monitors CH₄ concentrations in animal gaseous emissions over short periods of time.

The amount of methane generated in ruminant animals is substantially influenced by the degree of feed intake of individual animals, the kind of diet, and the presence or absence of inhibitory elements in the diets (Chagunda, 2013). Numerous studies have recently demonstrated that feeding tannin-rich foods to ruminants reduces methane emissions (Gemeda and Hassen, 2015). Tannins affect methanogenesis either directly or indirectly by inhibiting methanogens (Animut *et al.*, 2008; Hristov *et al.*, 2013). Tannins are polyphenolic chemicals that bind to protein, according to Makkar (2003), and so reduce ruminal protein fermentation. Tannins are complex polymers with a variety of links and bonds that differ between plant species and within plant tissues (Makkar, 2003; Patra, 2011). Baobab cake is one such non-conventional feed source that contains a considerable amount of tannins. Baobab oil cake has been found to contain 2-12 % tannin on various occasions (Michalet-Doreau *et al.*, 1998; Lock *et al.*, 2004). The baobab seed is high in protein and has a significant quantity of calories (Mwale *et al.*, 2008). Even during the dry season, the baobab tree is a cheap and readily available drought and fire-resistant plant (Lock *et al.*, 2004; State and State, 2018). The baobab tree is an inexpensive and widely available drought and fire-resistant plant even during the dry season (Lock *et al.*, 2004; State and State, 2018). The purpose of this research was to evaluate how successfully LMD could be used to estimate methane gas emissions from



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Savannah Boer goats given varying amounts of baobab oil seed cake. It was hypothesized that baobab oil seed cake had no effect on the intestinal methane emissions of Savannah Boer goats.

4.2. Methods and materials

4.2.1. Study site (Same as 3.2.1).

4.2.2. Animal management, diets, feeding and experimental design (Same as 3.2.2).

4.2.3. Measurements

All procedures followed in this study were according to the principles for use of animals in experiments established by the Committee of Ethics on Animal use. Permission to use animals in this trial was granted by the University of Fort Hare Research Ethics Committee. The LMD used throughout experiments was the SA3CO6A LMD from Tokyo Gas Engineering Co. Ltd. (supplied by Crowcon Detection Instruments Ltd., Abingdon, UK) as described by (Doran and Doran, 2014). Enteric methane was measured using a hand-held LMD (Crowcon, Tokyo Gas Engineering Co Ltd 2006) in the afternoon hours when the animals are no longer eating. The principles of Laser methane detectors were described by (Chagunda and Yan, 2011). The LMD equipment measures the concentration of CH₄ between the equipment and the target point. It is based on infrared absorption spectroscopy and measures CH₄ values as a plume(Chagunda and Yan, 2011; Chagunda *et al.*, 2013; Mapfumo *et al.*, 2018). Thus the measurements are in parts per million-metre (ppm-m) (Chagunda *et al.*, 2013). The equipment usually operates in the temperature range between 0 and 40 °C, in the humidity range of 20–90%, with a reaction time of 0.1 seconds. The LMD can detect CH₄ concentrations between 1 and 50,000 ppm within a distance of up to 150 m. Gas column density was measured by directing the auxiliary LMD targeting (visible HeNe) laser

beam at the nostrils of goats (Mapfumo *et al.*, 2018). The measurements were taken continuously for three minutes by 60 s intervals (60s, 120s, and 180s). In a distance of 1.5 m away from each animal. Goats were restrained; this was done to ensure the accuracy of measurements. This is because the goats were running within the cage as they were trying to avoid laser beam into the nostrils. Before the commencement of the measurements for each day, the LMD was off-set to adjust it to the ambient CH₄. Off-setting the LMD is done to account for the CH₄ in the environment before the machine records the gas concentrations from the point source (Chagunda and Yan, 2011). The measurements were taken Weekly (every Tuesday) for a period of 9 weeks.

4.4. Statistical analyses

The Procedures of General Linear Model of the Statistical Analysis System package (SAS) software, Version 9.2. (SAS Institute Inc., Cary, NC, USA) was used to analyze the data on sex and treatment on methane gas production (Methane was measured in Litres/day; grams /kgDMI; grams /day and enteric methane emissions (ppm-m)). Linear Model: Model: $Y_{ij} = \mu + T_i + S_j + W_k + (T*S)_{is} + (T*W)_{ik} + (T*S*W)_{isk} + e_{ij}$. The data were presented as Mean $\pm$ SE, with a 5% significance level.

Where:

Y_{ij} = response variable (Methane in litres/day, Methane in grams/kgDMI, Methane in grams/day, and Enteric methane in ppm/m);

μ = overall treatment means;

T_i = effect of treatment i^{th} (0%, 15%, 30%, and 45% BOSC);

S_j = effect of sex j^{th} (Males, and Females),

W_k = effect of week and

$T*S_{is}$ = Interaction between treatment and sex

$T*W_{ik}$ = Interaction between treatment and week of successive feeding

$T*S*W_{isk}$ = Interaction between treatment, sex, and Week of successive feeding

e_{ij} = random error

4.5. Results

Enteric methane production is related to DMI, whereby the more feed is consumed; the more methane is produced. The results in Table 4.1 show that goats that consumed more feed emitted significantly more methane gas than those that consumed less feed. It was observed that goats fed on a diet with 0% baobab oil cake emitted higher CH_4 gas (CH_4 liters/day, CH_4 g/kg DMI, CH_4 g/day/head, and CH_4 ppm-m) than goats fed on a diet supplemented with Baobab oil cake ($P < 0.05$). Female goats emitted more methane gas than male animals ($P < 0.05$). The results in Figures: 2.1, 2.2, 2.3, and Figure 2.4 show that methane production was not consistent ($P < 0.05$) with time. Generally, from week 1 to week 4, animals emitted more methane with time; but from week five onwards, there were many fluctuations. Graphical illustrations in Figures: 2.1, 2.2, 2.3, and Figure 2.4 also show that methane output was decreasing as the level of the test diet increases (0% BOSC, 15% BOSC, 30% BOSC, and 45%BOSC).

4.5. Discussion

According to the findings of the current study, animals that consumed more feed produced much more methane gas than those who consumed less feed. The amount of dry matter consumed is a crucial driver of methane generation. According to earlier research, over 95 percent of methane released during intestinal fermentation is lost to the atmosphere via mount, whereas just 2-3 percent is lost through rectal emissions (Ramin and Huhtanen, 2013). Nonetheless, CH₄ emission varies greatly based on a variety of circumstances, with the most important determinants of methane generation being dry matter intake (DMI), digestibility, and food composition (Ramin and Huhtanen, 2013). According to Lovett *et al.* (2005), the connection between gross energy intake and methane output is inverse.

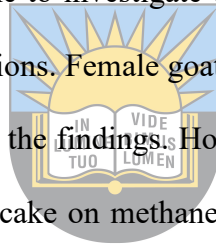


Additionally, Scholtz *et al.* (2013) inferred that the production system is the major contributing factor in the total amount of methane produced, with animals in the rangeland expected to produce more methane than those in an intensive production system. In the current study, goats produced an average of 49.49 g/kg DMI of methane which is extremely higher when compared to the results of Washaya *et al.* (2018) on growing goats which produced an amount 12 to 13 g/kg DM CH₄. This could be an indication of the effect of forage legumes on CH₄ production. Similarly, Burke *et al.* (2000) agreed that forage legumes could be used significantly to reduce CH₄ emissions.

Some researchers have demonstrated that increasing the presence of tannins in ruminant feed reduces enteric methane emissions (Bhatta *et al.* 2009; Sebata *et al* (2011). According to Patra (2011), tannins may favourably modify ruminal fermentation, reducing protein breakdown in the rumen, minimizing bloat, and inhibiting methanogenesis. Tannin-containing forages have been shown to lower methane emissions in both in vivo and in vitro studies (Patra and Saxena, 2010).

Animut *et al.* (2008) reported a similar occurrence, as well as the fact that feeding varied doses of *L. striata* in goats' striata reduced methane production in a linear fashion. The presence of condensed tannins was blamed for this (Puchala *et al.*, 2012). Tannins have the ability to decrease enteric CH₄ generation in ruminants, according to Hess (2011). The reason for the decrease in methane output as the level of condensed tannins increases in the ruminant diet could be ascribed to a decrease in fiber digestibility (Gemed and Hassen, 2015). Baobab oil cake contains 2-12 % tannins, according to Michalet-doreau *et al.* (1998) and Lock *et al.* (2004). In the current study, it was observed that when the amount of baobab seed cake increases, enteric methane output decreases. The presence of tannins, as reported by various authors, could be the reason for this. However, future research could be done to investigate the potential effect of tannins present in baobab seeds on enteric methane emissions.

Female goats produced more methane gas than male goats in the current study, according to the findings. However, there is little evidence to support or refute the effects of baobab oilseed cake on methane emissions from the rumen. The current study's findings can be attributed to the fact that female goats consume more feed than male goats, resulting in higher DMI in females than males. Male goats released less methane gas as a result of this than female goats. Findings in the current study contradict that of Washaya *et al.* (2018), who reported that male goats (17.400 ± 0.008 L/day; 12.46 ± 0.008 g/kg DMI; 0.126 ± 0.008 g/day) produced more methane gas than female goats ($15.47L \pm 0.002$ L/day; 12.28 ± 0.002 g/kg DMI; 0.0109 ± 0.002 g/day). This is conceivable because male animals typically consume more feed (with a higher DMI) than female animals. Washaya *et al.* (2018) were in this situation. Figures 1, 2, 3, and 4 indicate that methane production did not follow a predictable pattern over time. Animals exhaled increasing methane with time from week 1 to week 4; however there were considerable swings from week 5 onwards. This could be explained by the fact that animals become accustomed



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to the nutritional treatments over time, consuming more feed and hence producing more methane gas.



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Table 4.1: LS means of methane emissions (Litres/day); (grams /kgDMI); (grams /day) and enteric methane emissions (ppm-m)

Parameter	Treatment				Sex		P-values		
	1	2	3	4	M	F	T	S	T×S
Methane(l/day)	1971.46 ^a ±18.826	1682.98 ^c ±18.826	1746.71 ^b ±18.826	1671.10 ^c ±18.826	1751.85 ^a ±12.161	1786.33 ^b ±12.161	<0.0001	0.0468	0.0002
Methane(g/kgDMI)	49.78 ^a ±0.581	46.57 ^b ±0.581	43.70 ^c ±0.581	42.91 ^c ±0.581	48.99 ^a ±0.371	50.04 ^b ±0.371	<0.0001	0.0468	0.0002
Methane(g/day)	37.44 ^a ±0.358	33.96 ^b ±0.358	30.51 ^c ±0.358	29.07 ^c ±0.358	32.94 ^a ±0.230	33.60 ^b ±0.230	<.00001	0.0468	0.0002
Methane(ppm/m)	18.09 ^a ±0.756	8.14 ^b ±0.756	8.03 ^c ±0.756	7.53 ^c ±0.756	7.75 ^a ±0.350	13.74 ^b ±0.350	<0.0001	<0.0001	<0.0001

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ab Least square means with different superscripts in a row are significantly different at $P < 0.05$. Least square means with different superscripts in a column are significantly different at $P < 0.05$. T= treatment; S= sex; T×S= Treatment and sex interaction; F= female goats; M= male goats.

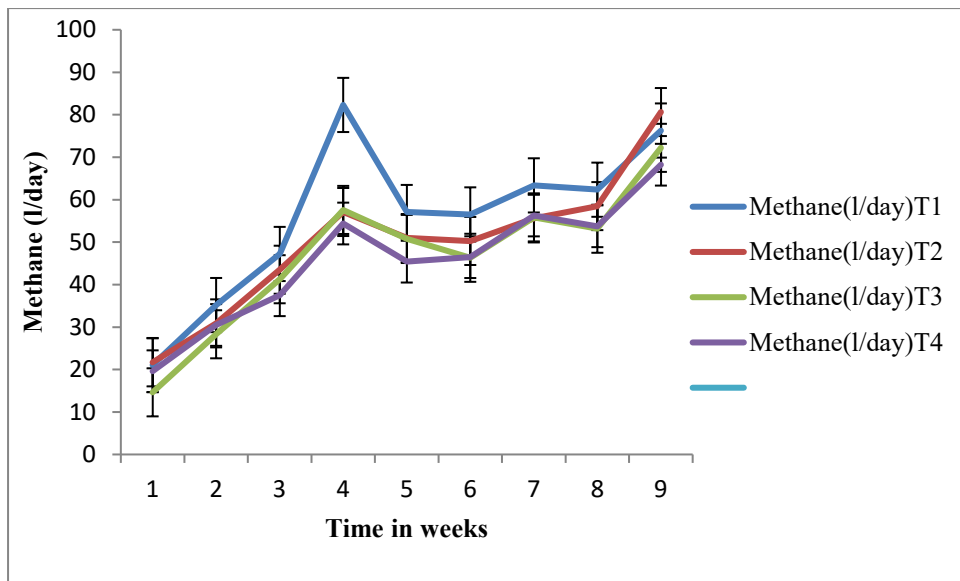


Figure 4.1: Relationship between time in weeks and level of baobab inclusion on methane (litres/day)



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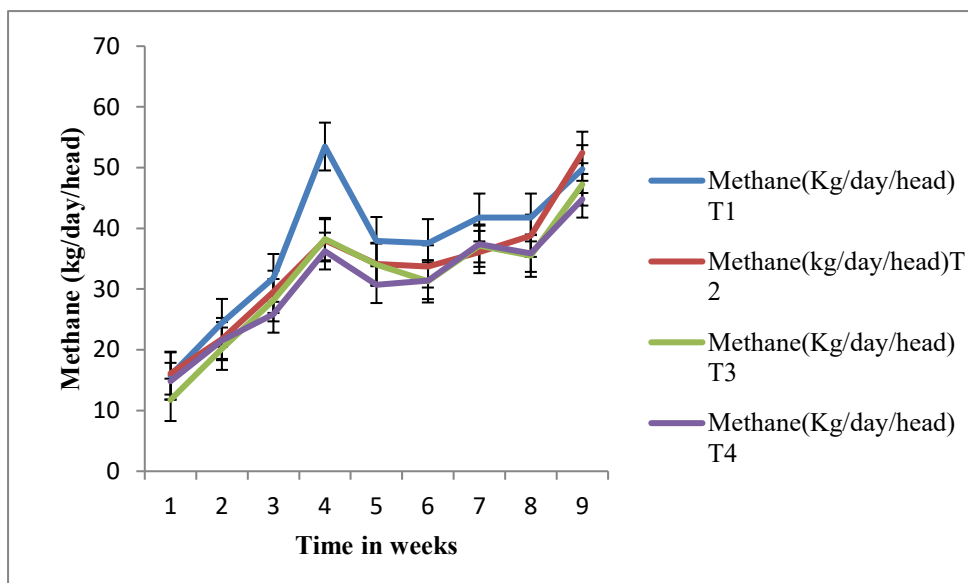


Figure 4.2: Relationship between time in week and baobab oil seed cake inclusion level on methane (kg/day/head)



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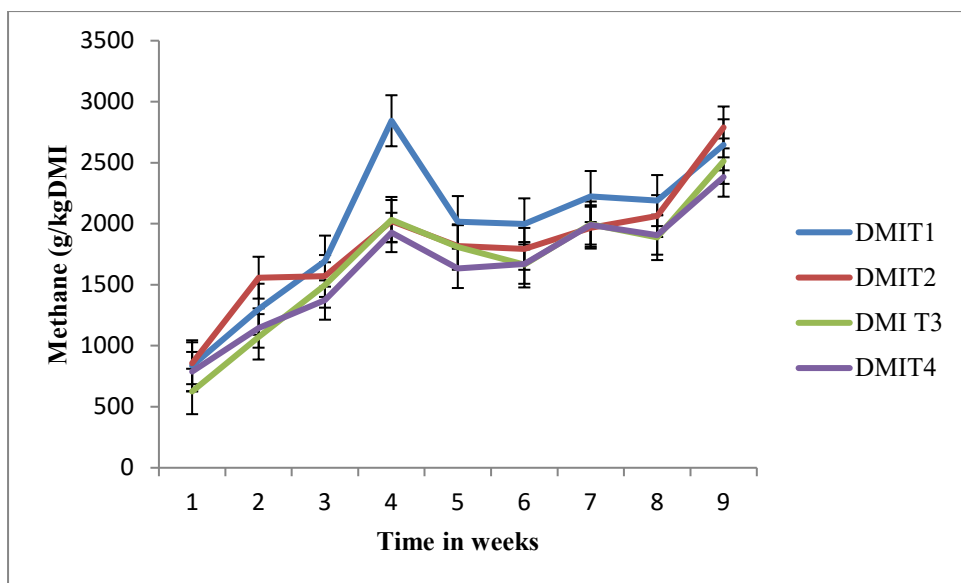


Figure4. 3: Relationship between time in weeks and inclusion level of baobab oilseed cake on methane (g/kgDMI)



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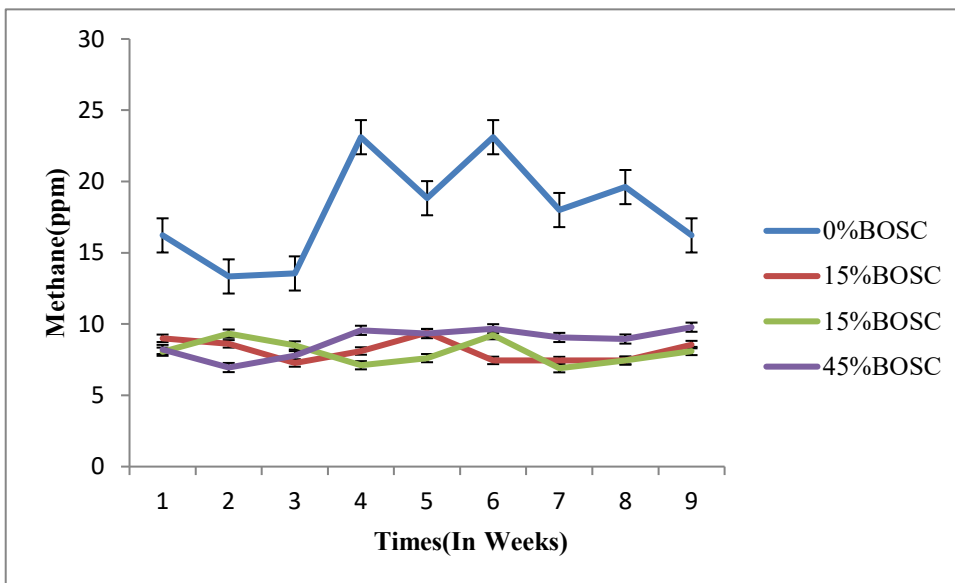


Figure 4.4: Relationship between time in weeks and inclusion levels of baobab oilseed cake on enteric methane (ppm-m)



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4.6. Conclusion

An increase in Baobab oil seed cake inclusion significantly reduced methane output in goats. Sex of the animal significantly affected methane production in goats, with female animals producing more methane gas than males. Sex and treatment diets both contributed significantly to CH₄ emissions individually and interactively. Therefore, BOSC should be included in the ruminant diet to reduced methane emissions. Enteric methane gas emission is also related to DMI. Thus the more feed is consumed, the more methane is produced.



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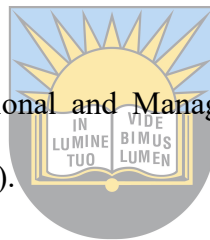
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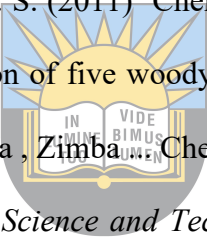
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Chapter Five: General Discussion, Conclusion and Recommendation

5.1 General discussion

The study's main goal was to explore how Baobab oilseed cake (BOSC) affected cross-breed goats' growth and enteric methane emissions. There was an increase in feed intake across all treatments for the feed intake and growth performance metrics determined in Chapter 3. As a result, the study found that Baobab oilseed cake is a good source of nutrients and might be used to substitute commercial protein sources like soya bean meal. This could be related to Edwin (2005) reporting an increase in food palatability, which could be attributable to the aromatic properties of baobab oil seed cake described by Chimvurahwe *et al* (2011). State and State (2018) found that significantly ($P < 0.05$) increased concentrate consumption in treatment groups fed West African Dwarf goats could be an indication of the concentrate's palatability with fermented baobab inclusion. When compared to other leaves such as *Blighia sapida*, *Entada africana*, and *Gliricidia sepium*, Belewu (2007) found that young goats fed a diet containing 40% baobab leaf meal had increased dry matter intake. There were significant differences that were noted on ADFI amongst different levels of BOSC and sex. Females were notably having higher ADFI than males across all treatments. This finding contradicts Lu *et al.* (2005), who found that between the intervals of 21 to 24 weeks and 17 to 32 weeks of age, male castrates consumed more dry matter than female castrates. The differences in body size between male castrates and female kids could be the cause of these effects. Sun *et al.* (2014), on the other hand, found no significant variation in dry matter consumption between male and female goats ($P > 0.05$). This could be due to the fact that animal feed intake is impacted by feed palatability as well as individual animal hunger, which means that any animal with a high appetite, regardless of sex, is more likely to consume more feed. All treatments show a general increase in weight gain, showing that the goats were able to convert dietary protein into additional muscle. Weekly changes in body weight gains could also be attributed to the

adaptability of the animals to dietary treatments. ADG readings were greater in females than in males. Solaiman *et al.* (2011), on the other hand, found contradictory results, claiming that Boer-cross bucks fed Marshall Ryegrass had higher ADG than those who were not. Due to the availability of the growth hormone testosterone, male goats should be expected to outperform females in terms of body weight gains. This could be explained by the fact that male goats were castrated 4 weeks prior to the start of the feeding study, so some of them may not have fully recovered and hence growth rate was slowed by castration stress. The results on FCR are corroborated by comparable trends on ADFI, ADG, and BWG, implying that as the animals grew on a weekly basis, their feed intake and growth rate increased as well, indicating that the animals were able to convert feed into muscle. The findings differ from those of Inayat and Salim (2005), who found a reduced FCR in the diet with a 10% BBSM inclusion level and a greater FCR with a 15% Baobab seed meal (BSM) inclusion level. This rise in FCR was linked to a rise in the anti-nutrient content of the diet, as well as a rise in BSM inclusion. Ruminants may not all be equally affected by anti-nutritional factors just as they affect monogastric animals. This means that, in as much as anti-nutrients might increase with an increase in the inclusion level of BOSC, they may not be toxic to ruminant animals. This could result from the fact that ruminal activity transforms or degrades these compounds into less toxic products through the process called rumen microbial detoxification (Naumann *et al.*, 2017). The results in treatment 4 (45%BOSC), could be supported by Kikelomo (2014) who reported that nutrient intake was higher in bucks than does, hence growth rate was also higher in bucks than in does, and this might be attributed to bucks' ability to utilize nutrients more efficiently than does.

The results in Chapter 4 of the current study show that goats that consumed more feed emitted significantly more methane gas than those that consumed less feed. Methane output declined with an increase in the inclusion level of BOSC. In the current study, goats produced an average of 49.49 g/kg DMI of methane which is higher when compared to the results of Washaya *et al.*

(2018) on growing goats which produced an amount 12 to 13 g/kg DM of CH₄. This could be ascribed to the effect of forage legumes on CH₄ production. Several authors support the notion that forage legumes are more likely to reduce methane emissions when fed to ruminants as mentioned by Burke *et al.* (2000). The latter reported that forage legumes can be used to reduce CH₄ emissions significantly. On methane in ppm-m, animals subjected to the control treatment (0% BOSC) produced more methane (18.09±0.756 ppm-m) than animals subjected to 15%, 30%, and 45% BOSC. This could be associated with the fact that there was an increase in the level of tannins as the level of test diet increases, which might have led to a decline in CH₄ production. This agrees with findings by Meale *et al.* (2012); Hassen *et al.* (2016), who reported that tannins have the potential to reduce enteric CH₄ production in ruminants. The results show that female animals produced more methane gas production than male animals in the current study. This may be because female animals ate more feed than male animals in the current study, so DMI was higher in female animals than male animals, resulting in male animals emitting less methane than female animals. Findings in the current study contradict that of Washaya *et al.* (2018), who reported that male animals produced significantly more (17.400 ± 0.008 L/day; 12.46 ± 0.008 g/kg DMI; 0.126 ± 0.008 g/day) methane gas than females (15.47L ± 0.002 L/day; 12.28 ± 0.002 g/kg DMI; 0.0109 ± 0.002 g/day). This could be possible because male animals typically are the ones that usually consume more feed (higher DMI) than female animals.



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5.2. Conclusion

The goats' growth performance was increased when baobab oil seed cake was added to their diet. ADFI and goat growth performance were also affected by the animal's sex. In goats, the gender of the animal had a substantial impact on methane generation, with females creating more gas than males. Individually and in combination, sex and treatment diets both contributed considerably to CH₄ emissions. As a result, up to 45 percent of BOSC can be included in the goats' diet without causing harm to the goats' health. In addition, as compared to a soybean meal-based diet, baobab oil seed cake considerably reduced enteric methane output in goats (control diet). By reducing methane generation in goat production, Baobab oil seed cake could improve overall performance of crossbreed goats and contribute greatly to climate change stabilization.



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5.3. Recommendations

- ✓ According to the current study, Baobab oilseed cake positively affected goats' growth performance parameters and reduced enteric methane emissions. However, these effects need further validation with additional research.
- ✓ Since the reported study proved that Baobab oilseed cake could be used as a potential replacement for commercial protein sources such as soya bean meal for goat's diets. There is a need to investigate different treatment methods that can be used to suppress

the anti-nutritional factors in the seed to formulate appropriate inclusion levels for goats' ration.

- ✓ There are limited studies on meat quality, fatty acid composition, and nutritional status of goats fed baobab seeds. Thus, there is a necessity to conduct research studies investigating the effects of BOSC in goats' meat.
- ✓ The use of baobab seed cake in the goats' diet showed positive results. This means that even poor-resourced goat farmers in communal areas can opt for baobab oilseed cake at low inclusion levels over conventional feed sources to reduce feed costs.



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5.4. References

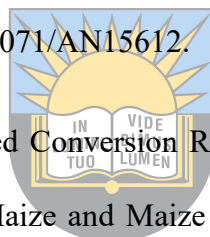
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APPENDICES

APPENDIX A: ETHICAL CLEARANCE CERTIFICATE



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ETHICAL CLEARANCE CERTIFICATE AREC-150311-008

Certificate Reference Number: MPE011SSAH01

Project title: **Effect of Baobab (*Adansonia digitata*) seed cake on feed intake, growth performance, methane emission, and meat quality of the Xhosa ear-lobbed goats.**

Nature of Project MSc Animal Science

Principal Researcher: Samkelo Saho

Supervisor: Dr. C.T. Mpendulo

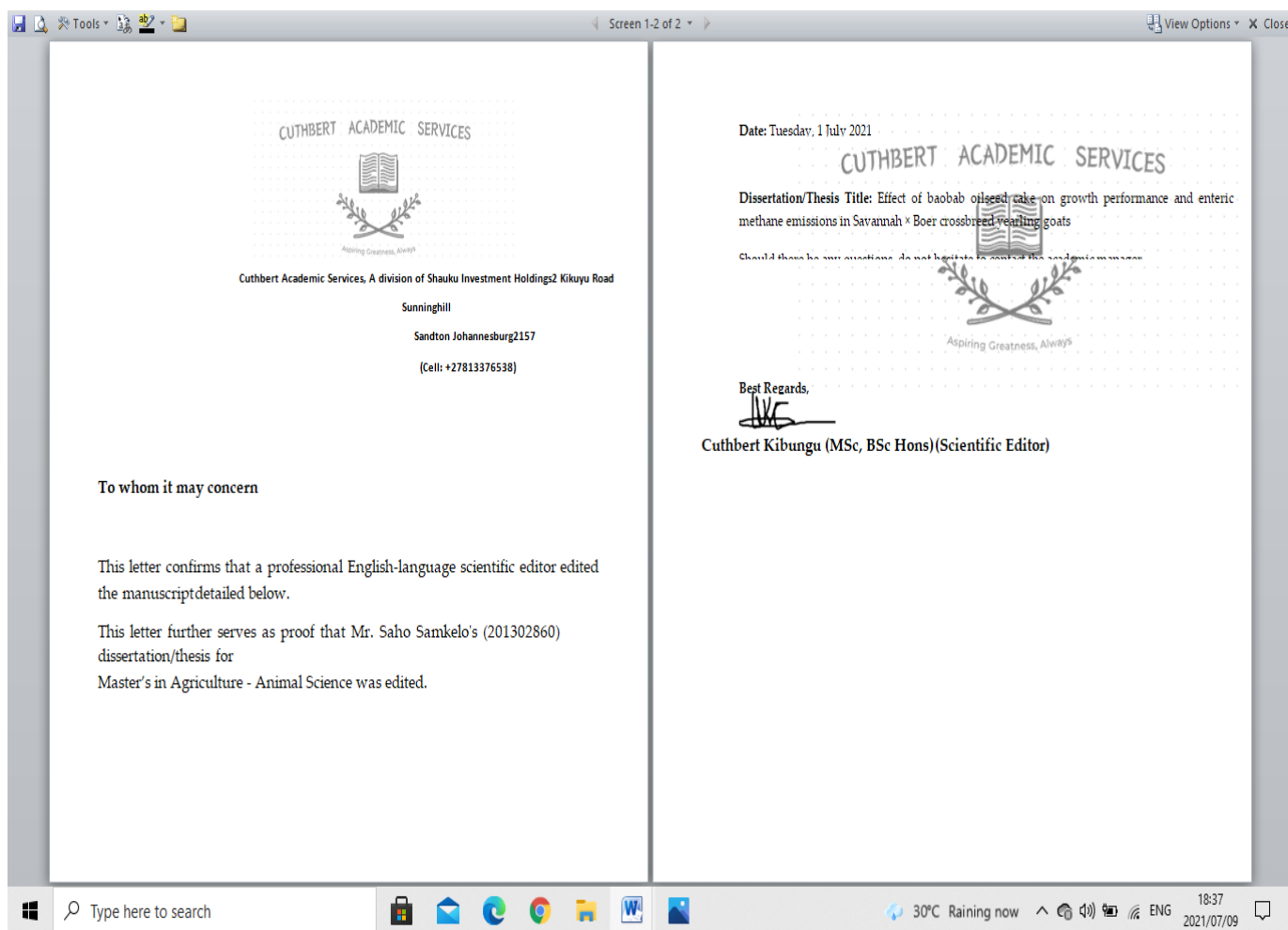
Co-supervisor: Prof. J.F. Mupangwa

On behalf of the University of Fort Hare's Animal Research Ethics Committee (AREC) I hereby give ethical approval in respect of the undertakings contained in the above-mentioned project and research instrument(s). Should any other instruments be used, these require separate authorization. The Researcher may therefore commence with the research as from the date of this certificate, using the reference number indicated above.

Please note that the AREC must be informed immediately of

- Any material change in the conditions or undertakings mentioned in the document;
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research.

Appendix B: English editing certificate



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1 of 1

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Translational Animal Science

Influence of graded levels of baobab oilseed cake on growth performance and enteric methane emissions in Savannah x Boer crossbreed yearling goats.

Journal:	Translational Animal Science
Manuscript ID	TAS-2021-0843
Manuscript Type:	Companion Animal Nutrition
Date Submitted by the Author:	21-Jan-2021
Complete List of Authors:	Samkelo, Saho; University of Fort Hare, Livestock and Pasture Science Ikusika, Segun; University of Fort Hare, Livestock and pasture science Mpendulo, Conference; University of Fort Hare, Livestock and Pasture Science Mupangwa, John; University of Namibia, Animal Science Moyo, Davison; University of Pretoria, Animal Science
Key Words:	Baobab oilseed cake, Goats, Growth performance, Methane emission., goat, feed efficiency, Crude Protein

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