



Inclusion of Kalahari melon (*Citrullus lanatus*) meal in lamb diets: Effects on growth and meat quality

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DECLARATION

I, the undersigned, hereby confirm that the work contained in this research dissertation is my original work for a Degree of Master of Science in Agriculture in Animal Science under the supervision of Professor Upenyu Marume. This dissertation has not been previously submitted to any University. Materials and evident information from any other sources have been fully recognized.

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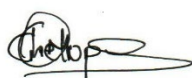
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GENERAL ABSTRACT

The study was carried out to evaluate the effect of substituting SBM with KMOC on growth performance, economic evaluation, protein utilization efficiency, blood parameters, carcass characteristics, meat quality and internal organs of lambs. Forty Meatmaster lambs were used in the experiment. Lambs were randomly assigned to five dietary treatments in a completely randomized block design and fed in individual pens for 54 days. Animals were allocated five dietary treatment groups with inclusion levels of KMOC: 0% (control), 25 %, 50%, 75%, and 100%. Each treatment was replicated 8 times. Lambs in the different dietary treatment groups had initial weights (IW) of 27.6 ± 3.21 Kg. There were significant differences ($P < 0.05$) in overall FW, ADFI, ABWG, ADG, FCR fed KMOC in between treatment groups. The lambs fed a 50% KMOC diet had the highest ($P < 0.05$) BWG, ADFI and ADG. ADFI increased with the increasing levels of KMOC in the diet but decreased at 75% and 100% KMOC inclusion levels. Diet significantly affected PC and PER. Lambs fed a 50% KMOC diet had the highest overall PC (162.05 ± 5.16) whilst a 100% diet had the lowest overall PC value (118.34 ± 5.16). Diet did not affect SGR and GE. SGR and GE declined with increasing levels of KMOC in diets.

Diet significantly affected the RBC, haemoglobin, MCV, WBC, platelets, neutrophils, lymphocytes, monocytes, neutrophils and lymphocytes. The RBC was lowest (14.73 ± 0.85) in the lambs fed the 50% KMOC diet and the highest (16.81 ± 1.04) in the diet containing 75% KMOC. Generally, the lambs fed the 25% KMOC-containing diets had the lowest values (8.55 ± 1.79) for the WBC compared to other treatment groups. However, diet did not affect haematocrit value and MCH. Diets did not significantly ($P < 0.05$) affect CA, TP, ALB, GGT and AMY. Lambs fed the 25% KMOC had the highest levels ($P < 0.05$) of TALB (Total albumin) (25.60 ± 5.77), lowest observed by 75% KMOC-fed lambs (17.92 ± 9.76). Diet did not significantly ($P < 0.05$) affect GLU, SMDA, UREA, ALKP, LIPA, PHOS and GLOB. Splenic indices (SSI) were not influenced by diet.

There was significant difference on carcass profits, GI, feed, TVC and GM. The higher the inclusion levels of KMOC the higher the gross margin. And this proves to be cost-effective to replace SBM with KMOC. The results indicate that diet significantly affected dressing %, HCW and CCW. Lambs fed the control diet had the highest HCW ($18.02 \text{ kg} \pm 1.10$). The CCW was high in lambs fed 50% KMOC ($16.15 \text{ kg} \pm 0.99$) as expected. The lambs fed higher levels of KMOC had the lowest values on carcass parameters except Chilling loss. Nevertheless, the

lambs fed 25% of KMOC in diets marginally had higher dressing percentages (50.30 ± 2.23) although it was significantly different and declined as inclusion levels increased. The carcass length was high in lambs fed 50% KMOC ($70.43 \text{ cm} \pm 2.07$), followed by those fed a 25% KMOC ($67.06 \text{ cm} \pm 2.07$). The lambs fed a 50% KMOC diet had the heaviest heart ($155.00 \text{ g} \pm 6.33$) while lambs fed with a 100% KMOC diet had the lowest weight ($116.87 \text{ g} \pm 6.33$). However, kidney weights were highest ($P < 0.05$) in lambs fed control (109.37 ± 4.46) as compared with all other treatments. The spleen and lungs were significant higher (69.37 ± 5.74 and 380 ± 23.55) in 50% KMOC. Diet significantly affected ($P < 0.05$) meat colour coordinates, water holding capacity, cooking loss, dripping loss and meat shear force in response to incremental levels of KMOC. Meat temperature was higher ($P < 0.05$) for carcasses fed 75% KMOC. The highest meat colour coordinates were observed in lambs fed 100% KMOC diets with L^* (34.15 ± 0.78) and b^* (2.87 ± 0.44). The highest a^* (13.24 ± 0.52) was observed in lambs fed 75% KMOC. In terms of WHC % the lambs fed 75%, KMOC had the lowest value ($9.76\% \pm 1.76$). The highest value observed was in lambs fed 25% KMOC ($12.87\% \pm 1.76$). The dripping loss was observed to be higher in the lambs fed 100% KMOC (36.83 ± 2.98). The lowest cooking loss was observed in lambs fed 50% KMOC (32.08 ± 2.98), while the highest was observed in lambs fed 100% KMOC (36.83 ± 2.98). The lambs fed 75% KMOC had the highest ($P < 0.05$) and shear force texture (16.50 N). The lowest meat texture ($P > 0.05$) was observed from diets containing 100% KMOC (12.19 N). The findings of the study suggest that KMOC can partially substitute SBM up to 50% without compromising the health of lambs.

Keywords: Kalahari melon, oil cake, Growth, Performance, Meat, Blood, Lambs, Economics.

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LIST OF ABBREVIATIONS

%:	Percentages
A*:	Redness
b*:	Yellowness
L*:	Lightness
ADG:	Average Daily Gain
ADFI:	Average Daily Feed Intake
BWG:	Body Weight Gain
Ca:	Calcium
CRD:	Complete Randomized Design
CCW:	Cold Carcass Weight
CWG:	Cumulative Weight Gain
CP:	Crude Protein
FAO:	Food and Agriculture Organization
FI:	Feed Intake
FCR:	Feed Conversion Ratio
GE:	Growth Efficiency
GLM:	General Linear Model
HGB:	Haemoglobin
HCT:	Haematocrit
HCW:	Hot Carcass Weight
HEO:	Highland Essential Oils
KM:	Kalahari Melon
KMOC:	Kalahari Melon Oilcake
MCH:	Mean Corpuscular Haemoglobin

MCHC:	Mean Corpuscular Haemoglobin Concentration
MCV:	Mean Corpuscular Volume
N:	Newton
PER:	Protein efficiency ratio
PC:	Protein consumed
RDW:	Red cell distribution width
SAS:	Statistical Analysis System
SBM:	Soybean meal
SDMA:	Symmetric dimethylarginine
TALB	Total Albumin
SGR:	Specific growth rate
WMSC:	Watermelon seed cake
WHC:	Water Holding Capacity

CHAPTER 1

INTRODUCTION

1.1 Background

The livestock sector plays a significant economic role in most developing countries and is essential for ensuring food security of populations. However, the productivity of farm animals, particularly sheep in most tropical countries especially in resource-poor areas is generally low mainly due to poor quality and reduced abundance of available feeds. Furthermore, conventional feed resources (grains, cereals, legumes, etc.) for animal production are increasingly becoming scarce and expensive in many parts of the world (Abbas, 2013). This has been attributed to the reduced planted hectares and yields as a result of recurring droughts, climate changes and land pressure caused by the increasing human population and settlements (Zhou *et al.*, 2012). Additionally, most developing countries are situated in the tropics where the infrastructure is not well developed to optimise production of the vital feed ingredients for livestock feeding (Melesse *et al.*, 2013). In South Africa, there is a deficit in terms of the productivity of grains for both animals and humans due to the 2015/2016 drought which has shifted the market into a net importer situation. In the event of below normal rainfall, SA might have a total production of 3.9 million tons of yellow maize and assuming that domestic consumption would slightly increase on the back of increase in livestock (GSA, 2015). South Africa will then have to import 2.27 million tons of yellow maize to meet the domestic demand. On the other side, SA still imports significant volume of oilcake. The 2014 soyabean oilcake import amounted to 511014 tons which was a 45 share of domestic consumption (GSA, 2016). It is therefore imperative to explore all the alternative feed sources for sheep that may ensure the viability and sustainability of animal production.

Optimum dietary protein provision is one of the key factors affecting the performance of sheep. High-quality rations must be offered to animals to ensure proper growth maintenance and body condition. A good quality lamb concentrate ration should consist of approximately 30% protein and the major source of highly digestible and degradable protein is Soybean meal (SBM). Soybean meal has traditionally been used as a preferred protein source for livestock, especially in the feedlots, because it contains high protein content, has an excellent balance of amino acids and has high energy levels (13.5MJ/kg DM) (Miller-Cushon *et al.*, 2014). The production of Soyabean was expected to increase to a record of 2.7million tons in 2022/23 season as

compared to the 2021/22 season (DALRRD, 2023a). A variety of alternative protein sources that can be integrated into sheep feeding systems exist in South Africa (SA) and worldwide. For example, sunflower oilcake meal and cotton seed meal have been successfully integrated into animal feeding systems without influencing the performance of both ruminants and non-ruminants. Other unconventional protein sources include sesame meal, flax seed meal, faba beans, velvet beans, canola and lupines. In SA, Kalahari melon (KM) is often produced for the extraction of seed essential oils which are mainly used in the cosmetic industry. The remaining oilcake meal was initially considered an environmental nuisance. Nevertheless, the oilcake meal contains considerable amounts of protein (up to 35%) and some important fatty acids (Van Wyk & Gericke, 2000) and hence it can be a protein source for livestock. There is, therefore need for investigations into the feasibility of integrating such protein sources in sheep diets as they may allow for least-cost diet formulations and sustainable feeding strategies.

1.2 Problem statement

Considering the present-day agricultural constraints and challenges, especially the recurring droughts in SA and the rest of Southern Africa, the use of SBM in animal production is becoming rather uneconomical and unsustainable. There is now a growing realization by nutritionists, researchers, industry and even by government and other stakeholders about the importance of the use of alternative crops as substitute foodstuffs to improve food security. One such crop is Kalahari melon (*Citrullus lanatus*) which is found abundantly in Southern Africa. Despite the potential of KMOC as a protein source for animals, there seems to be very limited detailed empirical information available on its use in animal feed especially in ruminant diets as most research has been fundamentally focused on cultivation, human nutrition uses, pharmaceutical and industrial applications. Therefore the study proposes to assess the efficacy of the inclusion of KMOC in ruminant diets and its effects on growth performance, health and meat characteristics of lamb fattening.

1.3 Justification of the study

Feed cost remains the major factor limiting the development and expansion of any animal production enterprise. A bulk of the feed cost arises from protein sources such as soybean meal, cotton seed meal, fish meal and groundnut oilcake meal. Considering the prices of conventional protein sources like soybean meal (SBM) that soared so high in recent times it became

unsustainable to continue using them in animal feeds (Esonu *et al.*, 2021). Certainly, alternative feed resources must be identified and evaluated for least-cost animal feed development (Odunsi, 2003). The study is therefore of significance in that it will enhance the accumulation of information on the usage of KM and also enhance its integration into sustainable animal feeding systems. It will also allow the inclusion of KM in the feed inventory for animals while providing opportunities for least-cost diet formulations. This will also aid in compensating the huge feed costs that are being incurred as well as reducing the dependence on SBM as a protein source for animal production. Currently, Kalahari melon cake is being considered an environmental nuisance as it lacks utilisation, resulting in the piling up of the cake. Its utilisation in animals can enhance environmental control of the by-product while increasing options for protein sources in ruminant diets.

1.4 Objectives of the study

Main objectives

The major objective of the study was to investigate the effect of feeding different levels of Kalahari melon oil cake on the growth performance, health and meat quality in lambs.

Specific objectives:

1. To determine the effect of the inclusion of KMOC on growth performance and blood parameters of lambs
2. To determine the economics of using varying levels of KMOC in the diet of lambs.
3. To determine the effect of varying levels of KMOC inclusions on carcass characteristics, meat quality and internal organs of lambs
- 4.

1.5 Research Hypothesis

H₀: Kalahari melon oilcake inclusions in the lamb diet do not affect growth performance and blood parameters

H₀: Kalahari Melon oilcake inclusion levels in the diet of lambs have no effect on economics.

H₀: Kalahari Melon oilcake inclusion levels have no effect on carcass characteristics, meat quality and internal organs of lambs

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CHAPTER 2: LITERATURE REVIEW

LITERATURE REVIEW

2.1. Mutton production in South Africa

South Africa produced 4.81million heads volume of slaughter sheep in 2022 (Cowling, 2024). In addition, the livestock industry contributes 34.1% of the total domestic agricultural production and provides 36% of the population's protein needs. Based on the latest information according to Cowling (2024) the overall number of sheep in the country (SA) has generally declined since 2010. In 2022 the sheep heads dropped by 30000 from 21.34 million. As of 2022 some 4.81 million heads of sheep were slaughtered in SA. The North West Province's (NWP) sheep numbers declined from 611214 in 2018 to 606973 in 2019 (which is 2.7% less), due to stock theft and the numbers were expected to decline further in 2021. Approximately 86% of the sheep are in the Eastern Cape, Northern Cape, Free State and the Western Cape. The other five Provinces share 14% of the country's sheep numbers which includes NWP. Between 1999 and 2019 the national sheep flock decreased from approximately 29 million sheep to the current 22 million. While this 24% decrease in the national flock can be attributed to many factors, they all come down to the economics of sheep production. Imports from overseas and Namibia of mutton (including offal) in May 2020 were 37.1% less compared to the previous month and 63, 7 % more year-on-year. When offal were excluded the imports were 42.3% less against the previous month and 121.6% more year-on-year, (FAO, 2012).

2.2 Animal dietary protein production and supply

In the animal production system, dietary proteins are critical macronutrients which are expensive constituents of animal feed (Raj *et al.*, 2016). While the use of protein for animal feed in SA was expected to rise from 1.98 million tons in 2015 to 2.8 million tons by 2024, the domestic supply of protein is expected to increase from 60 to 79% during the same period (de Jager, 2016). Protein quality is critical for optimum performance in animals. Quality refers to the characteristics of protein source relative to its influences on envisaged digestibility functions (Millward *et al.*, 2008). The efficacy of the inclusion of ingredients (e.g. protein and energy sources) in ruminant rations is often established through evaluation of their ruminal quality (Hoffman & Falvo, 2004).

2.3 Conventional protein sources

The most preferred protein sources for animal diets are legume seed oilcakes. Oilcakes are by-products of seed oil extraction. Seed oilcake meals from soybean, sunflower, groundnut, cottonseed and olives are considered conventional sources of nutrients for animal feed (Ramachandran *et al.*, 2007). Soybean meal is the commonly utilised source of protein of the plant-derived conventional protein sources that are utilised in the livestock feed industry in SA, (Acheampong-Boateng *et al.*, 2016). The chemical composition of oilcakes and meals differ according to their edaphic environments, quality of seeds and nuts, extraction methods (industrial processing methods) and storage methods (Ramachandran *et al.*, 2007). Apart from the differences in chemical composition, some of the plant protein sources may contain anti-nutritional factors (ANTFs) that can compromise animal performance when used as feed ingredients and thus their utilization is limited by the presence of ANTFs (Marghazani *et al.*, 2013). Nevertheless, many of these conventional plant protein sources have low levels of ANTFs with no need for treatments before inclusion in animal diets. The ANTFs are substances produced naturally in feed ingredients by the regular metabolism of plants and interaction through diverse mechanisms. Saponins, oxalic acid, gossypol, phytate, cyanogen, tannins, nitrates, protease inhibitors, alkaloids, aflatoxins and mycotoxin are some of the ANTFs that are found in plant-derived nutrient sources (Tadele, 2015). By interacting with other components ANFTs can result in the deactivation of nutrients, obstruct the digestive system and feed metabolic utilization.

2.4 Alternative protein sources

A variety of non-conventional plant protein sources are currently being explored. Non-conventional protein (NCP) sources may sometimes be comparable to conventional protein sources in terms of their nutritive value (especially high crude protein and energy content) and thus may be utilised as potential alternative protein sources for formulating ruminant rations (Raj *et al.*, 2016). Non-conventional plant-derived protein sources include oilcakes and meals from Baobab, Macadamia, Marula, Pumpkin, Velvet bean, Castor, Palm, Moringa and Rubber seeds (Sharma *et al.*, 2014; Chisoro *et al.*, 2018). Others such as Kalahari melon oilcake and sweet melons still require a lot of investigations with regards to their suitability as protein sources in animal diets. The NCP sources therefore possess the nutritional potential of being utilised as nutrient (energy, protein, amino acids and minerals) sources for animal feed (Sudake *et al.*, 2013). Castor seed, for instance, in a trial evaluating dietary effects of feeding castor seed oilcake meal in place of groundnut oilcake meal on a protein source basis in lamb diets,

showed no adverse effects on the growth performance, feed intake, nutrient digestibility and calcium, phosphorus as well as nitrogen balance. However, metabolizable energy was lower in rams that were fed on a ration that contained castor seed oilcake meal in comparison to those fed a ration supplemented with groundnut oilcake meal (Nagalakshmi & Dhanalakshmi, 2015). In SA, The Kalahari Melon Oilcake (KMOC) is produced as a by-product of essential oils extraction for cosmetic and ethno-medicinal uses. However, no studies have been conducted on the potential use of the cake as a potential protein source for ruminants.

2.5 Characteristics of Kalahari Melon

2.5.1 Description, origin and distribution of Kalahari Melon

The Kalahari melon (*Citrullus lanatus*) belongs to the family of *Cucurbitaceae*, which is a large family found in the warmer parts of all continents (Maharaja *et al.*, 2020). Kalahari Melon is also locally known as “Tsamma”. Kalahari melon produces a fruit that consists of more than 90% water; hence it is also referred to as wild watermelon or bitter watermelon in Afrikaans. The “melon” refers to a large round sweet spongy flesh. “*Citrullus*” is the diminutive of Citrus and the specific epithet “*lanatus*” refers to the woolly hairs on the young plant (Erhirhie & Ekene, 2013). It occurs in different morphological forms of *Citrullus* species (Vermaak *et al.*, 2011,). According to Highland Essential Oils; Vermaak, 2011 as well as Zhou, (2011), KM is a pale yellow or green plant with or without stripes, tastes bitter, the fruits are small and round and cultivated fruits are large and oval. Kalahari Melon has been referred to as *Africa’s Secret Gift* because it is one of the most drought-resistant plants in SA (Vermaak *et al.*, 2011).

Kalahari melon is found throughout Southern Africa but is more common in the drier or more arid and semiarid regions of Botswana, Namibia, SA and Zimbabwe where rainfall is below 650 mm annually (Mujaju *et al.*, 2010). The Kalahari melon is indigenous to the Kalahari Desert, which stretches across Botswana, Namibia and SA and is found in river banks and dry lakes (African Origin Oil, 2018). Bitter watermelon is common in some provinces of SA, including Limpopo, Free State, North-West, Gauteng and Northern Cape (Komane *et al.*, 2017). In 2007, *Citrullus lanatus* was responsible for approximately 7% of the total world vegetable tonnage (FAOSTAT, 2008).

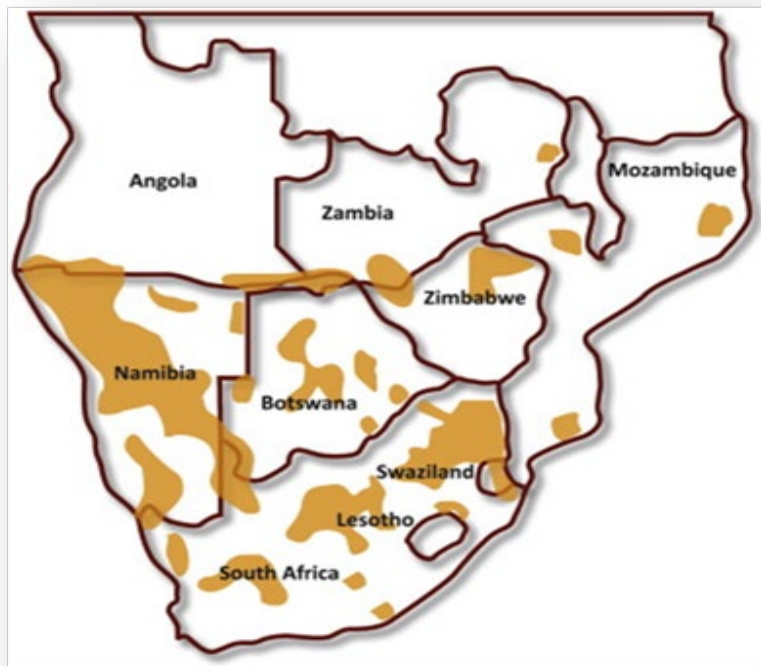


Plate 2.1: Distribution Map of Kalahari Melon (Yellow shading) in Southern Africa, Komane *et al.*, 2017)



Plate 2.2: Typical Kalahari Melon (*Citrullus lanatus*)

2.5.2 Chemical Composition of Kalahari Melon

Liu *et al.* (2009) described KM as one of the medicinal plants and herbs commonly used in communities with great potential. The Kalahari melon seeds oil has been used traditionally in Southern Africa as a cosmetic product, primarily as a face and body scrub which is said to impart a blemish-free complexion to the skin (Vermaak *et al.*, 2011). The seeds are also rich in fat and protein and are an excellent source of energy (African Origin Oil, 2014). Moreover, the essential oils from seed contain large amounts of fats including palmitic, stearic, oleic, and various linoleic acids isomers (Berry, 2015). Cheikhyyoussef *et al.* (2017) observed fatty acids such as linoleic acid that range between 52.57–56.96% in *C. lanatus* seed oil. Marume *et al.* (2020) observed that the *C. lanatus* seed oil consists of 11.6%, palmitic, 8.32% stearic, 13.81% oleic and 65.17% linoleic acid. In particular, conjugated linoleic acids have been reported to have a wide range of health-beneficial effects, including anti-carcinogenic, anti-atherogenic, anthelmintic, anti-diabetic, and immune stimulatory effects. Kalahari melon oilcake meal has also been reported to contain significant quantities of glutamic acid, aspartic acid, arginine and leucine (Egbonu, 2015) and low content of lysine and Sulphur-containing amino acids (Falade *et al.*, 2020).

The Kalahari Melon oilcake (KMOC) is a rich source of proteins, vitamin B, minerals such as magnesium, potassium, phosphorous, sodium, iron, zinc, manganese, copper and lipid, fibre and carbohydrates. The KMOC has excellent nutritional qualities and is rich in linoleic fatty acid 62%-71% and oleic fatty acid 12%-20% (PhytoTrade 2008). According to SA medicinal plants the KM oil seeds are high in protein (35%), which therefore can be considered to be used as an alternative protein source in the formulation of livestock feeds. Van Wyk & Gericke, (2000) also mentioned that the fresh fruits of KM have been used for animal feed during drought in the Kalahari regions and are high in protein and lipids.

Furthermore, the seeds have a high nutritive value and are a potential source of unsaturated fat, vitamins, antioxidants, minerals and proteins (Mogotlane, 2015). Toure *et al.* (2016) observed that the crude protein (CP) content of Kalahari melon oilcake is 27.0% while Beshir & Babiker (2009) reported 29.42%. Ojieh *et al.* (2008) observed that the *C. lanatus* “Egosi” type consists of 23.4% of CP content. The crude protein content of sun-dried, roasted and defatted melon was found to be between 26.74% and 40.03% (Bolu *et al.*, 2011). *Citrullus lanatus* seeds contain considerable amounts of minerals such as potassium (3252.10 mg), sodium (2519.1 mg), calcium (2076.07 mg), magnesium (1608.67 mg), iron (90.65 mg), zinc (35.0 mg), manganese (23.50 mg), and copper (16.57 mg) along with vitamins such as A, B1 (0.16 mg),

B2 (0.05 mg), B5 (0.27 mg), B6 (0.45 mg), C (0.91 mg) and total folate (0.11 mg) and thiamine, and the seeds' minerals also assist in growth development (Gwana *et al.*, 2014). Beshir & Babiker (2009) as well as Mogotlane (2015) observed crude fibre (CF) content of up to 29.9% for KMOC meal, almost similar to the one reported by Mustafa & Alamin (2012).

2.5.3 Secondary metabolites

The KMOC also contains some secondary plant metabolites such as alkaloids, flavonoids, tannins and total phenols (El Zawawy, 2015). Saponin, alkaloids, tannins, phenol and flavonoids have the potential to stimulate good general health, and improve meat quality and fatty acid profiles (Kumar *et al.*, 2018). Nevertheless, saponins may have a bitter taste that is associated with lower feed intake of animals. Wild KM still retains its use as an emergency source of human food and animal feed for agricultural and agro-pastoral communities in times of drought, as well as a source of water and food for inhabitants of the Kalahari Desert, notably the San. The oilcake which remains after the oil has been extracted is used mainly as animal feed, but also as a treatment against human malnutrition, sometimes as a paste with Mahangu (pearl millet) porridge and to treat eye conditions through oral consumption (the type of condition is not determined but suggests a vitamin or mineral deficiency) (Carr, 2007).

2.6 Possibility of inclusion of Kalahari melon in ruminant diets

2.6.1 Potential effect on growth performance

Kalahari Melon contains considerable amounts of protein (between 26.74 and 40.03% depending on region) and hence it could be a potential alternative protein source in ruminants' diets. Generally, protein is a vital requirement in growing young ruminants as is required in their diets to satisfy protein needs for growth (Khalid *et al.*, 2012). Reduced CP intake may affect the growth performance of sheep (NRC 1985). In a study by Beshir *et al.* (2009) replacing groundnut and KM on growing lambs with inclusion levels of 0%, 25%, 50%, 75% and 100% showed a decrease in feed intake and average daily live weight gain with increasing diet levels of KM, though there was no significant effect on feed conversion ratio (FCR) and final body weight. Lambs that were fed 0% of KM in their diet were found to be superior over the other treatment groups. While in a study by Heddia *et al.* (2018) showed that final live weight, daily weight gain and total weight were higher in sheep fed 10% of KM diets compared to the 0% group. The FCR was also higher in the 10% KM inclusion diet as compared to the 0% diet. Groups fed 100% of KM in diets had the lowest fat content and higher moisture

content and the fat content decreased with increasing levels of KM inclusion while moisture content increased with increasing levels.

2.6.2. *Kalahari Melon Potential effects on health*

The secondary plant metabolites found in the Kalahari melon seeds can have some antimicrobial, anti-inflammatory and antioxidant effects and may promote immunocompetence in animals (Vandermark, 2011). The study by Braide *et al.* 2012 indicated that saponins, flavonoids, cyanogenic glycosides, alkaloids, tannins and oxalate were present in watermelon seeds in varying quantities. Alkaloid had the highest concentration of about 1.23% whereas cyanogenic glycoside had the lowest of about 0.024%. The evaluation of watermelon seeds showed their antimicrobial potential. Four extracts of the seeds, including hot water, cold water, ethanol and methanol were tested for antimicrobial activity using a disc diffusion assay method against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella pneumoniae* and *Bacillus cereus*. Hot water extract showed the highest antimicrobial activity against *Pseudomonas aeruginosa* with a 14 mm diameter zone of inhibition whereas ethanol and methanol extracts showed the lowest against *Escherichia coli* and *Klebsiella pneumoniae* with an 8 mm diameter zone of inhibition. While studies have been conducted using common watermelon extracts, the high levels of the polyphenols on KM cake have a higher potential to influence the health of animals. Studies therefore need to be conducted to ascertain the influence of the KM cake on health in animals.

2.6.3 *Potential effects of Kalahari Melon on meat quality*

Finishing of animals in an enclosed area such as pens and or feedlots is one of the major systems used in the sheep industry to increase productivity. It is also believed that finishing animals in a confined space has a positive effect on carcass quality. The KMOC meal contains some secondary plant metabolites such as alkaloids, flavonoids, tannins and total phenols (El Zawawy, 2015). Saponins, alkaloids, tannins, phenols and flavonoids have the potential to stimulate good general health, and improve meat quality and fatty acid profiles (Kumar *et al.*, 2018). Heddia *et al.* (2018) in the study of the use of watermelon seed cake (WMSC) in diets for fattening lambs with inclusion levels of 0%, 10% and 20%, discovered that the diets did not affect carcass composition (muscle, fat and bone) and meat chemical composition. However, the water-holding capacity and cooking loss were significantly different among treatment groups. Lambs fed on 10% inclusion had inferior water-holding capacity and higher cooking loss. Although the treatment diets (0%, 10% and 20%) showed no significant

difference in meat lightness, redness and yellowness in the 0% group compared to the 10% and 20% groups. Heddia *et al.* (2018) concluded that the inclusion of up to 20% of WMSC in lamb diets supports sufficient feedlot carcass characteristics and meat quality. It can therefore be expected that the inclusion of KMC can have varying and desirable effects on carcass and meat quality in ruminants.

2.7 Summary

The productivity of farm animals, particularly sheep in SA most especially in resource-poor areas is generally low, mainly due to poor quality and reduced abundance of available feeds. Conventional feed resources for animal production are increasingly becoming scarce and expensive in many parts of the world. Protein sources and their quality are critical for optimum animal performance. Kalahari Melon has been referred to as *Africa's Secret Gift* because it is one of the most drought-resistant plants in SA and contains a considerable amount of protein (between 26.74 and 40.03% depending on region) and hence could be a potential alternative protein source in ruminants' diets. It is also found in most provinces of SA. Generally, protein is a vital source in growing young ruminants as it is required in their diets to satisfy protein needs for their growth (Khalid *et al.*, 2012). Some studies have also proved that the inclusion of WMSC in animal diets as a protein source improved growth performance (Average daily gain (ADG), FCR, etc.) with even lower levels as 10%. It is also proven to have a wide range of health benefits, including anti-carcinogenic, anti-atherogenic, anthelmintic, anti-diabetic, and immune stimulatory effects. Nevertheless, no studies have been carried out on the effects of KMSC on ruminant performance. Therefore we must accumulate information on the usage of KM which can enhance its integration into sustainable animal feeding systems. This will also aid in offsetting the huge feed costs that are being incurred as well as reducing the reliance on conventional protein source

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CHAPTER 3

GROWTH PERFORMANCE, PROTEIN UTILIZATION EFFICIENCY, BLOOD PARAMETERS AND ECONOMIC EVALUATION IN LAMBS FED KALAHARI MELON OILCAKE IN PLACE OF SOYBEAN MEAL.

ABSTRACT

The study was carried out to evaluate the effect of substituting SBM with KMOC on growth performance, economic evaluation, protein utilization efficiency, blood parameters of lambs and economic evaluation. Forty (40) Meatmaster lambs were used in the experiment. Lambs were randomly assigned to five dietary treatments in a completely randomized design and fed in individual pens for 54 days. Animals were allocated five dietary treatment groups with inclusion levels of KMOC: 0% (control), 25%, 50%, 75%, and 100%. Each treatment was replicated 8 times. Lambs in the different dietary treatment groups had initial weights of 27.6 ± 3.21 Kg. There were significant differences ($P < 0.05$) in terms of overall FW, ADFI, ABWG, ADG and FCR when KMOC was included in the ration. The lambs fed a 50% KMOC diet obtained the highest ($P < 0.05$) BWG, ADFI and ADG followed by those fed a control diet. The ADFI increased with the increasing levels of KMOC in the diet but decreased at 75% and 100% KMOC inclusion levels. CWG improved significantly in lambs fed 50% KMOC diets from week 1. Nonetheless, the 100% KMOC-fed lambs gain less weight. Diet significantly affected both the PC and PER. Lambs fed a 50% KMOC diet had the highest overall PC (162.05 ± 5.16) whilst a 100% diet had the lowest overall PC value (118.34 ± 5.16). Diet did not affect both the SGR and GE respectively. Diet significantly affected the RBC, haemoglobin, MCV, WBC, platelets, neutrophils, lymphocytes, monocytes, neutrophils and lymphocytes. The RBC was lowest (14.73 ± 0.85) in the lambs fed the 50% KMOC diet and the highest (16.81 ± 1.04) in the diet containing 75% KMOC. Generally, the lambs fed the 25% KMOC-containing diets had the lowest values (8.55 ± 1.79) for the WBC compared to other treatment groups. However, diet did not affect haematocrit value and Mean Corpuscular Haemoglobin (MCH). Lambs fed the 50% KMOC diet had the lowest haematocrit values (39.36 ± 1.10) while those fed the 75% KMOC diet had the highest (46.90 ± 1.35). Diet did not significantly ($P < 0.05$) affect CA, TP, ALB, GGT and AMY. Lambs fed the 25% KMOC had the highest levels ($P < 0.05$) of TALB (25.60 ± 5.77), lowest observed by 75% KMOC-fed lambs (17.92 ± 9.76). Diet did not significantly ($P < 0.05$) affect GLU, SMDA, UREA, ALKP, LIPA, PHOS and GLOB. Splensomatic indices (SSI) were not influenced by diet. The findings of the study suggest that

KMOC can partially substitute SBM up to 50% without compromising the health of lambs. There was significant difference on carcass profits, GI, feed, TVC and GM. The higher the inclusion levels of KMOC the higher the gross margin and this proves to be cost-effective to replace SBM with KMOC.

Keywords: Kalahari melon, Growth, Performance, Protein utilization, Blood, Efficiency, Physiological, lambs

3.1 Introduction

In any sheep production system, feed is the most expensive component of the production inputs. Protein provision is one of the important aspects that significantly affect the performance of sheep. When lambs are provided with high-quality protein, the performance is optimised, ultimately ensuring profitable animal production. Different conventional plant protein sources such as cotton seeds meal, SBM, sunflower meal and rape seed meal are used to formulate rations for growing and fattening lambs (Khalid *et al.*, 2012). Soy bean meal has long been considered an exceptional source of supplemental protein in diets for livestock. It also has a high concentration of protein (44% to 49%), the protein is highly digestible, and the amino acids that are released from the protein following digestion consist of a blend that is ideal for livestock (Cromwell, 1999). On the contrary, the variations in availability and pricing of SBM have been a major factor affecting affordability, especially by farmers. Therefore, alternative protein sources need to be explored.

Proteins that reach the small intestine of ruminants are made up of digestible microbial proteins and digestible rumen undegradable proteins, which in summation are regarded as metabolizable proteins. According to Ruzic-Muslic *et al.* (2014), microbial protein is not adequate to supply the amino acids required for optimum animal growth; therefore, protein sources with high rumen undegradable protein (RUP) are required for better growth performance. Most conventional plant protein sources used to supplement protein and energy in ruminants are very expensive for resource-limited farmers. Unconventional oilseed cakes like KM meal can be explored further for use in ruminant diets to lower the cost of livestock production. Of all these sources, KMOC meal is proving to be popular and has great potential as a natural protein source. The rapid expansions in cultivation and production of Kalahari Melon in SA coupled with expanding oil extraction capacity have increased the availability of KMOC meal for use in animal production.

Kalahari melon has been described by Liu *et al.* (2009) as one of the medicinal plants and herbs commonly used in communities with great potential. The Kalahari melon seed essential oils have been used traditionally in Southern Africa as a cosmetic product, primarily as a face and body scrub which is said to impart a blemish-free complexion to the skin (Vermaak *et al.*, 2011). The remaining cake from essential oil extraction is also rich in fat and protein (African Origin Oil, 2014). Moreover, seed cake also contains large amounts of fats including palmitic, stearic, oleic, and various linoleic acid isomers (Berry, 2015). Cheikhoussef *et al.* (2017) observed fatty acid such as linoleic acid that ranges between 52.57–56.96% in *C. lanatus* seed

oil. Marume *et al.* (2020) observed that the *C. lanatus* seed oil consists of 11.6%, palmitic, 8.32% stearic, 13.81% oleic and 65.17% linoleic acids. In particular, conjugated linoleic acids have been reported to have a wide range of health-beneficial effects, including anti-carcinogenic, anti-atherogenic, anthelmintic, anti-diabetic and immune stimulatory effects (Liu *et al.*, 2017).

Citrullus lanatus seed cakes have also been reported to contain significant quantities of glutamic acid, aspartic acid, arginine and leucine (Egbuonu, 2015; Falade *et al.*, 2020) and low content of lysine and sulphur-containing amino acids. The relatively high protein content in the KMSC qualifies it as a potential protein source for ruminants. Some studies have been carried out with the use of sweet watermelon cake with promising results. Nevertheless, no attempts have been made to assess the inclusion of the bitter Kalahari melon seed cake in diets on the performance of lambs. On the other hand, the fattening of lambs represents a production practice that requires a large amount of financial resources. Choices regarding the type of protein source to use in diets and whether or not to invest in such are not straightforward. These choices can however be simplified by using economic concepts that could quantify the risks associated with such investment choices (Pacheco *et al.*, 2017). Furthermore, quantification of the probability of return on invested capital remains an important aspect as it relates to the profitability of the protein source of choice. Animal nutrition studies that compare different protein sources tend to have a narrow look at the consequential economic implications. The focus is often on the comparative advantage between treatments. Modern animal science research on the finishing of livestock may include some economic components but often neglects to focus their studies through the lens of a system by profit function (Stockton *et al.*, 2012). This neglect consequently fails to consider what is known as the law of diminishing returns as a principle of the economic optimum. The economic evaluation of which protein sources to be used is therefore cardinal if alternative low-cost fattening diets are to be formulated. It can therefore be hypothesized that Kalahari melon seed cake has the potential to cost effectively replace soybean meal in lamb diets without negatively affecting performance. Therefore, this study was carried out to assess the effects of the inclusion of graded levels of KM cake on growth performance, digestibility, protein utilisation efficiency and blood metabolites in growing lambs. Furthermore, the study intended to conduct an economic analysis of the inclusion of Kalahari melon cake in lamb diets.

3.2 Materials and Methods

3.2.1 Study site description

The experimental procedures were approved by the NWU-ANIMPROD REC of the North-West University and the ethical number NWU-00822-21-A5 was allocated.

The study was conducted at the North West University experimental farm (Molelwane). The study site is situated in SA, North-West Province. The farm's GPS Coordinates are between 25°86'00" S, 25°64'32" E and temperature ranges from 2 °C to 25 °C and 22 °C to 35 °C in winter and summer seasons, respectively. It has a uniform terrain with an altitude of 1400 meters above sea level. The farm receives 300 mm-600 mm of rainfall per annum. The farm is located 8 KM from Mahikeng city on the road to the Botswana Ramatlabama boarder gate.

3.2.2 Sourcing of Kalahari melon oilcake

The KMOC was obtained from Highland Essential Oils (HEO) in Free State. The cake is a by-product of oil extraction. The seed cake was ground using a Hammer Mill (TRF 400) to pass through a 2 mm sieve. Other feed ingredients such as maize, soybean, molasses, urea, lucerne and salt were purchased from Chicken Ranch Animal Feeds & Agricultural Supplies (PTY) Ltd in Pretoria, SA.

3.2.3 Chemical composition

Nutritional compositions of experimental KM diets and oilcakes were determined. Proximate analysis was done on all treatment diets to determine crude protein (CP), ash (A), calcium (Ca), phosphorus (P) and ether extract (EE) composition using a standard method AOAC (2000) at the UNW-Mafikeng Campus, Department of Animal Science Laboratory. KM and SBM were sun-dried for 24 hours and then milled through a 1-mm screen before analysis of DM, OM, CP (Method 976.05), Ash, EE, crude fibre (Method 962.09), calcium, and phosphorus in a Kjeldahl method. Acid detergent fibre (ADF), nutrient detergent fibre (NDF) and acid detergent lignin (ADL) were also determined according to the official methods of analytical chemistry (AOAC, 2000). Kjeldahl method was used to determine total protein. A 1g of the sample was put into a filter paper and put into a Kjeldahl flask, 10 cm³ of concentrated H₂SO₄, and placed in a digestion machine with a fumehood to cool titrate. Get titration volume and then convert to nitrogen, then multiply by 6.25 to get protein content.

3.2.4 *In Sacco* CP disappearance

The *in sacco* technique (Ørskov & McDonald, 1979) was used to determine the protein degradation and disappearance in a cannulated cow. The degradation of protein in rumen was assessed through the measurement of utilisation levels of each protein source, i.e. soy bean meal vs Kalahari melon meal and 50 g of each of the protein sources were measured and placed into nylon bags. Each sealed bag was individually attached to a metal ring disk, which was attached to the cannula plug with a piece of nylon string. The free length between the plug of the cannula and the bag was 25 cm (Mehrez & Ørskov, 1977). All the bags were simultaneously inserted and submerged in the rumen, after which they were collected at the relevant time intervals. After the bags were removed from the rumen, they were placed into buckets of cold water, after which they were rinsed under running cold tap water to halt microbial activity. The bags were then washed in cold water in a twin- 49 tub washing-machine for ten minutes, using the gentle cycle. The water was drained off after five minutes of washing, after which the bags were washed in fresh water for an additional five minutes. The (0h) ruminal incubation bags containing feed samples were washed in the same way as were the other bags to determine the soluble fraction. All the bags were then dried in a forced draught oven at 65 °C, as described by Nocek (1985) and Janicki & Stallings (1988). At the end of the drying period, bags were cooled in a desiccator and weighed to calculate the residual DM. Residues were then removed from the bags and stored for further analysis. The contents of the duplicate bags (48h, 72h and 96h) were combined for analysis.

The *In Sacco* ruminal DM degradability will be determined using the following formula:

$$\%ISTD (DM \text{ basis}) = \frac{100 - (W3 - (W1 \times C1))}{W2 \times DM} \times 100$$

Where, W1 = Bag tare weight, W2 = Sample weight, W3 = Final bag weight after *In Sacco* treatment and C1 = Blank bag correction factor (final oven-dried weight ÷ original blank bag weight).

The DM and nitrogen degradability parameters were estimated by fitting the degradation data to the following equation (Ørskov & McDonald, 1979) using SAS software (2010):

$$Y = a + b (1 - e^{-ct}),$$

Where Y = the degraded fraction after t hours of incubation; a = the soluble or rapidly degradable fraction; b = insoluble or slowly degradable fraction; c = fractional rate constant of degradation of b (%/h); and t = incubation time (0, 2, 4, 8, 12, 24, 36, 48 and 72 hours).

Effective rumen degradability value was calculated as:

$$ED = a + \frac{b*c}{k*c},$$

Where a , b , and c are the Orskov-McDonald parameters defined above and k = outflow rate assumed to be 5%/h.

Table 3.1: Ingredient composition (g/kg as fed basis) of dietary treatments

Ingredients	Dietary treatments				
	0%	25% KMOC	50% KMOC	75% KMOC	100% KMOC
Yellow maize-coarse	38.3	38.3	38.3	38.3	38.3
Lucerne	12	12	12	12	12
Wheat bran/Pollard	8.6	8.6	8.6	8.6	8.6
Soy hulls/ Sunflower husks	7.9	6.9	6.5	6.1	5.9
Molasses	4.3	4.3	4.3	4.3	4.3
Limestone powder-fin	1.5	1.5	1.5	1.5	1.5
Salt-coarse	0.6	0.6	0.6	0.6	0.6
Ammonium Chloride	0.6	0.6	0.6	0.6	0.6
Premix B (Vit-Min)	0.2	0.2	0.2	0.2	0.2
Urea	0.08	0.08	0.08	0.08	0.08
Kalahari Melon oilcake	0	6.3	12.7	19	25.3
Soybean meal	25.3	19	12.7	6.3	0

Table 3. 2: Chemical composition of Kalahari melon oil cake compared to Soy bean meal

Parameter	Kalahari Melon	Soy bean meal
Moisture	7	8
Dry matter	92.9	92.0
Organic matter	93.3	92
Crude Protein	35.6	44.4
Crude Fibre	6.4	3.5
Carbohydrates	7.2	13
Energy value (kcal per 100 g)	516	208.7

3.2.5 Experimental design and treatments

Five isonitrogenous and isoenergetic dietary treatments which substituted SBM with KMOC were formulated. The control diet (T1) was a normal conventional feedlot diet containing 100% SBM. In the test diets, the SBM was replaced by KMOC meal at the following graded levels of KMOC 25% (T2), 50% (T3), 75% (T4) and 100% (T5).

1. **T1**- The lambs were fed commercial lamb diets containing **100%** soybean meal as protein source (**Diet 1; Control**).
2. **T2**- The lambs were fed experimental lamb diet containing Kalahari melon (*Citralluslanatus*) oilseed cake at 25% in place of soybean meal (**Diet 2**).
3. **T3** –The lambs were fed experimental lamb diet containing Kalahari melon (*Citralluslanatus*) oilseed cake at 50% in place of soybean meal (**Diet 3**).
4. **T4** –The lambs were fed experimental lamb diet containing Kalahari melon (*Citralluslanatus*) oilseed cake at 75% in place of soybean meal (**Diet 4**).
5. **T5** –The lambs were fed experimental lamb diet containing irradiatedKalahari melon (*Citralluslanatus*) oilseed cake at 100% in place of soybean meal (**Diet 5**).

Each lamb was kept in individual pens for 7 days of the adaptation period followed by an experimental period which lasted for 52 days. Each treatment had replicate animals with a lamb in an individual cage considered an experimental unit in a completely randomised design (CRD).The diets were formulated in accordance with NRC (2007) to meet the nutrient requirements for growing lambs. The diet was offered *ad libitum* at regular intervals and were allowed access to clean cool water. The feed leftovers were removed and weighed daily to determine dry matter intake (DMI).

3.2.6. Animal management

Forty four-months old Meatmaster lambs (Av weight: 27.6 ± 3.21 kg) were purchased and housed in individual pens at North West University - Molelwane farm. On arrival, the lambs were dosed with Ivermectin against endoparasite and Ectoparasite 0.2ml per/kg body weight. Five dietary treatments were formulated with the inclusion of KMOC in place of SBM as follows: control (commercial diet), commercial diets + 25% KMOC, commercial diets + 50% KMOC, commercial diets + 75% KMOC, commercial diets + 100% KMOC. The feeding trial

lasted for 54 days with 7 days adaptation period. During adaptation period animals were fed treatment diets gradually until they fully adapted to the diets. Hay was also initially used as a basal diet during adaptation to the environment while 7 days were allowed for the animals to adapt to the experimental diet. Animals were fed in the morning at 08H00 and had access to clean fresh water. Lambs were fed at 4% of their body weight. The orts were collected and weighed every morning before feeding. The quantity of feed given was adjusted every week after recording the body weight of each lamb in order to meet the nutritional requirement for growth. The welfare of the lambs was also evaluated by the local Veterinary doctor and the National Society for the Prevention of Cruelty to Animals (NSPCA).

3.3 Growth performance parameters and Economic Evaluation

3.3.1 Feed intake, feed conversion ratio, body weight gains and protein utilization *efficiency*

Feed was given twice per day, in the morning and afternoons and refusal was recorded every morning before the subsequent feed. Feed intake (FI) was recorded daily as the difference between the feed offered and the refusal. Growth performance was monitored by weighing animals at the beginning of the experiment and weekly thereafter on an empty stomach. Each lamb was weighed with a commercial sheep weighing scale once in the morning after every seven days (weekly weights) and the following growth performance parameters were calculated:

$$ADWG(toT) = \frac{W(T) - W(to)}{T - to}$$

Where: t_0 = initial time, T = final time (54th day), $W(T)$ = final body weight, and $W(t_0)$ = initial body weight. The average daily gain (ADG) was calculated to determine feed efficiency. The efficiency of feed utilization and live weight gain was monitored every 14 days and other growth performance parameters were calculated as follows:

$$Total\ liveweight\ gain = new\ liveweight - initial\ liveweight$$

$$FI = feed\ offered - feed\ refusal$$

$$ADG = \frac{Finish\ weight - start\ weight}{Duration\ of\ feeding\ (days)}$$

$$FCR = \frac{FI}{Weight\ gain}$$

Protein consumed (PC g/animal) was calculated by multiplying the concentration of crude protein (CP_d) in the diet (g/kg DM consumed) by feed intake over the feeding phase and protein efficiency ratio (PER g/kg) was calculated by dividing mean body weight gain (BWG) by the mean protein consumed. Specific growth rate (SGR), which is the per cent growth per feeding phase and growth efficiency (GE) was also calculated using the following formulas:

$$PC = FI \times CP_d$$

$$PER = \frac{BWG}{PC}$$

$$SGR = \frac{(In\ final\ weight - In\ initial\ weight)}{14\ d} \times 100$$

$$GE = \frac{BWG}{Initial\ weight}$$

3.3.2 Body condition score and body condition index

As lambs were weighed before the start of the experiment and weekly and concurrently body condition was assessed using the 5-point scale (1 = very thin to 5 = obese) (Aumont *et al.*, 1994). The body condition index (BCI) was determined by measuring the length/weight.

$$BCI = length/weight.$$

3.3.3 Economic Evaluation

Livestock production entails feeding animals with various feedstuffs to attain product output in a projected period. Positive gross margins are dependent on the live weights of the sold carcass and the cost of added weight to the marketed animal. The variable costs included labour, feed, abattoir costs, and transportation of lambs to the abattoir and purchase costs of lambs. The values of the carcasses and edible offal for each treatment were summed up to estimate revenue. Gross income was then calculated as:

$$\text{Gross Margin (GM)} = \text{Gross Income (GI)} - \text{Total Variable Costs (TVC)}$$

3.4. Haematology, Serum biochemistry, Liver and Spleen indices

Blood samples were collected from the jugular vein using an 18-gauge needle at 0800 hours at the end of the trial for analysis of health indicators and nutritionally related blood metabolites. Blood collected into purple vacutainer tubes with anticoagulants was used for haematological analyses, while that collected into the red top tubes was used for serum biochemical analysis. The blood for biochemical analysis was allowed to coagulate at room temperature and centrifuged for 10 min at 1000 ×g within 2 hours of collection and serum separates in propylene tubes and kept at −20 °C, pending analyses. Serum samples were analysed using a Chexcks machine (Next/Vetex Alfa Wasserman Analyser, Woerden, Netherlands) and commercially purchased kits (Siemens, SA). The serum was analysed spectrophotometrically for total proteins (TP) (Weichselbaum, 1946), albumin (Doumas & Biggs, 1972), non-esterified fatty acids (NEFA) (De Villiers *et al.*, 1977), calcium (Cali *et al.*, 1972), magnesium (Tietz, 1976), inorganic phosphorus (Young, 1990) and iron (Tietz, 1976). Enzymatic methods were used for glucose (Gotchman & Schmitc, 1972), cholesterol (Allain *et al.*, 1974) and urea (Tietz, 1995) analyses. Blood samples for haematology were analysed immediately after collection for packed cell volume (PCV) and haemoglobin (Hb) concentration as described by Benson *et al.* (1989) and Jain, (1993). Red Blood Cells (RBCs) and White Blood Cells (WBCs) as well as the differential WBC counts were determined using the Neubauer haemocytometer after appropriate dilution (Lamb, 1981). Values for the constants: mean corpuscular haemoglobin concentration (MCHC), mean corpuscular haemoglobin (MCH) and mean corpuscular volume (MCV) were calculated from RBC, Hb and PCV values as described by (Simon & Casmir, 2001). The haematology analyses were done by using the automated IDEXX LaserCyte machine for haematology. At the end of the feeding trial, internal organs (liver and spleen were obtained to calculate the relationships between the liver and spleen and body weight as these influence the immune function of the body of animals. Hepatosomatic (HSI) and spleensomatic (SSI) indices were also calculated using the following equations.

$$HSI = \text{Liver wt} / \text{Slaughter wt} \times 100$$

$$SSI = \text{Spleen wt} / \text{Slaughter wt} \times 100$$

3.5 Statistical analysis

Data of Soybean meal and Kalahari melon oil cake meal on DM and N degradability parameters (a, b and c fractions, and ED values) were evaluated by analysis of variance using the model:

$$Y = \mu + a_i + e_{ij} \quad (\text{Model 1})$$

Where, μ = the overall mean; a_i = the effect of feed and e_{ij} : the residual error. Means were separated using the Tukey's procedure. Statistical significance was declared at $P \leq 0.05$.

Statistical significance was declared at $P \leq 0.05$.

Data on growth performance was analysed using the mixed models for repeated measures taking into account the effect of diet and week (SAS) version 9.3 (2010). The initial weight was used as a covariate. The probability of difference (PDIFF) option of SAS was used for the separation of means, and the level of significance was declared at ($P < 0.05$).

$$Y_{ijk} = \mu + T_i + E_{ijk} \quad (\text{Model 2})$$

Y_{ij} = response variable (Weekly ADFI, ADG, FCR)

μ = overall mean observation,

T_i = effect of the i th diet ($i = 0\%, 25\%, 50\%, 75\%, 100\%$ of KMOC levels),

E_{ij} = random error

$$Y_{ijk} = \mu + T_i + W_j + (T \times W)_{ij} + \varepsilon_{ijk} \quad (\text{Model 3})$$

Y_{ijk} = is the dependent variable (weekly growth parameters)

μ = overall mean, T_i = effect of diet levels ($i = 5$ graded levels of Kalahari melon: 0%, 25%, 50%, 75% and 100% replacement of soybean meal),

W_j = effect of week

$(T \times W)_{ij}$ = interaction effect

ε_{ij} = random residual error.

3.6 Results

3.6.1 *In Sacco* protein disappearance

The *in sacco* rates of CP disappearances for soy bean meal and Kalahari melon cake are presented in Figure 3.1. Initial rate of disappearance for the soy bean meal inclined steadily over the period of incubation giving a concave trend. At 24 to 36 hrs of incubation, the rate reached a plateau becoming constant. On the other hand, the rate of disappearance for Kalahari melon cake was initially subdued but began to incline at 36hr of incubation giving a convex trend. The two trends appeared to show slow degradability with regards to Kalahari melon cake while soy bean meal showed a high rate of ruminal degradation.

3.6.2 *Growth Performance, body condition index and feed Intake*

The effect of the KMOC inclusion in diets on growth performance and body condition index of lambs are presented in Table 3.3. At the start of the experiment, lambs in the different dietary treatment groups had similar initial weights (IW). The lambs fed a 50% KMOC diet obtained the highest ($P < 0.05$) final weight, BCI and BWG. The lambs fed the 100% KMOC diet had the lowest FW (31.37 ± 1.44) and BWG (3.87 ± 0.99). It appeared that the ADFI increased with the increasing levels of KMOC inclusion in the diet but decreased at 75% KMOC inclusion levels onwards. However, with regards to the FCR, the lambs fed the control diet had the lowest value (5.61 ± 0.94) followed by those fed the 50% KMOC (6.78 ± 0.94) diet. The lambs fed the 100% KMOC diet had the highest value (10.71 ± 0.94) for FCR. The effect of replacing SBM with KMOC meal in the diets of lambs on weekly live weight is presented in Figure 3.1. The IW values of all dietary treatments were similar from the start of the experiment. From week 1 of age, 50% KMOC diets-fed lambs appeared to gain more weight (9.12 ± 0.99) as compared with all other treatment groups and outperformed the control group. The lambs fed 100% KMOC had the lowest weekly weight values compared to all other treatments

Table 3.3: *In Sacco* ruminal dry matter degradability (g/kg) of soybean meal and Kalahari melon cake KMC at various incubation times.

Incubation time: 2h = Dry Matter Degradability at 2 h after inoculation; 4h = Dry Matter Degradability at 4 h

Substrate	Incubation time						
	2h	4h	8h	12h	24h	36h	48h
SBM	219.56	347.34	479.09	547.09	937.01	994.30	997.49
KMC	192.35	224.31	251.89	280.22	409.25	496.33	617.42
SEM	7.76	34.26	63.29	7.83	11.11	7.88	63.29

after inoculation; 8h = Dry Matter Degradability at 8 h after inoculation; 12h = Dry Matter Degradability at 12 h after inoculation; 24h = Dry Matter Degradability at 24 h after inoculation; 36h = Dry Matter Degradability at 36 h after inoculation; 48h = Dry Matter Degradability at 48 h after inoculation.

Substrate: SBM = soybean meal included herein only for reference purposes; KMC= Kalahari melon cake.
SEM = standard error of the mean

Table 3.4 *In sacco* ruminal dry matter degradation parameters (g/kg DM, unless otherwise stated) of soybean meal and KMC meal.

Substrate	Parameters				
	<i>A</i>	<i>B</i>	<i>c</i> (h^{-1})	<i>PD</i>	<i>ED</i>
SBM	223.73	854.20	0.05	1077.93	653.62
KMC	256.30	644.07	0.05	866.39	597.87
SEM	14.02	75.06	0.01	79.36	42.01

Parameters: *a* =rapidly soluble DM fraction; *b* = potentially degradable DM fraction; *c* = fractional degradation rate of fraction *b*; ED = effective degradability calculated as $a + (b * c)/(k * c)$, where k is assumed to be 5%/hour.

Substrate: SBM = Soybean meal included herein only for reference purposes; KMC = Kalahari melon cake meal.
SEM = standard error of the mean

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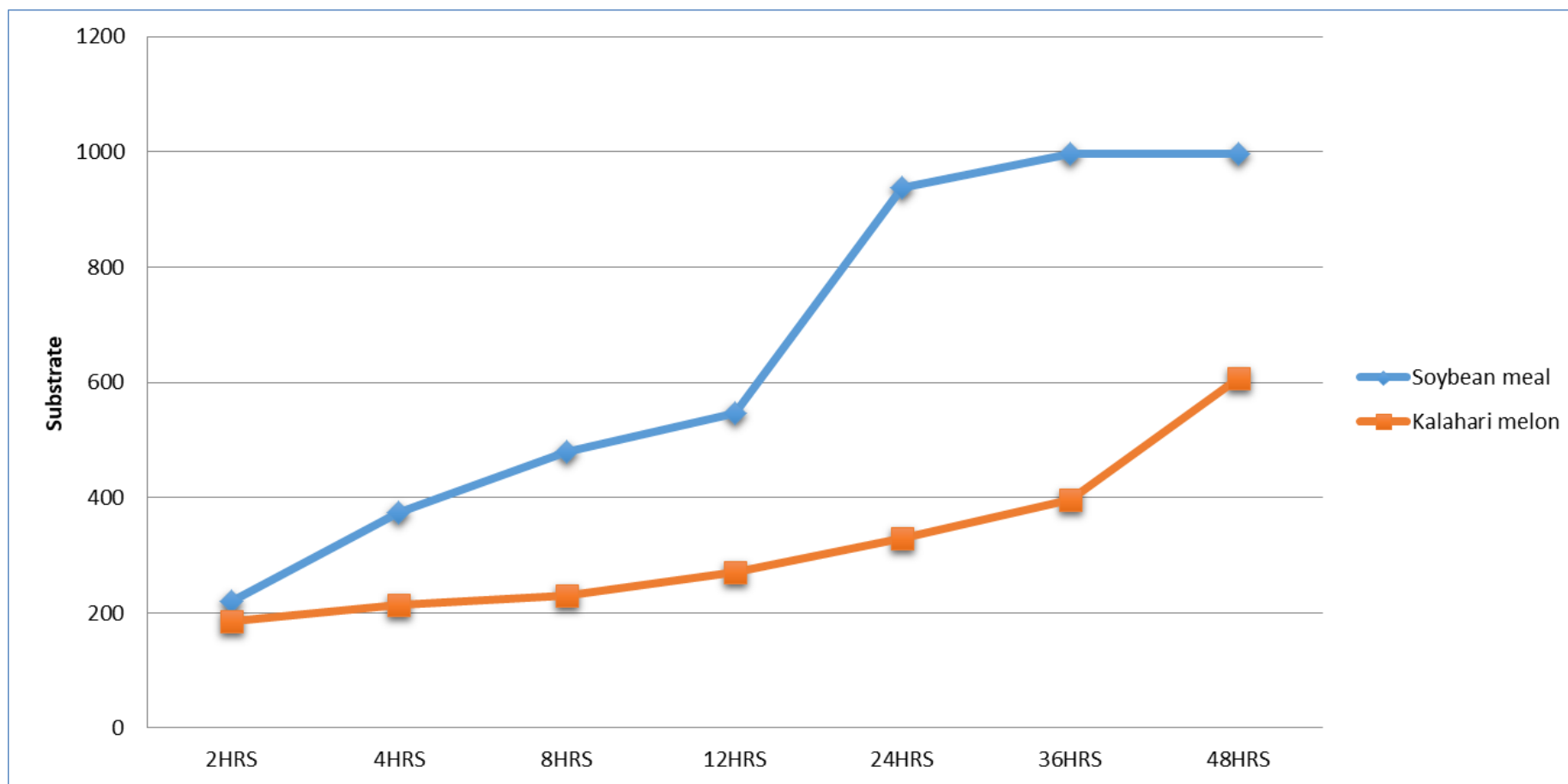


Figure 3.1: *In vitro* ruminal dry matter degradability (g/kg) of untreated soybean meal and Kalahari melon cake at various incubation times

Table 3.5: The effect of Kalahari Melon Oilcake meal inclusion levels on growth performance parameters of lambs.

Parameters	Dietary treatments					SEM
	Control	25% KMOC	50% KMOC	75% KMOC	100% KMOC	
Initial Weight (kg/lamb)	26.87	28.00	28.25	27.25	27.50	1.04
Final Weight (kg/lamb)	35.87 ^{ab}	35.75 ^{ab}	37.37 ^b	33.37 ^a	31.37 ^a	1.44
BWG (kg/lamb)	9.00 ^c	7.75 ^b	9.12 ^c	6.12 ^b	3.87 ^a	0.99
ADFI (g/d)	827.79 ^b	886.11 ^b	1012.81 ^c	954.44 ^c	739.62 ^a	32.30
ADG (g/d)	166.66 ^c	143.5 ^{bc}	168.98 ^c	113.42 ^b	71.76 ^a	18.39
FCR	5.61 ^a	7.44 ^b	6.78 ^b	9.14 ^c	10.71 ^c	0.94
BCI	8.26 ^a	16.34 ^c	8.64 ^a	11.93 ^b	17.63 ^c	3.46

^{a, b, c} means in the same row with different superscripts are significantly different (P <0.05). BWG= Body Weight Gain, ADFI = Average Daily Feed Intake, ADG =Average Daily Gain, FCR = Feed Conversion Ratio, BCI = Body condition Index. Control = 0%KMOC; 25% KMOC; 50% KMOC; 75% KMOC, 100% KMOC. SEM = standard error of the mean

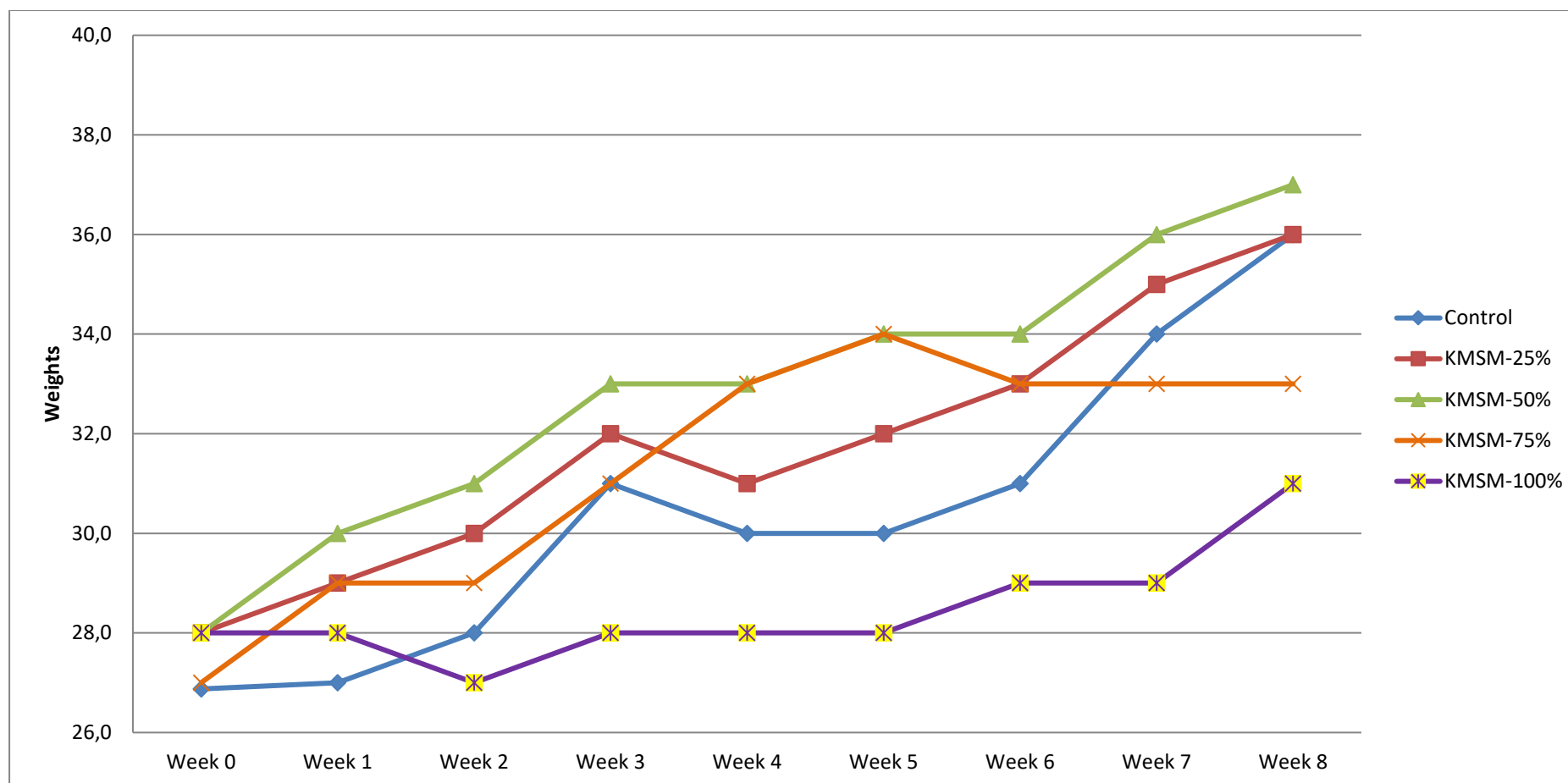


Figure 3.2: Effect of Kalahari melon oilcake inclusion levels on cumulative weight gain on lambs.

3.6.3 Protein utilization and growth efficiency

The results on the effects of KMOC inclusion in diets of lambs on protein utilisation efficiency are presented in Table 3.4. From the results, diet had a significant effect on all measured parameters ($P < 0.05$). Lambs fed a 50% KMOC diet had the highest overall PC (162.05 ± 5.16) whilst a 100% diet had the lowest overall PC value (118.34 ± 5.16). The PC appeared to increase with increasing levels of KMOC in the diets of lambs, later declining at 75% and 100% KMOC inclusion levels. However, the highest PER values (1.23 ± 0.11) were observed in lambs fed the control diet followed by those fed the 50% KMOC diet (1.03 ± 0.11). SGR and GE were also highest in lambs fed both the control and 50% KMOC diet (0.34 ± 0.03 and 0.32 ± 0.03) separately and inevitably lower (0.14 ± 0.03) in those fed the 100% KMOC diet. As with the PC and PER, the SGR and GE appeared to initially increase with inclusions of KMOC up to 50% and declined at higher levels.

3.6.4 Haematology parameters

The results on haematological parameters are presented in Table 3.4. Diet significantly affected the RBC, haemoglobin, MCV, WBC, platelets, neutrophils, lymphocytes and monocytes. The RBCs were lowest in the lambs fed the 50% KMOC diet and the highest ($P < 0.05$) in the diet containing 75% KMOC. Generally, the lambs fed the 25% KMOC- containing diets had the lowest values (8.55 ± 1.79) for the white blood cells (WBCs) compared to other treatment groups. In addition, the control group consistently had the highest ($P < 0.05$) values for neutrophils, lymphocytes and eosinophils. Moreover, lambs fed 25% KMOC inclusion level had the lowest values on lymphocyte, monocytes, basophils, neutrophils and eosinophils differential count except for monocytes. Diets did not significantly ($p < 0.05$) affect haematocrit value and MCH. Lambs fed the 50% KMOC diet had the lowest haematocrit values (39.36 ± 1.10) while those fed the 75% KMOC diet had the highest (46.90 ± 1.35). Nonetheless, lambs fed 100% KMOC inclusion levels had the highest ($P < 0.05$) MCV values (28.00 ± 1.70) as compared to the other treatments. The HSI appeared to decline with increasing inclusion of KMOC in the diets with the lambs fed the control diet having the highest value (16.76) whereas those fed the 100KMOC diet had the lowest value (12.43). Diet did not affect SSI.

Table 3.6: Effect of partially replacing of soybean with Kalahari melon oilcake on protein utilization efficiency of lambs.

Parameters	Dietary treatments					SEM
	Control	25% KMOC	50% KMOC	75% KMOC	100% KMOC	
PC (g/lamb)	132.44 ^b	141.78 ^b	162.05 ^{ab}	152.71 ^{ab}	118.34 ^a	5.16
PER (g/lamb)	1.23 ^b	1.00 ^b	1.03 ^b	0.73 ^a	0.60 ^a	0.11
SGR (% day ⁻¹)	0.53 ^b	0.45 ^{ab}	0.51 ^b	0.37 ^a	0.24 ^a	0.05
GE	0.34 ^b	0.28 ^{ab}	0.32 ^b	0.22 ^{ab}	0.14 ^a	0.03

Means in the same row with different superscripts are significantly different ($P < 0.05$). PC = Protein Consumed, PER = Protein Efficiency Ratio, SGR = Specific Growth Rate, GE = Growth Efficiency. Control (Commercial diet without KMOC), Commercial + 25% KMOC, Commercial + 50% KMOC, Commercial + 75% KMOC, Commercial + 100% KMOC. SEM = standard error of the mean.

Table 3.7: The effect of Kalahari Melon Oilcake inclusion levels on haematology parameters of lambs

Parameters	Dietary treatments				
	Control	25% KMOC	50% KMOC	75% KMOC	100% KMOC
Haematocrit %	42.86±1.10	43.95±1.35	39.36±1.10	46.90±1.35	44.35±1.35
MCV (fl)	27.93±1.38 ^b	27.10±1.70 ^b	26.93±1.38 ^a	27.90±1.70 ^b	28.00±1.70 ^c
MCH (pg)	29.90±0.59	28.65±0.73	33.06±0.59	29.30±0.73	27.60±0.73
Haemoglobin % (g/dl)	12.80±0.41 ^a	12.60±0.50 ^a	13.00±0.41 ^{ab}	13.75±0.50 ^b	12.25±0.50 ^a
RBC (x 10 ¹² /l)	15.38±0.85 ^b	16.34±1.04 ^c	14.73±0.85 ^a	16.81±1.04 ^c	15.83±1.04 ^b
WBC (x 10 ⁹ /l)	12.56±1.46 ^{bc}	8.55±1.79 ^a	11.29±1.46 ^b	11.35±1.79 ^b	13.49±1.79 ^b
Neutrophils (x 10 ⁹ /l)	6.94±0.90 ^c	4.06±1.10 ^a	6.40±0.90 ^c	5.89±1.10 ^{ab}	5.59±1.10 ^a
Lymphocytes (x 10 ⁹ /l)	0.43±0.14 ^b	0.26±0.17 ^a	0.54±0.14 ^c	0.27±0.17 ^a	0.40±0.17 ^b
Monocytes (x 10 ⁹ /l)	0.38±0.09 ^c	0.17±0.11 ^a	0.18±0.09 ^a	0.16±0.11 ^a	0.20±0.11 ^b
Eosinophils (x 10 ⁹ /l)	0.29±0.06	0.12±0.06	0.12±0.06	0.11±0.06	0.08±0.06
Platelets	314.00±241.10 ^b	1042.50±295.29 ^c	498.00±241.10 ^a	408.50±295.29 ^a	428.00±295.29 ^a
HIS	16.76 ^c	15.94 ^b	14.95 ^b	14.59 ^b	12.43 ^a
SSI	1.79	1.59	1.86	2.01	1.17

MCV= mean corpuscular volume, MCH = mean cell haemoglobin, WBC= White blood Cell, RBC=Red Blood Cell, Control = 0%KMOC; 25% KMOC; 50% KMOC; 75% KMOC; 100% KMOC. SEM = standard error of the mean. HSI, hepato-somatics index, SSI, spleen-somatics index

3.6.5 Serum biochemical parameters

Table 3.5 presents the effects of KMOC inclusion levels in diet on serum biochemical parameters in lambs. Diet did not affect all serum parameters apart from the symmetric dimethylarginine (SDMA), creatinine, calcium, total protein, total albumin and total urea ($P < 0.05$). SDMA initially increased with increasing levels of KMOC in the diets but declined at higher levels. Creatinine concentration was highest and higher inclusion levels of KMOC in the diets while urea concentrations appeared to decline with increasing levels of KMOC in the diets. Similarly, TA and TP declined at higher levels of KMOC in the diets. Lambs fed the 25% KMOC had the highest levels ($P < 0.05$) of total albumin (25.60 ± 5.77), the lowest was observed in lambs fed the 75% KMOC diet (17.92 ± 9.76). However, the 75% KMOC-fed lambs had the highest Ca levels (2.31 ± 0.18). The lambs fed the control diet had the highest levels of amylase levels while those fed the 75% KMOC inclusion diet had the lowest. Diet did not significantly ($P > 0.05$) affect glucose SMDA, ALKP, LIPA, phosphate and total globulin. While the concentrations of liver enzymes (ALT, ALKP and GGT) varied across treatments, the differences were not statistically significant.

Table 3:8 The effect of Kalahari Melon Oilcake inclusion levels on serum biochemistry parameters in lambs

Parameters	Dietary treatments				
	Control	25% KMOC	50% KMOC	75% KMOC	100%KMOC
Glucose	2.36±1.16	2.76±0.68	2.44±0.60	1.11±0.40	1.17±0.26
SDMA	17.50±3.69	17.60±2.96	20.40±5.50	36.20±6.61	15.00±4.58
Creatinine	53.00±11.22	53.60±8.70	55.00±6.59	70.60±3.97	61.33±8.50
Urea	10.47±0.83	10.68±2.07	6.22±2.18	4.12±1.09	4.56±1.87
Phosphorus	2.36±0.37	2.69±0.76	2.31±0.69	2.38±0.29	2.91±0.25
Calcium	2.21±0.09	2.27±0.16	2.31±0.18	2.07±0.13	2.11±0.06
Total protein	63.75±5.67	63.00±11.11	62.80±8.87	57.80±5.16	57.33±2.30
Total Albumin	24.50±1.29	25.60±5.77	24.60±2.19	17.92±9.76	20.66±1.52
ALT	78.66±40.52	132.75±100.61	47.80±29.78	28.80±8.49	25.00±9.84
ALKP	241.00±109.49	278.60±98.17	174.00±72.43	131.20±65.31	86.66±31.34
GGT	14.25±21.79	27.20±17.07	81.40±87.84	56.40±13.92	79.66±12.01
Total bilirubin	9.34±11.13	17.60±17.65	7.66±3.51	6.33±5.77	8.56±4.68.
Cholesterol	7.84±13.12	0.65±0.40	0.88±0.38	0.99±0.33	0.63±0.38
Amylase	46.50±7.73	22.80±3.70	19.00±4.12	17.20±3.70	20.00±6.00
Lipase	154.25±105.89	368.40±148.03	157.00±52.96	181.80±123.94	190.66±67.09
Globulin	31.25±20.66	8.00±17.88	38.20±6.61	13.64±15.94	36.66±1.52

ALP =Alanine aminotransferase, ALT =Alkaline phosphatase & AST =Aspartate aminotransferase. Control (commercial lambs diet without Kalahari melon), Commercial lambs diets + 5% KMOC, Commercial lambs diets + 10% KMOC, Commercial lambs diets + 15% KMOC, Commercial lambs diets+ 20% KMOC. SEM = standard error of the mean

Table 3.9: Economic evaluation for lambs fed different inclusion levels of Kalahari Melon Oilcake in place of Soybean meal

Items	0%KMOC	25%KMOC	50%KMOC	75%KMOC	100%KMOC
Carcass income (R/kg)	1333.62 ^c	1362.47 ^c	1433.47 ^d	1216.01 ^b	1036.27 ^a
Edible offal profit (R/kg)	79.00	79.00	79.00	79.00	79.00
Head & feet profit (R/kg)	38.00	38.00	38.00	38.00	38.00
Gross income (R)	1450.62 ^c	1479.47 ^c	1550.47 ^d	1333.01 ^b	1153.27 ^a
Feed (g/animal)	1204.96 ^a	1563.40 ^b	3957.31 ^d	4004.54 ^d	3240.41 ^c
Lambs (R)	2000.00	2000.00	2000.00	2000.00	2000.00
Abattoir charges	42.00	42.00	42.00	42.00	42.00
Transport costs (R/Km)	652.25	652.25	652.25	652.25	652.25
Labour costs (R/hour)	250.45	250.45	250.45	250.45	250.45
Total variable costs	3899.21 ^a	4257.65 ^b	6651.56 ^d	6698.79 ^d	5934.66 ^c
Gross margin ®	2448.59 ^a	2778.18 ^b	5101.08 ^d	5365.77 ^d	4781.38 ^c

3.6.6 Economic Evaluation

The gross margin (GM) analysis of the diets presented in Table 3.9 indicated that the diets affected the total carcass income, gross income, total variable costs (TVC) and gross margins. Total carcass income and gross income increased ($P < 0.05$) with the inclusion of KMOC up to 50% and declined thereafter. The lambs fed the 50%KMOC diet has the highest carcass income and gross income followed by those fed the 25%KMOC diets. Nevertheless the total variable costs appeared to increase with increasing levels of the KMOC in diets, with 75% KMOC being the highest (R6698.79) followed by those fed the 50%KMOC diet with 0% KMOC diet having the lowest (R3899.21). However, the high TVC in the lambs fed the 50%KMOC diet were offset by the high gross margin (R5101.08 together with the 75% KMOC diet.

3.7 Discussion

3.7.1 *In sacco* ruminal protein disappearance

Chemical analysis in combination with *in sacco* degradability and protein efficiency ratio can aid in the preliminary evaluation of the value of different protein sources. The observed differences in ruminal degradation among the different protein sources may be associated largely to the variability in chemical composition (Agbagla-Dohnani et al., 2001). In the current study, the protein content of the Kalahari melon cake was lower than that of soybean meal while the fibre content was double that of soybean meal. This could have influenced the rate of ruminal degradation of the Kalahari melon cake when compared to the soy bean meal. Difference in *in sacco* degradability among various protein sources could have practical implication on diet formulation due to the close associations between *in sacco* degradability and voluntary feed intake and digestibility and hence should always be considered in diet formulations for ruminants (Kibon and Ørskov, 1993, Tolera and Sundstøl, 2001).

3.7.2. *In sacco* ruminal dry matter degradability

Lack of differences in degradation parameters and degradation kinetics of KMC in the current study could be an indication that irradiation doses were not sufficient to cause changes in chemical and physical properties of the canola meal. Gamma irradiation at all doses had no significant effect ($P < 0.05$) on the soluble “a” fraction of the meal. Moradi *et al.* (2015) reported an increase in the “a” and “b” fraction of pistachio by-product while others reported a decrease in the “a” fraction and increase in the “b” fraction in cotton seed meal (Sadeghi & Shawrang, 2007), canola meal (Sadeghi & Shawrang, 2006) and sunflower meal (Ghanbari *et al.*, 2015).

Increase in the “a” fraction found in this study could be ascribed to decreased NDF content of irradiated CM (Moradi *et al.*, 2015). The high proportion of soluble carbohydrates in CM can lead to a faster fermentation (Van soest, 1982). Electron beam at doses of 25, 50 and 75 kGy had no effect on the rate of degradation of the slowly degradable fraction “c” on sunflower meal as in this study (Ghanbari *et al.*, 2015).

Irradiation of canola meal did not affect the dry matter potential degradability (a+b) as reported in other studies (Moradi *et al.*, 2015; Taghinejad *et al.*, 2010). This could be due to the lower doses used in this study, which ranged from 15 to 90 kGy. Effective degradability of dry matter in this study were higher than those obtained for cotton seed (Ebrahimi-Mahmoudabad & Taghinejad-Roudbaneh, 2011; Taghinejad-Roudbaneh *et al.*, 2016) but lower than those reported for soybean and canola seed (Ebrahimi-Mahmoudabad & Taghinejad-Roudbaneh, 2010; Taghinejad *et al.*, 2009b). The dry matter effective degradability of canola meal irradiated at 15, 30 and 45 kGy was 637, 630 and 603 g/kg DM, respectively (Taghinejad-Roudbaneh *et al.*, 2010). These studies reported a decrease in effective degradability from the control as a result of irradiation.

3.7.3 *In vitro* ruminal nitrogen degradability

Although irradiation in this study showed no effect on ruminal nitrogen degradability of canola meal, it was expected that irradiation would reduce N degradability because irradiation produced oxygen radicals that cleave the disulfide bonds and crosslinks involved in secondary and tertiary protein structure (Taghinejad-Roudbaneh *et al.*, 2010). This leads to unfolding of the protein structure, the non-polar groups are exposed and the surface hydrophobicity of protein are increased thus leading to high molecular weight aggregates (Lee *et al.*, 2005) due to electrostatic forces, inter-protein cross-links and formation of disulfide bonds (Afify *et al.*, 2011; Guan *et al.*, 2006; Gaber, 2005). This is a favourable condition for protein molecule to aggregate, coagulate and precipitate thereby reducing crude protein degradability (Ebrahimi *et al.*, 2009). Finding of this study indicated that irradiation doses used were not high enough to denature the protein of CM but however increased its solubility. Upon irradiation, proteins unfold through deamination and thereby increasing the solubility of a protein molecule (Dogbevi *et al.*, 2000). During the process of deamination, protein solubility is increased as a result of the conversion of an amide group into the acid group which eventually changes the status of the protein into water binding molecule ((Shih & Kalmar, 1987). Similarly, defatted sesame seeds were gamma irradiated at the doses of 0.5, 1.0, 1.5 and 2.0 kGy and protein solubility was increased, which was reported to be at maximum at a dose of 1.0 kGy (Hassen

et al., 2018). Electron beam irradiation at 63 kGy increased ruminal degradability of soybean (Akbarian *et al.*, 2014). Irradiation of sunflower meal and cottonseed meal at 25, 50 and 75 kGy showed no effect on potential nitrogen degradability and the degradation rate of the “b” fraction (Ghanbari *et al.*, 2015; 2012) as is the case in the current study. In their studies, irradiation decreased both the “a” fraction and ED while increasing the “b” fraction. A low dose of 15 kGy has been reported (Taghinejad *et al.*, 2009b) to have no effect on the “a” fraction and “b” fraction in soybean meal but for canola meal treatment with 30 to 45 kGy decreased the “a” fraction while increasing the “b” fraction (Taghinejad *et al.*, 2010; 2009a). For ruminant animals, solubility of nitrogen is significant as it renders nitrogen more available to ruminal microbial activities and metabolism (Van Soest, 1994). Nitrogen solubility can be reduced due to denaturation of protein (Abu *et al.*, 2006; Lacroix *et al.*, 2002) as a result of high irradiation doses (Lee *et al.*, 2005). Lack of difference in CP degradability of this study corresponds with the lack of DM degradability of CM. It then shows that doses used in this study were not high enough to bring about changes in the protein structure of CM.

3.7.4 Growth performance and feed intake

The current study was conducted to evaluate the potential of KMOC as an alternative protein source on the growth performance of lambs. Generally, there is a lack of information on the effects on the growth performance of lambs in relation to feeding of Kalahari melon. From the results, the lambs fed the 50% KMOC diet performed better than the other treatments in terms of all the growth performance parameters. The 50% KMOC-fed lambs had higher values in terms of FW, total BWG, ADFI and ADG albeit a higher FCR compared to the control. This is contrary to the findings by Heddia *et al.* (2018) where lambs fed graded levels of Watermelon Seedcake (WMSC) showed that the growth parameters were only higher in lambs fed 10% of WMSC diets compared to control.

The disparities between the results of the study can be explained by the fact that KMOC contains high levels of some desirable secondary plant metabolites such as flavonoids which could have increased the digestion dynamics and assimilation of nutrients in the gut resulting in improved performances (Correddu *et al.*, 2020). Moreover, some of the secondary plant metabolites have protective characteristics on the protein and hence could have enabled the escape of both the SBM and KMOC from degradation in the rumen resulting in increased bypass protein at the post-ruminal sites (Formato *et al.*, 2022). Nonetheless, high inclusion levels of KMOC in the diets suppressed all the growth parameters in lambs as reflected by the

lower values obtained in lambs fed both the 75% KMOC and 100% KMOC of FW,BWG & ADFI in both diets respectively.

Kalahari melon contains high fibre content and some secondary plant metabolites which, at higher levels, can suppress nutrient utilization leading to poor digestibility and growth performance. Lower inclusion levels of KMOC up to 50% can therefore be recommended in lambs' diets. In addition, strategies are being put in place to treat ANFs to reduce the effects of the high fibre content while increasing their utilisation of feed if the cake is to be used at higher levels (Alagbe, 2018). From the study, it is evident from the results that lambs fed 100% KMOC, consumed less feed as compared to other treatment groups. Unpalatability and unpleasant smell of KMOC might also be contributing factors to reduced feed intake. On cumulative body weight gains, the 50% KMOC-fed lambs showed a better growth performance from week 1 onward. The body condition index were nonetheless, different across the treatments which was highest in 100% KMOC (17.63) followed by 25%KMOC (16.34) and lowest in control (8.26).

3.7.5 Protein utilization and growth efficiency

Findings from the current study indicate that protein utilization efficiency and growth efficiency were significantly improved when KMOC was included in the diet of lambs. As with the growth performance parameters, the protein utilisation efficiency parameters also increased with the inclusion of graded levels of KMOC in diets but declined at higher levels. PC, PER, SGR and GE were all observed to be higher in lambs fed the 50% KMOC diet. While the Kalahari melon cake is characterized by comparatively lower protein content than the SBM, the presence of flavonoids and other polyphenols could have increased protein utilisation efficiency by increasing the bypass protein as explained earlier (Formato *et al.*, 2022). Protein efficiency ratio (PER) is the easiest method of assessing the quality of proteins.

Protein efficiency ratios were found to lie within the 1.2–2.4 range for many plant proteins (including pea flour, soy protein and beans) (Boye *et al.*, 2012). The PER of all the KM-based diets were observed to be below the expected range (Boye *et al.*, 2012) and it might have possibly affected the utilization of the diets. The decrease in PER with increasing levels of KMOC can be a result of high fibre content and secondary plant metabolites in KMOC that can ultimately affect protein quality (Kurpad, 2013). From the results, the PER of KMOC was lower (1.00 ± 0.11) than that of the SBM (1.23 ± 0.11) as anticipated. Nevertheless, it is common knowledge that protein, although important, is not the major limiting nutrient in the diets of

fattening lambs. Energy is the major component and hence the adequate energy supply will result in efficient consumption of the available protein through the use of rumen and resultant microbial protein even if it is of moderate quality.

3.7.6 Haematology parameters

Haematological parameters are used as important tools in the assessment of the health aspects of livestock (Disetlhe *et al.*, 2018). From the study, most of the parameters were within the expected ranges, especially the major indicator of the general health of the lambs (Chineke *et al.*, 2006; Mahieu *et al.*, 2007; Afolabi *et al.*, 2010; Addass, 2012). Blood parameters such as mean capsular volume (MCV), mean capsular haemoglobin (MCH) and mean capsular haemoglobin concentration (MCHC) are also valuable in monitoring feed toxicity and feed constituents that affect blood in lambs (Oyawoye & Ogunkunle, 2004; Awodi *et al.*, 2005) and all this was observed to be within the normal range. Mean capsular volume (MCV) appeared lowest and MCH higher in the 50% inclusion though they stayed constant within other levels.

Njidda *et al.* (2013) reported that MCH and MCHC are used in diagnosing anaemic conditions. Red blood cells were similar throughout the inclusion levels. White blood cells (WBC), increased as inclusion levels of KM increased though they were still within the physiological range. When WBC falls within the normal range it means that the feeding patterns did not affect the immune system (Ameen *et al.*, 2007). The neutrophils decreased as inclusion levels increased and lymphocytes increased in the 50% and control inclusion levels. The result also implies that a decrease in neutrophils is associated with an increase in lymphocytes and vice versa (Lazzaro & Razzaque, 2011). Monocytes were significantly affected within inclusion levels, with 0%KMOC being the highest (0.38 ± 0.09). The Haemoglobin (Hb) values obtained in this study of between 12.60 and 13.75 indicated the absence of microcytic and hypochromic anaemia occasioned by iron deficiency or its improper utilization for the formation of Hb.

The eosinophils appeared lowest (0.08 ± 0.06) in the 100% inclusion as compared to other levels. The platelets decreased as inclusion levels increased, which then suggests that the level of immunity increased as well. The hepatosomatic index (HSI) is the weight of the liver expressed as a percentage of total body weight (also known as the liver somatic index). Dietary changes, including the inclusion of KMOC with higher levels of some secondary plant metabolites compared to SBM, induced an increase in liver volume as it deals with increased bioactive compounds (Quentel & Obach 1992) and possible alterations to erythropoietic and leucopoietic tissues (Lizama *et al.*, 2006).

Nevertheless, this was not observed in the current study and the inclusion of the cake at higher levels resulted in lower liver weight consistent with the lower slaughter weights and carcass weights observed in lambs fed higher levels of KMOC in diets. Spleen size is an important diagnostic tool that indicates hematopoietic and leucopoietic functions thus serving as an immune system organ. In the current study, the SSI was not influenced by diet. Nevertheless, the relationship between splenic mass and dietary alterations in animals has not been studied too well and needs extensive investigations (de Bellocq *et al.*, 2007).

3.7.7 Serum biochemistry parameters

According to Ali *et al.* (2012), reference serum biochemistry values provide useful information on the condition of livestock. Some of the serum blood parameters were affected by the inclusion levels of KMOC. Serum uric acid levels indicate recent ruminal metabolism as they increase according to feed intake and nutritional quality of the feed. These factors also affect the number of microorganisms in the rumen. Blood urea and creatinine levels are also indicators of normal kidney functioning and these were within the normal ranges. Nevertheless, SDMA is regarded as more reliable than creatinine as an indicator of kidney function because it is not influenced by confounding conditions (Hall *et al.*, 2014; Hall *et al.*, 2015).

Most parameters of the serum were within the expected reference ranges except for ALT and lipase. With regards to digestive enzymes, diet significantly affects lipase. Generally, high levels of lipase and amylase result in reduced hydrolysis of carbohydrates and lipids (IDEXX, 2021). Amylase and lipase are used to diagnose pancreatic disease (IDEXX, 2021). Generally, the increasing levels of dietary KMOC in the diets of lambs tended to decrease the ALT contents. Liver enzymes (ALT, ALKP and GGP) are important indicators of toxicity and liver functioning (Hall *et al.*, 2014; Hall *et al.*, 2015). These were, however, not influenced by the inclusion of KMOC in the diets. Glucose and calcium were within the reference range and constant with all inclusion levels. Phosphorus was highest (2.91 ± 0.25) in the 100% inclusion level; GGT was highest (81.40 ± 87.84) at 50%, 75% (56.40 ± 13.92) and 100%. (79.66 ± 12.01).

3.7.8 Economic evaluation

The improvements of the total income with the inclusion of KMOC in diets up to 50% were apparent. These results accentuate that partial or complete replacement of conventional protein sources in animal feeding may reduce pressure on conventional energy and protein feed ingredients (Okendo *et al.*, 2006). Feeding lambs on 50% KMOC and 75% KMOC resulted in

similar GM's while 0% KMOC led to the lowest gross margin costs. Therefore, the gross margins analysis done in the current study can provide support to choices regarding the type of protein source to use in diets and the optimum inclusions and whether to invest in such protein sources which are not always straightforward as reported elsewhere (Chingala *et al.*, 2019) (Pacheco *et al.*, 2017).

3.8 Conclusion

From the results obtained in this study, the inclusion of KMOC can replace SBM in diets of lambs at levels below 50% without compromising growth performance, nutrient utilisation and the health status of lambs. The present study showed that the inclusion of KMOC to 50% significantly showed better growth and protein utilisation efficiency. The higher ADG, ADFI reduced FCR in diet and the improved protein utilization efficiency and blood metabolites are all indicative of the potential of KMOC as an effective alternative protein source for partially replacing SBM. Most haematological and serum parameters fell within the required ranges and suggest a well-developed immune system and healthy animals. There were also no signs of physiological stress that animals underwent throughout the study; Therefore, KMOC should be given adequate consideration in the diet of ruminant animals, especially lambs. The higher the inclusion levels of KMOC the higher the gross margin and this proves to be cost-effective to replace SBM with KMOC. Although GM seems to be highest (R5365.77) in 75% KMOC, the preferred inclusion would be the 50% KMOC (R5101.08) inclusion due to its low TVC (R6651.56 as compared to 75% KMOC (R6698.79) and this is due to the highest amount (R4000.54) consumed.

3.9 References

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CHAPTER 4

EFFECT OF KALAHARI MELON OILCAKE INCLUSION LEVELS ON CARCASS CHARACTERISTICS, MEAT QUALITY AND INTERNAL ORGANS OF LAMBS

ABSTRACT

The current study was conducted to determine the effects of the inclusion level of KMOC in diets on carcass characteristics, meat quality parameters and internal organ development of lambs. Forty Meatmaster lambs with an average initial body weight of $27 \pm 1,04$ kg were used.

Lambs were randomly assigned to five dietary treatments in a completely randomized design and fed in individual pens for 54 days. Animals were allocated five dietary treatment groups with inclusion levels of KMOC: 0% (control), 25%, 50%, 75%, and 100%. Each treatment was replicated 8 times. The results indicate that diet significantly affected dressing %, HCW and CCW. Lambs fed the control diet had the highest HCW (18.02 kg $\pm$ 1.10). The CCW was observed to be high in lambs fed 50% KMOC (16.15 kg $\pm$ 0.99) as expected. The lambs fed higher levels of KMOC had the lowest values on carcass parameters except Chilling loss. Nevertheless, the lambs fed 25% of KMOC in diets marginally had higher dressing percentages (50.30 $\pm$ 2.23) although it was significantly different and declined as inclusion %'s increased. The carcass length was high on lambs fed 50% KMOC (70.43cm $\pm$ 2.07), followed by those fed a 25% KMOC (67.06cm $\pm$ 2.07). There was a significance difference on all internal organs. The lambs fed a 50% KMOC diet had the heaviest heart (155.00g $\pm$ 6.33) while lambs fed with a 100% KMOC diet had the lowest weight (116.87g $\pm$ 6.33). However, kidney weights were highest ($P < 0.05$) in lambs fed control (109.37kg $\pm$ 4.46) as compared with all other treatments. The spleen and lungs were significant higher (69.37kg $\pm$ 5.74 and 380kg $\pm$ 23.55) respectively in 50% KMOC. Diet significantly affected ($P < 0.05$) meat colour coordinates, water holding capacity, cooking loss, dripping loss and meat shear force in response to incremental levels of KMOC. Meat temperature was higher ($P < 0.05$) for carcasses fed 75% KMOC. The highest meat colour coordinates were observed in lambs fed 100% KMOC diets with L^* (34.15 $\pm$ 0.78) and b^* (2.87 $\pm$ 0.44). The highest a^* (13.24 $\pm$ 0.52) was observed in lambs fed 75% KMOC. In terms of WHC % the lambs fed 75%, KMOC had the lowest value (9.76% $\pm$ 1.76). The highest value observed was in lambs fed 25% KMOC (12.87% $\pm$ 1.76). The dripping loss was observed to be higher in the lambs fed 100% KMOC (36.83kg $\pm$ 2.98). The lowest cooking loss was observed in lambs fed 50% KMOC (32.08 $\pm$ 2.98), while the highest was observed in lambs fed 100% KMOC (36.83kg $\pm$ 2.98). The lambs fed 75% KMOC had the highest ($P < 0.05$) and shear force texture (16.50N). The lowest meat texture ($P > 0.05$) was observed from diets containing 100% KMOC (12.19 N). Kalahari melon oilcake meal can therefore replace soyabean meal in fattening lamb diets resulting in good quality meat that is highly acceptable by consumers.

Keywords: Kalahari melon, carcass, meat quality, visceral organs, lambs, protein, efficacy

4.1 Introduction

The world population is growing at an exponential rate and is expected to reach 9.7 billion by 2050. Therefore, feeding the fast-growing population while enhancing their health are top priorities. The human body consists of 15-17% protein (Campos *et al.*, 2019) and much of that protein is obtained from animal-based products, such as meat, fish, egg and milk. The global annual meat consumption is expected to reach 373 million metric tons by 2030 and 465 million metric tons by 2050. This therefore requires regular assessment of animal production and sustainability. Consumers nowadays are increasingly demanding safe and quality food from animal products, especially meat. Meat is a good source of protein, fat, vitamin B, and minerals in human diets (Martins *et al.*, 2018). However, there has been a concern about saturated fatty acids from meat that are purported to predispose cardiovascular diseases in humans. According to Chiofalo *et al.* (2020), rumen microbes hydrogenate dietary unsaturated fatty acids resulting in the production of saturated fatty acids that are absorbed and deposited in animal tissues.

Currently, the growing meat consumption in the world, particularly in emerging countries including South Africa is not being matched by the growth of the local livestock production. This is causing imbalances (lower self-sufficiency levels in meat and meat products) in SA and the world over. The lower self-sufficiency levels, combined with the growing consumption are also the main reasons for the increased prices for livestock and meat worldwide. Moreover, the increasing prices of livestock feeds particularly protein sources are exacerbating the problems of high livestock and meat prices (Smit *et al.*, 2014). The main challenge faced by livestock farmers to produce a consistent supply of quality animal products is the inadequate supply of required nutrients due to seasonal fluctuation of forages from natural pastures. As a result, some farmers, as stated by Yagoubi *et al.* (2018), end up feeding their animals with low-quality forages or allowing them to graze on degraded natural pastures, especially during the dry season. Such animals will grow slowly and take a longer period to reach market weight. Therefore, the provision of protein or energy supplements will promote better utilisation of poor-quality roughages by ruminants and the synthesis of microbial proteins.

Dietary alterations can influence meat quality among other factors. In most sheep feeding systems, SBM is the most popular protein supplement and hence requires consistent supply (Cromwell, 2000). However, the shortages of SBM in SA are associated with high prices which necessitate research for alternative protein sources. The use of Kalahari melon in the ruminants' diets is an effective way of reducing overdependence on the scarce and expensive SBM. Due to differences in chemical composition, it may be expected that new protein sources such as

the KMOC may influence digestion and muscle metabolism subsequently improving the quality of meat (Borys *et al.*, 2006). The bioactive compounds contained in the cake may influence digestion dynamics and nutrient assimilation which can ultimately influence muscle metabolism. For example, the phenolic compounds and flavonoids contained in the cake may influence ruminal microbial composition favouring the diversity of microbes responsible for increased volatile fatty acids (VFAs) which are key precursors for intramuscular fat in meat (Correddu *et al.*, 2020).

These bioactive compounds may also influence energy metabolism that may ultimately affect muscle postmortem glycolysis and the conversion of muscle to meat. This study was therefore conducted to determine the effect of feeding different levels of KMOC based diets on carcass characteristics and meat quality of Meatmaster lambs.

4.2 Material and Methods

4.2.1 Study site, feed source and animal management.

The description of the study area and dietary treatments are explained in Section 3.2.1-3.2.3 whilst Section 3.2.4 explains the experimental design and animal management.

4.2.2. Slaughter procedures of the lambs

At the end of the feeding trial on day 54, the animals were subjected to overnight fasting and weighed to obtain the empty live weight considered as the slaughter weight. The lambs were then transported to the Burmansdrift abattoirs where they were humanely slaughtered according to the SA Meat Safety Act (SAMIC, 2016). Briefly, the lambs were first rested in the lairage. On slaughter, the animals were electrically stunned and bled by immediately cutting the jugular vein while being held upside down for maximum blood drainage. The animals were then skinned, eviscerated and cleaned. Carcass and non-carcass components were weighed immediately after slaughter. The heart, liver, spleen, kidneys and lungs were weighed together and designated as pluck. The non-carcass components such as the head, skin and feet were designated as offal. The weight of digestive contents (gut fills) was computed as the difference between a full and empty digestive tract (rumen and intestines). Visceral fats were removed and weighed.

4.2.3 Carcass traits and internal organs

Immediately after slaughter, carcasses were weighed to obtain hot carcass weight (HCW). The whole carcasses were then chilled at 4 °C for 24 hours after which, the carcasses were reweighed and recorded for cold carcass weight. Each carcass was split longitudinally into left and right halves and carcass length was measured subsequently. Carcass characteristic parameters were taken and calculated and or measured accordingly: Hot carcass weight (kg), cold carcass weight (kg), chilling loss (%), dressing percentage (%), carcass fat, fat (%), Pluck-heart, liver, kidney and lungs (% of carcass weight), viscera fat (% of total trimmable fat),

The dressing percentage was determined using the following equation:

$$\text{Dressing \%} = \frac{\text{Carcass weight}}{\text{slaughter weight}} \times 100$$

4.2.4 Meat pH and Temperature Measurements

Meat pH was measured on the *Longissimus dorsi* muscle. The measure meat pH and temperature were measured at 0 hours, 3 hours and 24 hours after slaughter. A pH meter (Crison pH 25, Crison instruments, S.A., Alella, Spain) was used for measurements. The carcasses were identified in the slaughter sequence for pH_u measurements.

4.2.5 Meat colour measurements

A Minolta colour guide (Spectrophotometer CM 2500c, Konika Minolta, Osaka, Japan) was used to determine the meat colour. Measurements were evaluated according to the following guidelines of the colour of the meat and were used CIELAB system where (L* = Lightness, a* = Redness and b* = Yellowness) measured at 0 Hours, 3Hours 45 and 24 hours post-slaughter.

4.2.6 Meat drip loss

The meat samples weighing 2 grams were obtained, hooked and suspended using wire steel in plastic bottles. The bottles were sealed properly with the samples avoiding the sides of the bottles. Bottles were subsequently placed in a cold room at 4 °C for 72 hours. The meat samples were reweighed to obtain weight after drip. Meat drip loss was calculated as follows:

$$\text{Drip loss \%} = \frac{\text{Weight before storage} - \text{Weight after storage}}{\text{Weight before storage}} \times 100$$

4.2.7 Meat Cooking Loss

The meat sample was evaluated for cooking loss percentage. The samples of 5 - 6 g were placed into sealed plastic bags and steam-cooked in a water bath at 80 °C for 40 minutes. Thereafter, cooled down at room temperature for 30 minutes and re-weighed to determine the weight after cooking. The cooking loss was calculated based on the difference between the weight of raw meat and cooked meat using the following equation:

$$\text{Cooking loss \%} = \frac{\text{Weight of raw meat} - \text{Weight after cooking}}{\text{Weight of raw meat}} \times 100$$

4.2.8 Water Holding Capacity%

The water holding capacity was determined using the filter-paper press method. A meat sample of freshly cut slices (5-6 grams) was placed between filter papers and left under pressure (60 kg pressure) for 5 minutes. The sample was then weighed and the water holding capacity was determined.

$$\text{WHC \%} = \frac{\text{Initial Weight} - \text{Weight after pressing}}{\text{Initial weight}} \times 100$$

4.2.9 Meat tenderness

Meat tenderness (shear force measurements) was determined using a Warner Bratzler shear blade mounted on a Texture analyser (TA XT plus, Stable Micro Systems, Surrey, UK). Following cooking, a sub-sample of specified core diameter was cored parallel to the grain of the meat and sheared perpendicular to the shear blade. The values reported in Newton (N) represented the average of the peak force measurements of each sample of 5 -6g.

4.3 Statistical Analysis

Data on carcass characteristics, internal organs and meat quality was analysed using the general linear models of SAS (2010). PDIFF option of SAS was used for the separation of means, the level of significance is set at (P<0.05).

$$Y_{ij} = \mu + T_i + \varepsilon_{ij}$$

Y_{ijk} = Response variable (carcass characteristics, meat quality and internal organ)

μ = overall mean,

T_i = effect of diet levels

ε_{ij} = random residual error

4.4 Results

4.4.1 Carcass characteristics

Table 4.1 shows the effect of dietary KMOC inclusion levels on the carcass characteristics of lambs. The results indicated that diet significantly affected all carcass characteristics apart from the dressing percentage. The lambs fed the 50% KMOC diet had the highest slaughter weights and the highest body length. On the contrary, the lambs fed the control diet had the highest HCW (18.02 kg $\pm$ 1.10). Cold carcass weight was observed to be higher in lambs fed 50% KMOC (16.15 kg $\pm$ 0.99) as expected. The chilling loss was highest in lambs fed the control diet while lowest in the lambs fed the 50% KMOC diet. The lambs fed with the 100% KMOC had the lowest values for all carcass characteristics. Nevertheless, the lambs fed 25% of KMOC in diets marginally had higher dressing percentages although not significantly different from the others. The carcass length was high on lambs fed 50% (70.43 cm $\pm$ 2.07). The lambs had a fat score of 2 and all carcass conformations were graded A1 and A2. This kind of fat is highly accepted and indicates that both KMOC meal and SBM can yield carcasses with the same fat content.

4.4.2 Internal organs

Table 4.2 reflects the effect of dietary KMOC inclusion levels on weight of the internal organs of lambs. The results indicated that there was no significant difference in all internal organs apart from the spleen, the liver, the lungs and the kidneys. The lambs fed a 50% KMOC diet had the heaviest heart (155.00 g $\pm$ 6.33) while lambs fed with a 100% KMOC diet had the lowest heart weight (116.87 g $\pm$ 6.33). However, liver and kidney weights were highest ($P < 0.05$) in lambs fed the control diet as compared with all other treatments. The spleen and lungs weight

was notably highest in lambs fed with a 50% KMOC diet, while those fed the 100% KMOC had the lowest. The heart was the only parameter influenced by diets.

4.4.3 Meat quality

The results of KMOC inclusion in the diet on meat quality measurements of lambs are presented in Table 4.3. From the results, dietary inclusion of KMOC had a significant effect ($P < 0.05$) on meat colour coordinates, water holding capacity, cooking loss, dripping loss and meat shear force. Meat ultimate pH was significantly higher ($P < 0.05$) in lambs fed 75% KMOC followed by those fed the 50% KMOC diet. The lambs fed the 25% KMOC diet had the lowest (9.68 ± 0.46) pH. The meat colour coordinates for lightness (L^*) appeared to decline with the inclusion of the KMOC in the diet while the redness (a^*) increased. The lambs fed the control and 100% KMOC diets had higher values (34.02 ± 0.78 and 34.15 ± 0.78) for L^* . The value for a^* was highest (13.24 ± 0.52) in lambs fed a 75% KMOC diet. The yellowness (b^*) was highest (2.87 ± 0.44) in the 100% KMOC diets. In terms of WHC % the lambs fed 75% KMOC had the lowest value ($9.76\% \pm 1.76$). The highest WHC observed was in lambs fed 25% KMOC ($12.87\% \pm 1.76$). The dripping loss was observed to be highest in the lambs fed 100% KMOC (36.83 ± 2.98). The lowest cooking loss was observed in lambs fed 50% KMOC (32.08 ± 2.98), while the highest was observed in lambs fed 100% KMOC (36.83 ± 2.98). The lambs fed 75% KMOC had the highest ($P < 0.05$) shear force texture (16.50N). Nonetheless, the lowest meat texture ($P > 0.05$) was observed from diets containing 100% KMOC (12.19 N).

Table 4.1: The effect of replacing soybean meal with Kalahari melon oilcake on carcass characteristics of lambs.

Parameters	Dietary treatments					SEM
	Control	25% KMOC	50% KMOC	75% KMOC	100% KMOC	
Slaughter weight (kg/lamb)	35.87 ^{ab}	35.75 ^{ab}	37.37 ^b	33.37 ^a	31.37 ^a	1.44
Hot Carcass Weight (kg)	18.02 ^d	17.17 ^c	16.65 ^c	14.30 ^b	12.75 ^a	1.10
Cold Carcass Weight (kg)	15.02 ^c	15.35 ^c	16.15 ^d	13.70 ^b	11.67 ^a	0.99
Chilling loss %	0.30 ^c	1.82 ^b	0.50 ^a	0.60 ^a	1.08 ^b	0.02
Dressing %	50.01	50.30	44.68	44.56	43.80	2.23
Body Length (cm)	64.68	67.06	70.43	66.31	64.18	2.07

Control = SBM; 25% Kalahari melon oilcake (25% KMOC); 50% Kalahari melon oilcake (50% KMOC); 75% Kalahari melon oilcake (75% KMOC); 100% Kalahari melon oilcake (100% KMOC). SEM = standard error of the mean

Table 4.2: The effect of replacing soybean meal with Kalahari melon oilcake on the internal organs of lambs.

Parameters	Dietary treatments					SEM
	Control	25% KMOC	50% KMOC	75% KMOC	100% KMOC	
Heart (g)	126.87 ^b	117.50 ^a	155.00 ^c	122.50 ^b	116.87 ^a	6.33
Liver (g)	601.25 ^c	570.00 ^b	558.75 ^b	486.87 ^b	390.00 ^a	31.45
Spleen (g)	64.12	56.87	69.37	67.25	53.75	5.74
Kidney (g)	109.37 ^b	89.37 ^a	105.50 ^b	85.00 ^a	73.75 ^a	4.64
Lungs (g)	347.12	337.50	380.00	326.25	299.37	23.55

Control = SBM; 25% Kalahari melon oilcake (25% KMOC); 50% Kalahari melon oilcake (50% KMOC); 75% Kalahari melon oilcake (75% KMOC); 100% Kalahari melon oilcake (100% KMOC). SEM = standard error of the mean,

Table 4.3: The effect of replacing soybean meal with Kalahari melon oilcake on meat quality measurements of lambs.

Parameters	Dietary treatments				
	Control	25% KMOC	50% KMOC	75% KMOC	100% KMOC
Ultimate Temp ($^{\circ}\text{C}$)	10.38 $\pm$ 0.46	9.68 $\pm$ 0.46	10.74 $\pm$ 0.49	10.75 $\pm$ 0.46	10.00 $\pm$ 0.46
Ultimate pH	5.67 $\pm$ 0.04	5.66 $\pm$ 0.04	5.73 $\pm$ 0.05	5.79 $\pm$ 0.04	5.82 $\pm$ 0.04
<i>Meat colour</i>					
L*	34.02 $\pm$ 0.78 ^b	33.87 $\pm$ 0.78 ^a	33.69 $\pm$ 0.84 ^a	33.60 $\pm$ 0.78 ^a	34.15 $\pm$ 0.78 ^b
a*	11.44 $\pm$ 0.52 ^b	12.17 $\pm$ 0.52 ^b	12.27 $\pm$ 0.55 ^b	13.24 $\pm$ 0.52 ^c	12.88 $\pm$ 0.52 ^b
b*	1.97 $\pm$ 0.44	2.63 $\pm$ 0.44	1.97 $\pm$ 0.47	2.44 $\pm$ 0.44	2.87 $\pm$ 0.44
Water holding capacity (%)	9.78 $\pm$ 1.76 ^a	12.87 $\pm$ 1.76 ^b	9.90 $\pm$ 1.76 ^a	9.76 $\pm$ 1.76 ^a	9.96 $\pm$ 1.76 ^a
Drip loss %	33.63 $\pm$ 2.98 ^a	33.29 $\pm$ 2.98 ^a	32.08 $\pm$ 2.98 ^a	33.26 $\pm$ 2.98 ^a	36.83 $\pm$ 2.98 ^b
Cooking loss (%)	33.63 $\pm$ 2.98 ^b	33.29 $\pm$ 2.98 ^b	32.08 $\pm$ 2.98 ^a	33.26 $\pm$ 2.98 ^b	36.83 $\pm$ 2.98 ^c
Shear force (N)	14.12 $\pm$ 1.41 ^b	14.04 $\pm$ 1.41 ^b	14.69 $\pm$ 1.41 ^b	16.50 $\pm$ 1.41 ^c	12.19 $\pm$ 1.41 ^a

Control = SBM; 25% Kalahari melon oilcake (25% KMOC); 50% Kalahari melon oilcake (50% KMOC); 75% Kalahari melon oilcake (75% KMOC); 100% Kalahari melon oilcake (100% KMOC); L* = lightness, a* = redness, b* = yellowness.

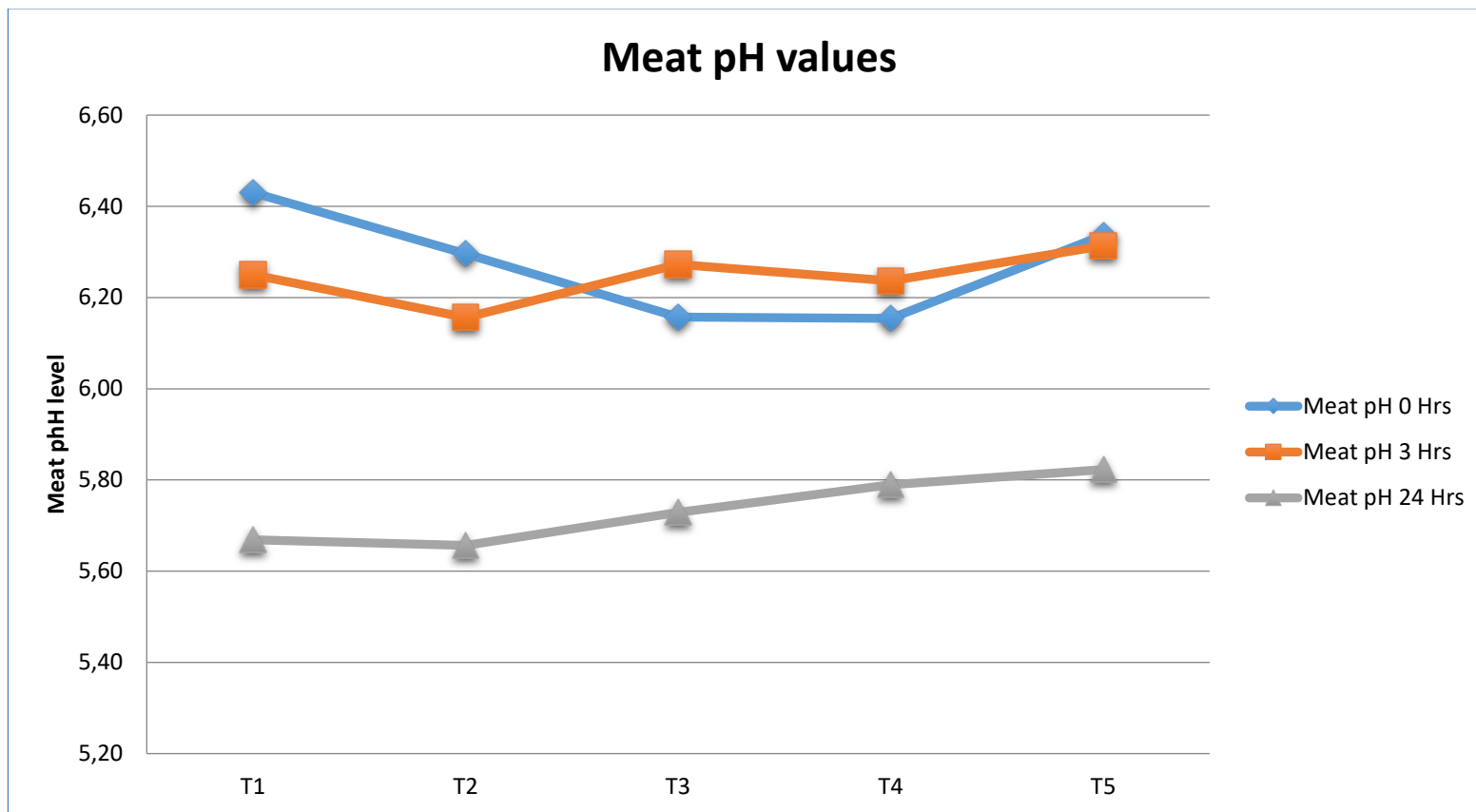


Figure 4.1 Effect of Kalahari melon oilcake inclusion levels on meat pH of lambs

4.5 Discussion

4.5.1 Carcass Characteristics

According to Assan (2020), nutrition plays a pivotal role in promoting ideal carcass characteristics and meat quality attributes. Some dietary perturbations have been observed to desirably influence carcass composition and meat quality. The findings from the study showed that diet significantly affected all carcass parameters. Slaughter (final weight) is an important variable as it determines both HCW and CCW. The slaughter weights of the lambs fed 50% KMOC were higher (37.37kg) than all other treatments. This is consistent with the findings in growth performance in Chapter 3 which showed higher growth rates and body weight gain in lambs fed the 50% KMOC. Inevitably, both the HCW and CCW were also influenced by the diet. The low chilling losses observed in diets containing 50% KMOC could be beneficial in reducing the loss in carcass weights that would influence the income per carcass. The lambs had a fat score of 2 and all carcass conformations were graded A1 and A2.

This kind of fat is highly accepted and indicates that both KMOC meal and SBM can yield carcasses with the same fat content. According to Clerk *et al.* (2003), carcass conformation may be positively related to intramuscular fat. Kerry *et al.* (2002) indicated that the presence of fat between 1-3% may lead to improved culinary characteristics and palatability. Additionally, Junkuszew *et al.* (2020) stated that dietitians recommend the consumption of meat low in fat and rich in n-3 and n-6 fatty acids to avoid heart-related diseases in humans. It has also been shown that since fat is an insulator; it slows down and provides insulation against severe heat-induced toughening of muscle fibres during cooking (Clark *et al.*, 2003).

4.5.2 Internal organs

From the results, a lot of similarities were observed between the control-fed lambs and those fed the 50% KMOC-fed lambs in terms of the measured internal organs. Generally, dietary compositional changes may elicit some responses in the gross histology and functions of internal organs (Atti *et al.*, 2004). However, the liver and kidneys can be affected by diet and physical activity and could be higher for animals grazing on natural pastures than the feedlots (Majdoub-Mathlouthi *et al.*, 2015). Some researchers showed that the changes in the weight of some organs especially the heart, lung, liver, spleen and kidney, are related to metabolic activity which can be affected by diet and slaughtering age (Pearson & Dutson, 1991).

4.5.3 Meat quality

The type of diet consumed by livestock affects meat quality attributes such as colour, pH and tenderness. The ultimate pH (pH_u) has a significant influence on all other meat quality traits (colour, firmness, marbling and cooking loss) (Zhang *et al.*, 2015; Disetlhe *et al.*, 2020). Muscle pH is expected to decline to 5.5 -5.9 about 12-24 hours after slaughter. This is attributed to the post-mortem muscle glycolysis resulting in the production of ATP and lactic acids under anaerobic conditions. In the current study, the ultimate pH values were all within the range of 5.5 – 5.9 although the lambs fed the 100% KMOC diet had the highest value. Meat colour is the most important factor affecting consumer acceptance, purchasing decisions and satisfaction with meat products (Muchenje *et al.*, 2009). The values for L^* seemed to decline across treatments as KMOC level increases while the a^* increased. This could be attributed to the high amounts that could have influenced the myoglobin redox reaction resulting in significant colour changes. Allan *et al.* (1993), also stated positive correlations exist between pH and meat colour. As the pH increases the lightness and yellowness values decrease (Bezerra *et al.*, 2016; Malila *et al.*, 2021). The discoveries are in concordance with the findings by Facciolongo *et al.* (2018) who reported dietary influences on the colour of meat when comparing linseed with soybean in complete diets.

The water-holding capacity of meat is a critical meat quality parameter that describes the ability of meat and meat products to retain water (Pearce *et al.*, 2011). It determines the visual acceptability of meat and also affects the amount of water loss during transportation, storage, processing and cooking which may influence income (Bertram *et al.*, 2003). There is a strong correlation between WHC, cooking loss and drip loss. Water losses during cooking procedures come from juices produced due to protein denaturation and muscle shrinkage (Kondjoyan *et al.*, 2013). The WHC, cooking loss and drip loss in this study were generally similar amongst dietary treatments apart from the lambs fed the 100% KMOC diet which had the lowest WHC and drip loss associated with the observed high meat ultimate pH observed in the treatment (Warriss, 2000). Meat shear force values were also similar among treatments apart from the 100% KMOC treatment. This may mean that the inclusion of KMOC at high levels in the diets has the effect of reducing most of the measured meat quality parameters.

4.6 Conclusion

From the results, lambs fed the 50% KMOC diet had the highest slaughter weight while those fed the control diet had the highest HCW. The chilling loss was highest (3 ± 0.02) in lambs fed the control diet while lowest (0.5 ± 0.02) in the lambs fed the 50% KMOC diet. The lambs fed with the 100% KMOC had the lowest values for all carcass characteristics. Meat quality parameters were all significantly influenced by diets. The meat colour coordinates for lightness appeared to decline with the inclusion of the KMOC in the diet while the redness increased. Water holding capacity and drip loss were also poor in lambs fed the 100% KMOC diet. In the same vein, tenderness was observed to be lowest in the same treatment group. The findings of the current study indicate that Kalahari oilcake meal can partially replace soybean meal in the weaner lamb diet without any negative effect on the quality of the meat.

4.7 References

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CHAPTER 5: GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 General discussion

The objectives of the current study was to determine the possible effects of replacing soybean meal with Kalahari Melon oilcake (KMOC) in finishing diets offered to Meatmaster lambs on growth performance, haematology, meat quality characteristics, and further evaluate the economic costs.

In Chapter 3, the growth performance haematological characteristics, serum biochemistry and economic evaluations were determined. From the results, the inclusion of KMOC can replace SBM in the diets of lambs at levels below 50% without compromising growth performance, nutrient utilisation and the health status of lambs. The present study showed that the inclusion of KMOC to 50% inclusion level significantly showed better growth and protein utilisation efficiency. The higher ADG, ADFI reduced FCR in diet and improved protein utilization efficiency and blood metabolites are all indicative of the potential of KMOC as an effective alternative protein source for partially replacing SBM. Most haematological and serum parameters fell within the required ranges and suggest a well-developed immune system and healthy animals. The red blood cell count of the lambs fed 50% inclusion level were within the ranges ($9 - 15 \times 10^{12}/L$) reported for sheep (Cheesbrough, 2004; Merck Manual, 2012). The Hgb values obtained were closer to 15g/dL, indicating that lambs were well nourished particularly with regards to their protein requirements. It has been reported that when haematologic values fall within the normal ranges for lambs, it shows dietary treatments had no adverse effect on health of animals during the trial (Egbe *et al.*, 2000). There were also no signs of physiological stress that animals underwent throughout the study. Therefore, KMOC should be given adequate consideration in the diet of ruminant animals, especially lambs. From the results of the economic evaluation, lambs fed a 50% inclusion level of KMOC and made more financial returns with low input costs as compared to other treatments. This is also in support shown throughout the study that this level has been showing positive results in all parameters.

In Chapter 4 the effects of replacing SBM with different levels of KM on carcass characteristics and meat quality were determined. The lambs fed the 50% KMOC diet had the highest slaughter weights. On the contrary, the lambs fed the control diet had the highest HCW ($18.02 \text{ kg} \pm 1.10$). Cold carcass weight was observed to be higher in lambs fed 50% KMOC ($16.15 \text{ kg} \pm 0.99$) as expected. The chilling loss was highest in lambs fed the control diet while lowest in the lambs fed the 50% KMOC diet. The lambs fed with the 100% KMOC had the lowest values for all carcass characteristics. The carcass length was high on lambs fed 50% KMOC (70.43 ± 2.07), followed by those fed a control diet ($33.63 \text{ cm} \pm 2.98$). Meat had the pH of 5.7 -5.8 indicating that

the meat was juicy, tender with an intense flavour (Okrouhla *et al.*, 2012). The meat colour coordinates for lightness appeared to decline with the inclusion of the KMOC in the diet while the redness increased. Water holding capacity and drip loss were also poor in lambs fed the 100% KMOC diet. In the same vein, tenderness was observed to be lowest in the same treatment group. The findings of the current study indicate that Kalahari oilcake meal can partially replace soybean meal in the weaner lamb diet without any negative effect on the quality of the meat.

5.2 Conclusion

The replacement of soybean meal with inclusion levels of Kalahari melon oilcake did not have any negative impact on the growth performance, haematological and meat quality characteristics of lambs. It was found that the growth performance, health and meat quality of the lambs were similar when fed either SBM or KM, especially with the 50% inclusion. The inclusion of KMOC meal can also produce meat of good quality which is tender and juicy and that is highly acceptable to consumers. Findings of the current study indicate that Kalahari oilcake meal can partially replace soybean meal in the weaner lambs' diet without any negative effect on growth performance, health and the quality of the meat. The use of KMOC in lamb fattening can be a viable option to adopt, especially during periods when the cost conventional protein sources are expensive due to high demand and limited supplies.

5.3 Recommendations

Farmer and feed companies can replace SBM with KMOC up to 50% KMOC with optimum performance being achieved. Further studies need to be carried out to determine the effect of replacing soybean meal on the fatty acids and antioxidant stability of the lambs. It will also be advisable that animal science research especially on finishing lambs may include some economic components because they often neglect to focus their studies through the lens of a system by profit function. This neglect consequently fails to consider what is known as the law of diminishing returns as a principle of the economic optimum. The economic evaluation of which protein sources to use and to what levels is therefore cardinal; if alternative low cost fattening diets are to be formulated. This will require an in-depth scrutiny of all economic aspects of the diet proposed in order to produce reliable results. More dissemination of information about the use of non-conventional protein sources such as Kalahari Melon needs to be improved especially to farmers and feed companies.