

**GROWTH PERFORMANCE, MEAT QUALITY, AND HAEMATOLOGICAL
PARAMETERS IN MUTTON MERINO LAMBS: EFFECTS OF DIETARY
REPLACEMENT OF SOYABEAN MEAL WITH CANOLA CAKE**

Mpolokeng Sekali

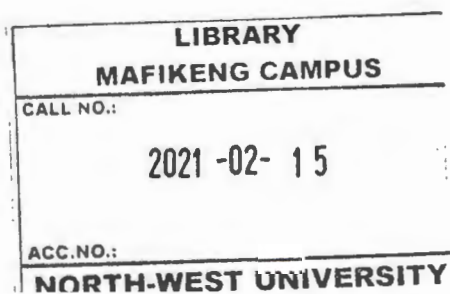
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DECLARATION

I, Mpolokeng Sekali, student number 21446490, declare that this dissertation for the degree of Master of Science in Animal Science at North-West University (Mafikeng Campus) hereby submitted, has not previously been submitted by me for a degree at this or any other university, that this is my original work in design and execution and that all material contained herein has been duly acknowledged. The work has been done under the supervision of Dr. U. Marume and Prof. V.Mlambo.

Signed:

Mpolokeng Sekali

Date:

This dissertation has been submitted with my approval as a University supervisor and would certify that the requirements for the applicable Master of Science degree rules and regulations have been fulfilled.

Signed:

Dr. U. Marume

Signed:.....

Prof V. Mlambo

Date:

ABSTRACT

The objective of this study was to determine growth performance, hematology, meat quality and sensory characteristics of lambs fed Canola (*Brassica napus*) cake as a replacement for soyabean meal (SBM). Nineteen lambs with an average body weight of $23 \text{ kg} \pm 2.64 \text{ kg}$ were used. The lambs were randomly assigned to five dietary treatments in a completely randomized design and fed in individual feeding pens for 60 days. The soya bean meal (SBM) in the control ration was replaced with Canola meal at 0% (control), 25 %, 50%, 75%, and 100% inclusion levels. There was no significant difference ($P > 0.05$) in the cumulative live weights and body weight gain of the lambs. The average daily gain (ADG) ($0.17 - 0.20 \text{ kg/day}$), average daily feed intake (ADFI) ($1.15 - 1.21 \text{ kg/day}$), feed conversion ratio (FCR) ($3.09 - 3.41$) and slaughter weight (SLW) ($33.2 - 34.7 \text{ kg}$) also showed no significant differences ($P > 0.05$) between the dietary treatments. The hematology blood count showed no significant difference in red blood cell (RBC) count ($9.54 - 12.8 \times 10^{12}/\text{L}$) and haematocrit (HCT/PCV) ($29.3 - 38.5\%$) values. The animals were slaughtered at the end of feeding trial to determine meat quality characteristics. There was no significant effect ($P > 0.05$) of dietary treatment on carcass weight (CWT) ($16.5 - 18.7 \text{ kg}$), cold carcass weight (CCWT) ($16.2 - 18.2 \text{ kg}$), carcass length ($78.7 - 83.7 \text{ cm}$), ultimate meat pH (pH_u) ($5.70 - 5.81$) and temperature ($9.07 - 10.7^\circ \text{C}$). Lamb meat from different dietary treatments showed no differences in terms of water holding capacity ($0.36 - 0.38$), cooking loss ($10.8 - 13.6\%$), drip loss ($2.27 - 3.67 \%$), evaporation loss ($8.53 - 10\%$), and thaw loss ($0 - 0.13\%$). The shear force measurements were also similar, ranging from 1.67 to 2.17 kg . Similarly, diets had no effect on meat colour parameters. For all the treatment groups, lamb meat was rated similarly by the sensory panels. From the foregoing, it can be concluded that Canola meal is a suitable alternative for soyabean meal in fattening lamb diets and can produce comparatively good quality meat that is

highly acceptable and it doesnot seem to compromise health of the animals. South African feed companies can therefore shift from using soyabean meal to canola meal in sheep ration to minimize costs. The results of this study show that livestock feed companies and farmers can incorporate canola meal in fattening lambs ration as a major protein source and this will also help to reduce the cost of importing soyabean meal in the country.

Keywords: Canola, growth performance, hematology, Meat quality, sensory evaluation

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DEDICATION

This work is dedicated to my late parents Mr and Mrs Sekali, my mother in-law Mrs Motsepa, my husband Mr T. Motsepa and my son Mabitsa.

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LIST OF ABBREVIATIONS

a* – Redness

ADF – Acid detergent fiber

ANOVA – Analysis of Variance

AOAC – Association of Analytical Chemistry

ARC – Agricultural Research Centre

b* – Yellowness

BASO - basophil

C – chroma

CL –Cooking loss

CM–Canola meal

CP – Crude Protein

CRD – Complete randomized design

DM –Dry Matter

EDTA – Ethylenediamine tetra-acetic acid

EE – Ether Extract

EOS - eosinophil

FA – Fatty Acid

FI – Feed intake

h* - hue angle

HCW – Hot carcass weight

Hgb – Haemoglobin

L* - lightness

LHS - left hand side

LYM - lymphocyte

MCH - mean corpuscular volume

MCHC - mean corpuscular volume concentration

MCV – Mean cell volume

MONO - monophil

NDF – Nutrient Detergent Fiber

NEU - neutrophil

NSPCA – National Society for the Prevention of Cruelty to Animals

PCV – Packed cell volume

pH – Potential of Hydrogen

pH_u – Ultimate pH at 24 hours

PLT - platelets

PUFA-Polyunsaturated fatty acids

RBC – Red blood cell

RDW – red blood cell distribution width

SBM - Soyabean meal

SFA – Saturated fatty acids

SLW– Slaughter weight

WBC - white blood cell

CHAPTER 1: INTRODUCTION

1.1 Background

Sheep are produced in all the regions of South Africa (SA) except in the far Northern areas. SA Mutton Merino is one such breed and is mostly produced on natural pastures. Sheep contribute 21% of the world total ruminant livestock meat output (Sebsibe, 2012). The increasing world population and the need to raise living standards have made the production of more and better meat and effectiveness of its preservation important more issues (Lawrie & Ledward, 2006). Mutton is, by proportion, the meat which represents a greater percentage of commercial exchange among countries (Sañudo *et al.*, 1998).

The demand for high quality protein for human consumption is increasing in the world (Band, 2007). Among the known protein sources, animal protein is the most preferred. Animal proteins are more similar to human proteins and therefore are used in the body more readily and rapidly than plant proteins. The amino acids derived from animal based protein are more readily available for protein synthesizing reactions in humans (Campbell, 2013). There is, hence, a need to increase production of animal protein particularly from small ruminants. Small ruminants, such as sheep, are easier to rear and require relatively low initial capital compared to large ruminants. In any sheep production system, feed constitutes the largest expense. In South Africa and most parts of the world, sheep are mainly raised on rangelands or pastures, but there are times these are not able to meet nutrient requirements of animals. In winter there is often a decline in both the quantity and quality of feed especially protein (Brand, 2007). Low quality protein supply in sheep leads to reduced growth rates, poor meat quality, poor milk production, poor reproduction and reduced disease resistance, mainly because of insufficient amino acids are absorbed by the body (Luginbuhl & Poore, 1998). Consequently, supplementing livestock feeds with good quality protein sources becomes critical. However,

farmers are facing serious problems related to feed shortages particularly in relation to protein sources.

Soyabean meal (SBM) is the most commonly used protein sources for lamb diets (Khalid *et al.*, 2012). SBM is a by-product of the extraction of soyabean oil by different processes that include solvent extraction process, combination of heating and mechanical treatments (Heuzé *et al.*, 2012). It has high concentration of protein, about 44% to 49%, that is highly digestible and composed of a superior blend of amino acids (Cromwell, 1999). It is used as a preferable plant source of protein for both humans and animal diets. Predictably, the competition between humans and animals for soyabean has resulted in shortages and escalation of purchase costs. Currently, most animal feed companies in South Africa are forced to import soyabean oil cake from abroad. The high price and scarcity of soyabean meal therefore necessitate the search for locally produced alternatives that can partially or completely replace soyabean meal in animal diets (Smith, 2005; Band, 2007). Among other plant protein sources, rapeseed meal (Canola oilcake) has been identified to be the most promising.

In recent years, the possibility of using Canola meal (CM) in place of soyabean meal has emerged as a topic of increasing interest to researchers (Sarıçiçek *et al.*, 2005). Canadian animal nutritionists have demonstrated that Canola can be used as a replacement diet for soyabean meal as a protein supplement in ruminants (dePeters & Bath, 1985). In South Africa (mainly in Western and Southern Cape) Canola/rapeseed is a relatively new commercially cultivated oilseed crop (Mosiane *et al.*, 2003; de Kock & Agenbag, 2009) whose cake contains up to 37% protein. It has been reported that it can be mixed in the ration of sheep at 10 to 15% and sheep can utilise it more efficiently because the proteins are easily degraded by microbial activity (Bonnardeaux, 2007). Canola meal also has balanced amino acids, notably high levels

of methionine (86%) and cystine (77%) compared to that of SBM (83% and 75% respectively) (Newkirk, 2009). However, Canola has been found to contain some secondary compounds such as sinapine and phytate known to have a detrimental effect on livestock performance (Brand *et al.*, 2007; Bonnardeaux, 2007; de Kock & Agenbag, 2009; Ben Salem, 2010). On the other hand, the presence of these compounds in Canola has been reported to improve the meat quality by increasing the shelf-life and improving the antioxidative stability of the meat (Pokorny *et al.*, 2001). Despite the potential of Canola as a protein source for ruminants, there is scant information on its use as a protein source in fattening diets of lambs in South Africa.

1.2 Justification

Soyabean meal is mostly used in formulations of livestock feeds as a major protein source but a large proportion of it is imported from outside South Africa. The cost of soyabean on the world market is high due to direct competition between animals and humans. On the contrary, Canola meal is locally grown in South Africa and its use is currently restricted to animals. Therefore, the use of Canola oilcake instead of soyabean meal in sheep diets may help feed industries reduce the cost of importing soyabean meal and reduce competition between animals and humans for food. There is some evidence (Stanford *et al.*, 2000) that Canola meal can improve animal performance by increasing weight gains and meat quality characteristics elsewhere in literature. Therefore there is a need to explore this resource in feeding lambs in South Africa.

1.3 Objectives

The major objective of this study was to determine growth performance, haematological profile, meat quality of lamb from animals fed Canola cake as a replacement for soyabean meal.

Specific objectives

- To assess the effect of substituting soyabean meal with Canola cake on feed intake and average daily weight gains Mutton Merino lambs.
- To evaluate the white blood cells, red blood cells and the platelets of the lambs.
- To determine carcass measurements, consumer sensory perceptions, meat losses and colour characteristics of lamb from animals fed different levels of Canola meal as a replacement diet for soyabean meal.

1.4 Hypotheses

- Substituting soyabean meal with Canola will increase feed intake and daily weight gain of the lambs.
- Feeding sheep on Canola diets will improve them eat and taste of lamb.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The use of nutritional strategies to improve animal performance involves both the sciences of animals and food. Animal nutrition plays an important role due to its regulatory effect on biological processes in growth and muscle (Anderson & Yu, 2005). This will be reflected in the meat although several other factors such as breed and genetics may also have an effect. Any diet is considered economically valuable and biologically efficient if it does not impair both the performance and carcass quality of the animals. Among protein sources for ruminant diets, Canola is considered to be one such feed ingredient that can be used as animal feed. It can meet the nutritional requirement of ruminants if fed together with required vitamins and minerals (Stanford *et al.*, 2000). However, the presence of some anti-nutritional factors, in Canola, such as alkaloids may reduce the growth performance in ruminant animals (Stanford *et al.*, 2000; Newkirk, 2009). Several studies have been done in evaluating the effect of replacing soyabean meal with Canola in pigs (Ekpe *et al.*, 2000), poultry (Leeson, 1986), aquaculture (Plaipetch & Yakupitiyage, 2013), small ruminants (Leupp *et al.*, 2006), and large stock (Murphy *et al.*, 1995). Even though Canola contains less protein and energy than soyabean (Plaipetch & Yakupitiyage, 2013), published results suggests that Canola meal can replace soyabean meal in animal diets without any adverse effect on general performance, nutrient retention or metabolism.

2.2 Production and nutritional composition of Canola oilcake

Canola is a plant protein source (Plaipetch & Yakupitiyage, 2013) and is only second to soyabean (de Kock & Agenbag, 2009; Suárez *et al.*, 2009) in terms of both production and trade. It is grown where soyabean cannot grow (Stein & Jongeneel, 2013). Canola currently contributes close to 14% of the total world production of oilseed (de Kock & Agenbag, 2009).

Statistics reported by de Kock & Agenbag, (2009) indicated that the total world Canola production was about 50 million tones grain per annum. France, England, Germany, China, and Canada contribute 87.1% of world production of Canola and were regarded as the most important Canola producing countries. South Africa was the lowest with 0.03-0.04 million tons of grain while Europe was the highest with 18.4-18.9 million tons of grain (de Kock & Agenbag, 2009). Canola (*Brassica napus* and *Brassica campestris/rapa*) is a genetically improved oilseed rape which was bred through standard plant breeding techniques to have less than 2% erucic acid in the oil and less than 30 $\mu\text{mol/g}$ of glucosinolates in the meal (de Kock & Agenbag, 2009; Newkirk, 2009). Canola is derived from the words **Canada** and **oleic acid**.



There are various other *Brassica* species, the most important being *Brassica rapa*, *Brassica juncea* (Indian mustard which is normally grown in South Africa), and *Brassica carinata* (Ethiopian mustard). In South Africa, only Canola (*Brassica napus*) is cultivated commercially, in Western and Southern Cape. Canola is a winter crop that requires relatively moist conditions, particularly during flowering, nodule forming and seed forming stage, for the best results. It is a relatively new crop in South Africa. In 1994 only 500 tons Canola grain was produced, but this has gradually increased to 41 000 in 2003/2004 and 2004/2005. (de Kock & Agenbag, 2009). Currently the annual production ranges between 35 000 and 38 000 tons. The area under cultivation is about 35 000 ha. Canola offers significant benefits as a rotation crop, particularly in terms of weed control. Seeds are imported mainly from Australia. It is shown in the table 2.1 below that soyabean meal has much higher protein Content than Canola but the amino acids types are similar for both the soyabean meal and Canola meal. Canola meal contains more of a fibre known to be indigestible but however, the new cultivars of Canola are less in fibre.

Table 2.1. Nutritional composition (%) of Canola meal and soyabean meal

Nutrients	Soyabean meal	Canola meal
Moisture	8.26	9.12
CP	46.9	38.9
Lysine	2.71	2.26
Arginine	3.57	2.11
Histidine	1.26	1.09
Threonine	1.86	1.63
Leucine	3.7	2.5
Isoleucine	2.3	1.48
Valine	2.49	1.81
Methionine	0.68	0.79
Phenylalamine	2.38	1.53
Tryptophane	0.66	0.48
Crude Fat	3.45	5.92
Crude Fibre	3.35	8.31
CHO	31.3	29.6
GE (KJ/g DM)	18.6	18.8
Ash	6.68	8.16

Source: Suárez et al. (2009)

2.3 Digestibility of Canola oilcake in ruminants

Several studies have reported that Canola in ruminant diets is highly digestible (Stanford *et al.*, 2000; Leupp *et al.*, 2006; Sharma *et al.*, 2007). With regard to organic matter (OM) digestibility, Canola was observed to be comparable with soya bean meal in terms of apparent ruminal, true ruminal or total tract digestibility (Leupp *et al.*, 2006). Canola supplementation was also reported to increase ruminal and true ruminal crude protein (CP) degradation and increased small intestines CP digestibility (Sharma *et al.*, 2007). In addition, small intestines nitrogen detergent fibre (NDF) digestibility was observed to increase with increasing amounts of Canola in steers (Leupp *et al.*, 2006). Nevertheless, high levels of Canola inclusion were reported to reduce OM digestibility in comparison with soyabean meal (Sharma *et al.*, 2007) indicating that canola did not have a negative impact on microbial population at lower levels and there was high nitrogen retention.

Generally, *In situ* ruminal disappearance of Canola was found to be more comparable with similar types of feedstuffs although the rate of Canola DM, NDF and ADF degradation increased for ground compared to the whole Canola (Leupp *et al.*, 2006). Grinding was observed to increase soluble CP fraction and degradation rate of Canola compared to whole Canola although no differences were observed in terms of ruminal fill or fluid dilution rate (Leupp *et al.*, 2006). Table 2.1 shows the nutritional composition of Canola oil cake in comparison with Soya bean meal.

Husein *et al.* (1995) reported that inclusion of whole or crushed Canola seed included at 5% dietary dry matter in steers fed high or low forage diets did not affect fibre digestibility.

Similarly, Stanford *et al.* (2000) reported no effect on fibre digestibility when canola screenings were included at 6% dietary dry matter in lambs but fibre digestibility was reduced when canola screening were included at 95%. Sharma *et al.* (2007) also reported lower digestibility of DM, NDF and ADF in high glucosinolate canola meal feed to calves while digestibility of DM, NDF and ADF was similar in lower glucosinolate canola meal and soyabean meal. Canola seeds bind oil in their cellular structure and the inhibition of fibre digestion by dietary fat is thought to be minimized by the release of this oil (Murphy *et al.*, 1987). Tefsa, (1993) also indicated that at levels approaching 10% of dietary DM, free Canola oil can exert toxic effects on protozoal and cellulolytic bacterial populations, resulting in depressed fibre digestion.

In a study by Stanford *et al.* (2000), nitrogen retention was observed to increase linearly with increasing inclusion levels of Canola. High full-fat Canola inclusion levels, however, were observed to result in low N retention and consequently low body weight gain in lambs. According to NRC (1985), a Canola diet with 14.4% CP can be provided without impairment of growth rates in lambs. Therefore, it was suspected that the low N retention by lambs receiving the full fat Canola diets could have been due to the toxic effects of Canola oil on the rumen microbial population that causes low digestibility of N and ultimately poor N retention (Laarveld *et al.*, 1981; Palander *et al.*, 2004).

2.4 Intake and growth performance in response to dietary inclusion of Canola meal

The use of Canola as animal feeds was observed to positively affect feed intake and growth rates of the animals (Rule *et al.*, 1994; Kowalska, 2008; Stanford *et al.*, 2000). In lamb, the increase in feed intake was observed to be both linear and quadratic with increasing levels of

Canola (Stanford *et al.*, 2000). However, lamb growth performance was observed to be affected by low N digestibility/retention and impaired fibre digestion with increasing Canola screenings in lamb diets (Stanford *et al.*, 2000). This was attributed to the fibrous (44.9% NFD, 30.8% ADF) nature of the screening with very little essential nutrients such as protein (15.3% CP). Canola screenings was a mixture of canola cereal grains, weed seeds, chaff and dust which are produced during seed cleaning (Darroch *et al.*, 1990). Nevertheless, it would be expected that with the use of Canola oilcake which is highly degradable and containing high amounts of protein and other essential nutrients, high growth rates can be achieved, which was the major focus of the current study. Like Soyabean and other oil grains, high levels of fat in full fat Canola have an effect of reducing palatability of the diets, although an initial increased feed intake was observed in some studies (Stanford *et al.*, 2000; Rule *et al.*, 1994). In addition, although feeding full-fat Canola might not affect the intake of hay and total organic matter, there is bound to be a knock-on effect on bacterial organic matter flow at the duodenum which tend to decrease with increasing full fat Canola inclusions (Leupp *et al.*, 2006). This therefore suggests that oil pressing is critical, as it reduced the amount of undesirable oil in Canola with the resultant oilcake providing an alternative high quality protein ingredient which is highly palatable, acceptable, degradable and digestible. Observations were made that bulls comparably consumed similar amounts of both SBM and Canola, but gained faster when fed Canola oil cake than full fat Canola and full-fat soyabean (Rule *et al.*, 1994). With steers, DM intake or feed efficiency were reportedly not different between soyabean and Canola (Rule *et al.*, 1994).

2.5 Effects of feeding Canola on reproduction, milk concentration and composition

In studying the effect of Canola on reproduction, Murphy *et al.* (1995) found that feeding Canola significant positively affected calving to service interval, calving to conception interval

percentage infertile, service per conception of conceived cows and service per conception of served cows. The type of feed that is given to the animal can also have an impact on its milk production and composition. Both high and low levels Canola inclusion levels were observed to have an effect on milk yield and composition (Murphy *et al.*, 1995) and the greatest impact was on the fat content of the milk (Murphy *et al.*, 1995; Borys *et al.*, 2006). The fat content of milk has been observed to increase by 17.2% when lambs were fed linseed and rapeseed as protein supplements (Borys *et al.*, 2006). On the other hand, the protein and lactose content were decreased significantly (Borys *et al.*, 2006). Milk yield was significantly increased by high levels of Canola oil cake while it was decreased by high levels of full fat Canola inclusions (Murphy *et al.*, 1995). Even though low full fat Canola inclusion levels significantly increased protein and lactose yield in milk, the increase was greater on high levels of Canola oil cake inclusion in animals' diet (Laarveld *et al.*, 1981). Laarveld *et al.*, (1981), also reported that when low glucosinolates rapeseed meal (Canola meal) was fed to cows at 13.2 and 18.9% levels it resulted in an increase in thiocyanate concentration in milk. However, iodide concentration and its secretions into milk decreased. In contrast, the use of high glucosinolate rapeseed meal increased unsaturated nitrile concentration and its daily secretion into milk thereby reducing the overall milk quality (Laarveld *et al.*, 1981).

In a study by Murphy *et al.*, 1995, supplementation with full fat Canola, either at low or high levels was reported to significantly decrease the proportion of C4:0, C6:0, C8:0, C10:0, C12:0, C14:1, C14:0, C16:0, C18:0 fatty acids and the reductions were significantly greater in higher levels of inclusion than lower levels for C4:0, C6:0, C8:0, C10:0, C12:0, CC18:3 fatty acids in milk. The C18:0 was not affected by dietary feeds while C18:1 was significantly increased by both levels of inclusion but greatly by high Canola levels which also increased C18:2 upon introduction of dietary Canola C16:0, concentration decreased, C16:8:1, increased while solid

fat content decreased. These changes were more pronounced in animals offered high Canola levels than low levels. Changes were observed approximately 10 days after the commencement of supplementation (Murphy *et al.*, 1995).

2.6 Dietary Canola oilcake and meat quality



Very little information is available on the effects of feeding Canola meal (oil cake) on the meat quality characteristics of ruminants, particularly, mutton. Most of the current studies are focused on digestibility, degradability and greenhouse gas emissions (Tesfa, 1993; Husein *et al.*, 1995; Stanford *et al.*, 2000; Leupp *et al.*, 2006; Sharma *et al.*, 2007). Of the available information, increasing levels of Canola screenings, which are highly fibrous, were observed to cause a linear reduction in subcutaneous fat thickness over the ribeye and ribeye depth in steers (Stanford *et al.*, 2000). Observations were also made that the influence of Canola screenings on carcass muscling and fatness over and above their influence of carcass weight was related to reduced digestibility of fibre and improved N metabolism with increasing levels of dietary Canola screenings (Stanford *et al.*, 2000). In addition, in bulls, dietary full fat Canola was observed to alter the fatty acid composition of lipid in the adipose tissue, muscle, kidney and liver such that 16:0 and 16:1 were decreased and 18:0, 18:1 and 18:2 and 20:1 were increased (Rule *et al.*, 1994). Of importance, Canola oilcake has been reported to favorably alter the compositions and amounts of saturated fatty acids which are of particular concern to human health as they are associated with cancers and heart conditions (Wood *et al.*, 2003). Canola was observed to reduce the saturated fatty acids (such as C12:0, C 14:0) and increase both unsaturated (C22:2, *trans* C18:1) and polyunsaturated fatty acids (Petit *et al.*, 1997; Derycke *et al.*, 1999; Rizzi *et al.*, 2002; Borys *et al.*, 2006; Tripathi & Mashra, 2007). Canola was also reported to increase the vitamin E level in meat. Vitamin E is said to be a good antioxidant in human bodies (Pokorny *et al.*, 2001) and there is a possibility to obtaining leaner carcasses with high levels of polyunsaturated fatty acids when oilseed cakes are used in the ration of

sheep that also help in reducing risk of diseases in human such as chronic atherosclerosis (Rizzi *et al.*, 2002). Despite the potential of Canola meal improving meat quality in ruminants, particularly with regards to characteristics such as tenderness and eating quality, its effects on meat quality in ruminants is largely unknown and needs extensive investigation.

2.7 Blood biochemical parameters in ruminants fed Canola oilcake

In calves Sharma *et al.* (2007) reported no difference in hemoglobin, PCV, glucose, total protein, albumin and alkaline phosphatase, while the levels of glucose, total protein, albumin, globulin and alkaline phosphatase differed for high and low levels of glucosinolates Canola and the soyabean meal. These diets also did not have a negative impact on the health of the animals. Additionally, glucose and cholesterol concentrations were high. It was further found out that Serum pyruvic transaminase activities (SGPT) and Serum oxaloacetic transaminase activities (SGOT) were lower in full – fat rapeseed (Canola) than the control groups (Murphy *et al.*, 1995).

2.8 Problems with the use of Canola oil cake

Canola has been found to contain some biochemical factors which, if not treated, might make it an unsuitable protein supplement in the diet of some animal species such as swine and poultry. Whilst some of the biochemical factors may be beneficial in ruminants at low concentrations (e.g., protein bypass with low tannin concentration), most of these can be toxic as can be evidenced by their effects on rumen microbial populations, digestion processes, intestinal damage, and/or metabolic toxicity post-absorption (Rogosic *et al.*, 2008). One typical phytochemical found in Canola is glucosinolate. Glucosinolates are sulphur containing secondary plant metabolites that are found in all *brassica* species (Tripathi & Mishra, 2007). Glucosinolates are unwanted and undesirable in animal feed material because they hinder

animal nutrition. They are associated with poor palatability due to bitterness or astringency, hence affecting feed intake. They also interfere with the nutrient uptake in the digestive system. In Canola, sinapine, a methylated substance that is converted into trimethylamine that is then absorbed by the animal, is also abundant (Newkirk, 2009). In chickens, sinapine leads to fishy or crabby eggs mainly because hens lack an enzyme to perform the conversion of trimethylamine to trimethylamine oxide, which can then be easily excreted in urine. It then builds up in the blood and accumulates in the eggs. The presence of sinapine also reduces the feeds palatability resulting in a depression effect on feed consumption (Bonnardeux, 2007).

Through genetic selection and plant breeding, the current Canola varieties contain very little undesirable phytochemicals (AOF, 2007). Most of these phytochemicals are contained in the seed hulls which makeup 16% of the seed weight and approximately 30% of the free oil seed meal (Bell, 1984). In the current varieties, glucosinolate levels are typically below 10 $\mu\text{moles g}^{-1}$ and thus do not significantly affect performance at such levels (Madiki *et al.*, 2002; AOF, 2007). In previous studies, Canola diets containing levels of 4.2 $\mu\text{mol/g}$ glucosinolates were shown not to depress intake and growth but induced iodine deficiency in lambs which influenced thyroid weight and histology (Derycke *et al.*, 1999; Mabon *et al.*, 2000). Nevertheless, the effect of dietary glucosinolates of less than 10 $\mu\text{mol/g}$ on intake and digestibility was reported to be insignificant while levels above 10 $\mu\text{mol/g}$ reduced growth in young lambs (Derycke *et al.*, 1999; Madiki *et al.*, 2002; Tripathy *et al.*, 2001).

2.9 Summary

Although there is scope in the use of alternative protein sources for lamb production, lack of broad based research could be a major constraint. Comprehensive research, therefore needs to be conducted to fill up the gaps and optimize cost effectiveness of feeding strategies that utilizes the available unconventional protein sources. Although several studies have been done in evaluating the effect of replacing soyabean meal with Canola in pigs (Ekpe *et al.*, 2002), poultry (Leeson, 1986), aquaculture (Plaipetch & Yakupitiyage, 2013), small ruminants (Leupp *et al.*, 2006), and large stock (Murphy *et al.*, 1995), much of this has focused on digestibility. In addition to this, it is also critical to thoroughly investigate the influence of Canola on the general welfare and health of animals and meat quality, which is the focus of the current study.

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**CHAPTER 3: GROWTH PERFORMANCE AND HAEMATOLOGICAL
CHARACTERISTICS IN MUTTON MERINO LAMB OFFERED CANOLA OIL
CAKE IN PLACE OF SOYABEAN MEAL**



Abstract

The study was carried out to evaluate the effect of replacing soyabean meal (SBM) with Canola (CM) in fattening diets on growth performance and haematological parameters in Mutton Merino lambs. Nineteen lambs with an average body weight of 23 ± 2.64 kg were used. Lambs were randomly assigned to five dietary treatments in a completely randomized block design and fed in individual pens for 60 days. The soyabean meal (SBM) in the control ration was replaced with Canola meal at 0% (control), 25 %, 50%, 75%, and 100% inclusion levels. There was no significant difference ($P > 0.05$) in the cumulative live weights and body weight gain of the lambs. The average daily gain (ADG) (0.17 – 0.20 kg/day), average daily feed intake (ADFI) (1.15 – 1.21 kg/day), feed conversion ratio (FCR) (3.09 – 3.41) and slaughter weight (SLW) (33.2 – 34.7 kg) also showed no significant differences ($P > 0.05$) between the groups. The haematological count showed no significant difference in red blood cell (RBC) ($9.54 - 12.8 \times 10^{12}/L$), haematocrit (HCT/PCV) (29.3 – 38.5%), haemoglobin (Hgb) (11.2 – 14.9 g/dL), mean corpuscular volume (MCV) (30.0 – 32.0 fl), mean corpuscular haemoglobin (MCH) (11.0 – 14.1 pg), red cell distribution width (RDW) (20.0 – 21.3 %), platelets (PLT) (0.99 – 2.95 $K/\mu L$), white blood cell (WBC) ($2.59 - 9.11 \times 10^9/L$), in both absolute ($\times 10^9/L$) and percentage neutrophil (NEU) (0.79 – 1.34), lymphocyte (LYM) (1.61 – 7.27), eosinophil (EOS) (0.10 – 0.23), and basophil (BASO) (0.02 – 0.07). There was a significant difference in mean corpuscular haemoglobin concentration (MCHC) ($P < 0.001$) and monocytes (MONO) (both absolute and percentage) ($P < 0.05$). The lowest MCHC counts (33.3 g/dL) were recorded in

the 75% level of Canola meal inclusion while the highest counts (38.6 g/dL) were recorded in the highest inclusion level (100%). The lowest absolute ($\times 10^9/L$) and percentage monocytes counts (0.08) were in the control diet and the highest counts (0.51) were recorded when soyabean meal was replaced with equal amounts of Canola meal. The results showed that canola meal can completely replace soyabean meal in fattening lambs diet with improved growth performance.

3.1 Introduction

In any sheep production system, feed is the most expensive outlay. Protein is one of the nutrients that significantly affect the performance of sheep. When lambs are provided with high quality protein, the performance is improved and it also ensures profitable animal production. Different plant protein sources (such as cotton seeds meal, soyabean meal, sunflower meal, rapeseed meal) are used to formulate rations for growing and fattening lambs (Khalid *et al.*, 2012). Soyabean meal has long been considered an outstanding source of supplemental protein in diets for livestock. Not only does soyabean meal have 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). However, the fluctuations in availability and pricing of soyabean are major factors affecting affordability by farmers. Therefore, alternative protein sources need to be explored, particularly because soyabean is also used for human consumption, a competition that is likely to push prices up.

Alternative protein sources include sunflower oil cake, cotton seed meal, peanut meal and Canola oil cake among others. Of all these sources, Canola meal is proving to be popular and has great potential as a natural protein source. The rapid expansion in cultivation and production of Canola in South Africa coupled with expanding crushing capacity avoid opportunity for an increased availability of Canola meal for use in the livestock sector of South Africa. Moreover, depending on the differences in environments, Canola meal can contain a minimum of 35% protein (AOF, 2007). More importantly, Canola meal is high in unsaturated fats (93 %), has no cholesterol or trans-fat, and has the lowest saturated fat (7 %) of any common seed meals pointing to the potential health benefits associated with reduced risk of coronary disease (Douaud, 2006). In ruminants, Canola meal has a high degree of palatability which has been attributed to the high sucrose content (Newkirk, 2009). It can be incorporated

in sheep diets without any effects on feed intake or other performance parameters (Hill, 1991), largely due to the fact that sheep can apparently tolerate high glucosinolate, in Canola meal quite well (Newkirk, 2009). Glucosinolates are sulfur bearing moiety which in all the economically important varieties of *Brassica* and they have a bitter taste that reduces intake (Tripathi & Mishra, 2007).

Canola meal also has balanced amino acids, notably the high levels of methionine (86%) and cystine (77%) compared to that of soyabean meal (83% and 75%, respectively) (Banaszkiewicz, 2011). And it has been observed that in growing lambs, the inclusion of protein sources with amino acid profiles that closely match their amino acids needs can result in better growth performance (Khalid *et al.*, 2012). Good results (Stanford *et al.*, 2000; Ponnampalam *et al.*, 2001; Khalid *et al.*, 2012) have been obtained for lamb performance in response to Canola meal and this has been related to changes in nutritional and metabolic status. Despite all the potential benefits associated with the utilization of Canola in animal feeds of increase in feed intake and body weight gains (Rule *et al.*, 1994; Kowalska, 2008; Stanford *et al.*, 2000), there has been very little research done in South Africa on its use as an alternative protein source to soyabean meal in sheep fattening rations. The current research was, therefore, carried out to determining the effect of replacing soyabean meal with Canola meal in fattening diets on growth performance and haematological parameters in Mutton Merino sheep. Evaluation of blood parameters was done in order to determine the response in terms of general health and nutritional status of the lambs.

3.2 Material and Methods

3.2.1 Description of the study area

The study was conducted at North-West University Farm, Animal Experimental Unit (latitude: 25° S and longitude: 25° E) in Mafikeng, South Africa. The area is semi-arid receiving less than 300mm of rainfall per annum (in late summer, peaking in February). Mafikeng is characterized by seasonal and daily variations in temperature, being very hot in summer (daily average high temperatures of 32 °C in January) and mild-to-cold in winter (average daily minimum in July is 0.9 °C). The relative humidity is below 28%. It has uniform terrain with an altitude of 1400 meters above sea level and is in a bushveld complex.

3.2.2 Experimental design and treatments

Nineteen female Mutton Merino lambs with an average body weight of 23 ± 2.64 kg were used in the experiment. The lambs (4 per dietary regimen) were randomly assigned to five isoenergetic diets in which soyabean meal was replaced with graded levels of Canola cake as the source of protein in a completely randomized experimental design (CRD). The diets were formulated to contain 15 % protein. The soyabean meal (SBM) in the control ration (T1, 100% SBM) was replaced with Canola oilcake (CM) at 0% (T1), 25 % (T2), 50% (T3), 75% (T4) and 100% (T5) levels. Nutritional composition of Canola oilcake and soyabean meal is shown in Table 3.1, while the composition of the diets is shown in Table 3.2.

Table 3.1 Nutritional composition of soyabean meal and Canola meal

Components (%)	Soyabean meal	Canola meal
Protein	47.0	36.26
Fat	2.0	2.94
Ash	7.0	7.16
NDF	8.5	23.28
ADF	6.5	16.19
Moisture	10.0	11.48
Fiber	3.72	10.36
RUP	14.1	10.88
Calcium	0.29	0.67
P	0.68	1.15
Mg	0.27	0.53
K	2.0	1.25
Cl	0.01	0.1
Na	0.007	0.08
S	0.4	0.64

ADF=Acid detergent fibre; NDF=neutral detergent fibre; RUP=rumen undegradable protein; P=Phosphorus; Mg=Magnissium; K=Potassium; Cl=Chlorine; Na=sodium; S=Sulfur

Table 3.2 Composition of the experimental diets (kg DM)

Components	CM0	CM25	CM50	CM75	CM100
Yellow maize-coarse	766	766	766	766	766
Lucerne	240	240	240	240	240
Wheat bran/Pollard	173	173	173	173	173
Soy hulls	165	165	165	165	165
Molasses	90	90	90	90	90
Limestone powder-fin	30	30	30	30	30
Salt-coarse	12	12	12	12	12
Ammonium Chloride	12	12	12	12	12
Acid buff	6	6	6	6	6
Premix B	4.5	4.5	4.5	4.5	4.5
Urea	1.5	1.5	1.5	1.5	1.5
Molasweet	0.27	0.27	0.27	0.27	0.27
Taurotec	0.26	0.26	0.26	0.26	0.26
Canola meal (%)	0	25	50	75	100
Soyabean meal (%)	100	75	50	25	0

CM0= 100 % SBM, CM25= 75% SBM& 25% CM CM50= 50% SBM& 50% CM, CM75= 25% SBM& 75% CM, CM100= 0% SBM& 100% CM

3.2.3 Chemical analysis

The ingredients and diets were analyzed for DM, CP, crude fat, crude fibre and ash using the protocols of the Association of Official Analytical Chemists (AOAC), 2006. The ingredients and diets were also analysed for crude fibre, ADF and NDF (AOAC, 2006). Fibre, acid detergent fibre (ADF) and neutral detergent fibre (NDF) were done by the use of ANKOM fibre analyzer according to the procedure described by van Soest *et al.* (1991). Crude protein was analyzed by the use of the Kjeldahl method.



3.2.4 Animal management

All lambs were brought into the experiment at approximately 5 months of age, after being ear tagged and treated for internal parasites (4 mL of Levamisole; active constituent 80 g/L Levamisole hydrochloride) and vaccinated for pulpy kidney and heartwater. During the experiment, the animals were allocated to individual pens, housed indoors and fed the assigned diet for a 60-day period. The experimental unit in the study was therefore the individual animal. Feed was offered in individual feeders and drinking water was available at all times. All experimental procedures were approved by the University Ethics Committee, North-West University, South Africa and the following ethical number was allocated: NWU-00100-14-S9. Lambs were fed at 4% of their body weight. Weighed quantities of the diet were offered twice daily at 08h00 and 15h00. The orts were collected every morning before feeding and weighed. The quantity of feed was adjusted every three weeks after recording the body weight of each lamb in order to meet their nutritional requirement for growth. The welfare of the lambs was also evaluated by the local vet and the National Society for the Prevention of Cruelty to Animals (NSPCA) in South Africa.

3.2.5 Feed intake, feed conversion ratio, body weight and body condition scores

Feed intake (FI) was calculated as the difference between the feed offered and the refusals collected the following morning before feeding. Each lamb was weighed using a lamb commercial weighing scale once in the morning in every seven days (weekly weights) and the average daily gain (ADG) was calculated as:

$$ADG(t_0, T) = \frac{W(T) - W(t_0)}{T - t_0}$$

Where: t_0 = initial time; T = final time (60th day); $W(T)$ = final body weight; and $W(t_0)$ = initial body weight.

Slaughter weight was recorded and feed conversion ratio was calculated as:

$$FCR = \frac{\text{feed intake}}{\text{average daily gain}}$$

Concurrently, body condition of the lambs was assessed throughout the experiment using the 5 point scale (1 = very thin to 5 = obese) (Aumont *et al.*, 1994).

3.2.6 Haematology

Blood samples were collected from the jugular vein by venipuncture using an 18-gauge needle into purple-top 7 ml ethylenediamine tetra-acetic acid (EDTA) coated vacutainer tubes at 0800 h at the beginning of the experiment and every fortnight for analysis of haematological parameters. The samples were taken for analysis immediately and analysis was done with an IDEXX LaserCyte Haematology analyser for full blood count, which included white cell count,

red blood cell (RBC) count, haematocrit/Packed Cell Volume (PCV, haemoglobin, mean cell volume, mean cell haemoglobin, mean haemoglobin concentration, red cell distribution width, platelets, platelets distribution width, and reticulocyte count. The differential count included neutrophil, lymphocyte, monocyte, eosinophil and basophil counts.

3.2.7 Statistical analysis

The effect of diets on ADG, average daily feed intake (ADFI), cumulative body weight gain and slaughter weights and blood hematology was analyzed using general linear model (GLM) (SAS, 2008) using the following model. The initial body weight was used as a covariate and data on weekly body weights was analysed using the repeated statement in the mixed model procedure for repeated-measures of SAS (2008) according to Littell *et al.* (1996).

$$Y_{ij} = \mu + D_i + E_{ij},$$

Where: Y_{ij} = observation of the dependent variable ij , μ = fixed effect of population mean for the variable, D_i = effect of dietary treatments ($i = 5$; graded levels of Canola cake: 0, 25, 50, 75, and 100% replacement of soyabean meal), and E_{ij} = random error associated with observation ij . For all statistical tests, significance was declared at $P \leq 0.05$. For variables where significant variation is detected, multiple comparisons of treatment means was carried out using the probability of difference (PDIFF) option of SAS (2008).

3.3 Results and discussion

The effect of replacing soyabean meal (SBM) with Canola meal (CM) in the diets of sheep on weekly live weight is presented in Figure 3.1. Replacing soyabean meal with Canola meal in lambs' diets did not have a significant ($P > 0.05$) effect on the live weights of lambs measured over the experimental period. In all treatments, there was a linear and steady increase in body weights throughout the experiment. The body condition scores were not different across the treatments and consistently ranged from 3.5 to 4. While it would have been expected that lambs

consuming diets with low Canola inclusion levels would perform better, the fact that the performance was similar across treatments suggests that substituting SBM with Canola does not negatively affect growth performance and thus making Canola a feasible alternative protein source to reduce cost of importing soyabean meal in South Africa. This is in agreement with the findings of Lough *et al.* (1991) and Ponnampalam *et al.* (2005) who observed remarkable performance in lambs fed Canola meal. The cumulative body weight gains in all dietary treatments followed a similar trend as live weight (Figure 3.2) as expected.

The results on average daily gain (ADG), average daily feed intake (ADFI), feed conversion efficiency (FCR) and final weight (FW) are presented in Table 3.3. There were no significant dietary differences for all these growth parameters. Similar observations have been made elsewhere (Lardy & Kerley, 1994; Khan *et al.*, 1997; Khalid, 2011). Although Canola meal is considered to be more fibrous than soybean meal (Table 3.1), this did not affect the ADFI and FCR. It would have been expected that the lambs in the high Canola inclusion groups would initially consume more feed to compensate for the increased amounts of fibre in their diets. Surprisingly, the lambs in the high Canola inclusion groups consumed similar amounts of feed as those in the low Canola inclusion groups.

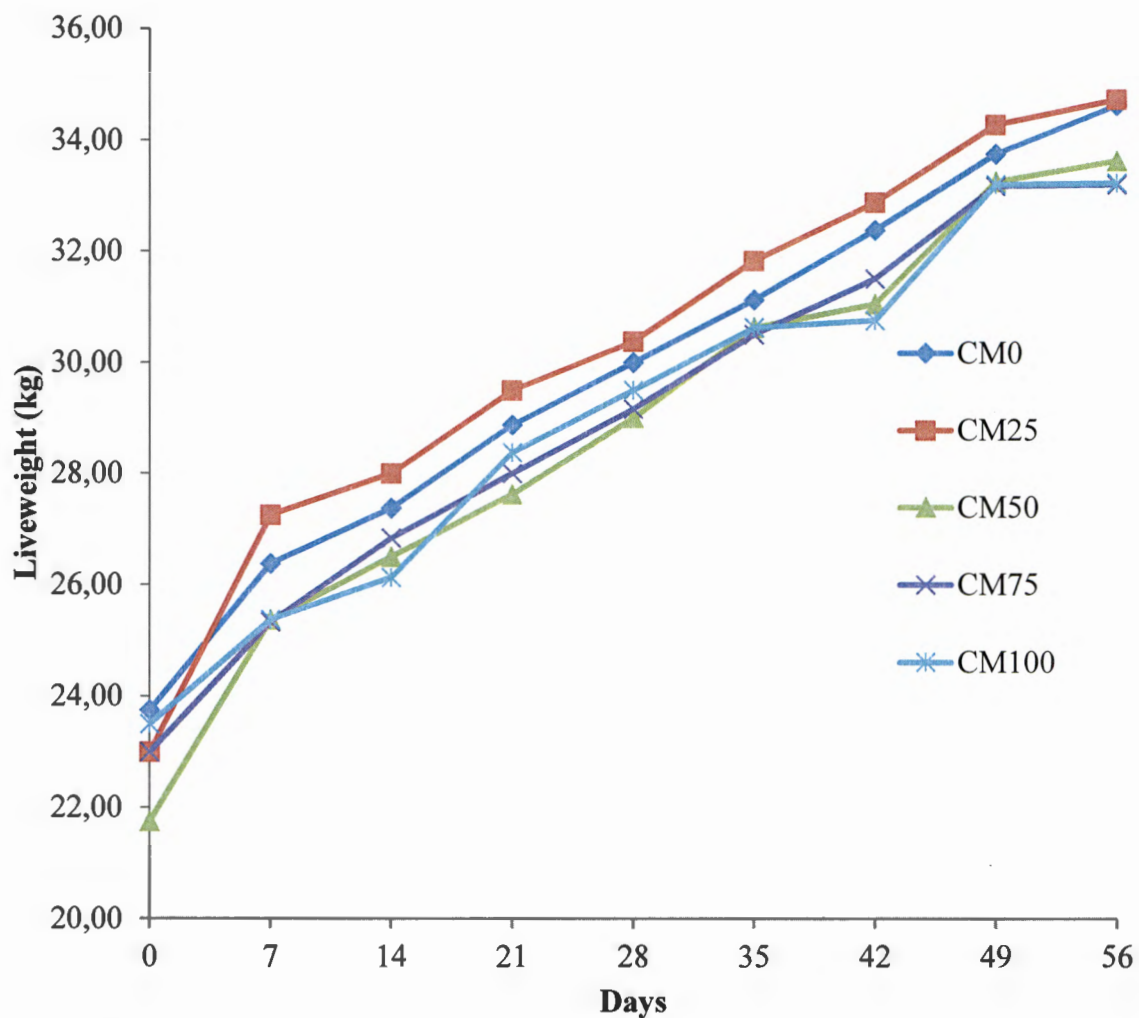


Figure 3.1: Effect of dietary treatments on weekly liveweight of lambs over a 56-day feeding period(CM0 = 0% Canola meal; CM25 = 25% Canola meal, CM50= 50% Canola meal, CM75= 75% Canola meal, 100%= 100% Canola meal).

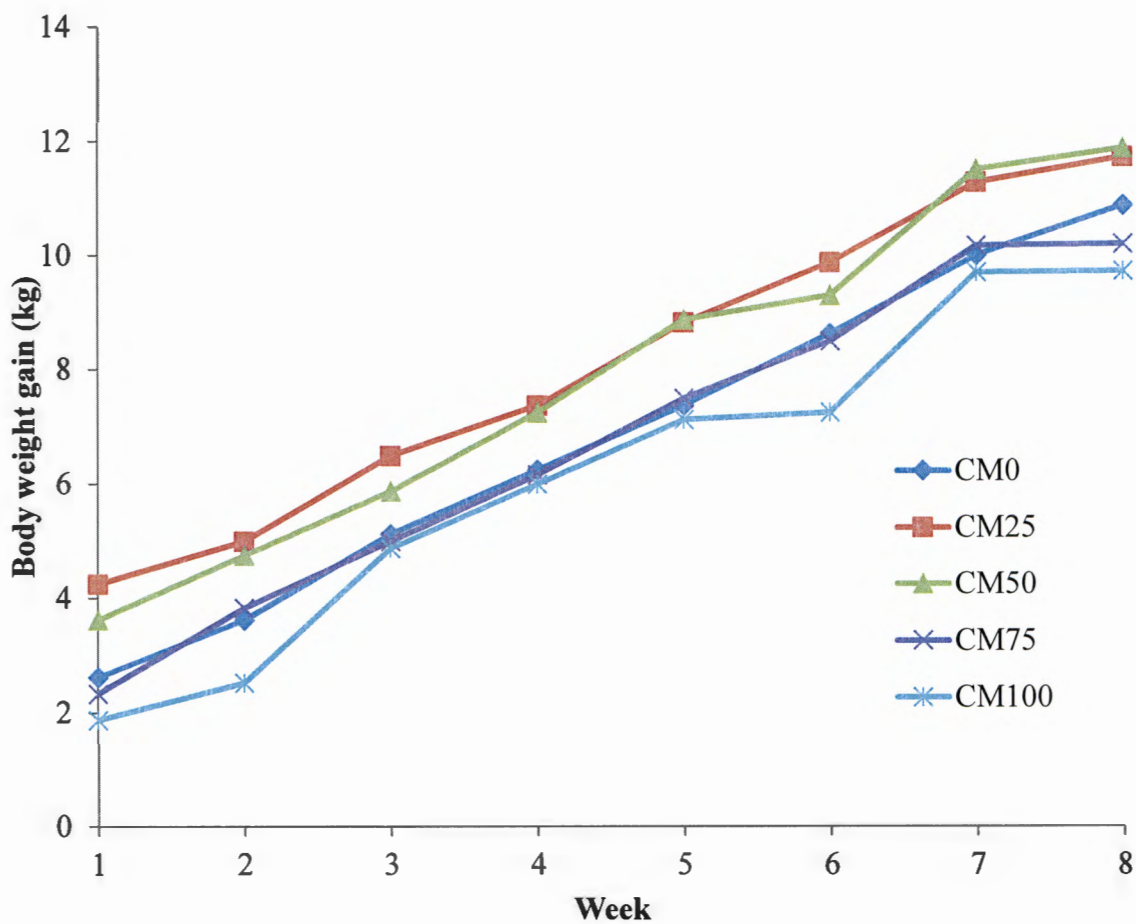


Figure 3.2: Effect of replacing soyabean meal with Canola meal on body weight gain of the lambs(CM0 = 0% Canola meal; CM25 = 25% Canola meal, CM50= 50% Canola meal, CM75= 75% Canola meal, 100%= 100% Canola meal)

The reason for this could be two fold. Firstly, it is common knowledge that protein, whilst important, is not the major limiting nutrient of lamb diets in feedlots. Energy is the major component and hence the adequate energy supply will result in efficiency utilization of the available protein through the use of rumen and resultant microbial protein even if it is of moderate quality. Secondly, the Canola cultivar (CM-HP) that is currently being produced has been genetically selected for low fibre content (AOF, 2007) and therefore the amounts of fibre in the diets were insignificant to have an effect on the performance of the lambs. In non-ruminant animals (pig and poultry), however, a decline in feed intake and ultimately body weight gain can be obtained with high Canola inclusion rates due to glucosinolates (Sarıçiçek *et al.*, 2005). This, therefore, means that there is need to take caution when utilizing Canola in pig and poultry diets.

The observed lack of differences in slaughter weight amongst the treatments is consistent with the lack of differences in live weight and body weight gain. This can probably allude to the fact that when finishing ruminants, variation in protein source may be of little importance in the performance of the animals due to the fact that energy is the major dietary component. This is provided microbial needs are optimized in terms of fermentable nitrogen. More importantly no rumen escape protein was provided in all treatment, which has cause increase in performance above that observed due to microbial contribution. Therefore not much difference would be expected between the treatment groups. Nevertheless, this still strengthens the suggestion that Canola meal can be a very good alternative to soya bean meal.

Table 3.3. Effect of replacing dietary soyabean meal with Canola meal on feed intake, growth performance, and slaughter weight

Parameters	Dietary treatment				
	CM0	CM25	CM50	CM75	CM100
ADG (kg/day)	0.18±0.02	0.20±0.02	0.20±0.02	0.18±0.02	0.17±0.02
ADFI (kg/day)	1.17±0.61	1.21 ±0.61	1.19±0.61	1.15±0.7	1.15±0.61
FCR	3.26±0.27	3.09±0.27	3.11±0.27	3.26±0.31	3.41±0.27
FW (kg)	34.63±0.9	34.73±0.9	33.62±0.9	33.20±0.04	33.48±0.9

ADG =average daily gain; ADFI =average daily feed intake; FCR =feed conversion ratio; FW = final weight; CM0 = 0%Canola meal; CM25 = 25%Canola meal; CM50 = 50%Canola meal; CM75 = 75%Canola meal; CM100 =100%Canola meal;



The effect of feeding Canola oilcake on the general health and welfare of lambs is reflected by the haematological characteristics presented in Table 3.4. The results showed that there were no significant differences in most of the hematological parameters except for the mean corpuscular haemoglobin concentration (MCHC), eosinophils (EOS) and the monocytes (MONO). Most of the parameters were also within the expected normal ranges, particularly the packed cell volume (PCV), red blood cell count (RBC) and white blood cell count (WBC), which are the major indicators of general health of the lambs (Chineke *et al.*, 2006; Mahieu *et al.*, 2007; Afolabi *et al.*, 2010; Addass, 2012; Merck Manual, 2012). Blood parameters such as mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) are also valuable in monitoring feed toxicity especially with feed constituents that affect blood in lambs (Oyawoye & Ogunkunle, 2004; Awodi *et al.*, 2005) and these were observed to be within the normal range. There was no significant difference in terms of white blood cell count and the values fell within the normal range.

Table 3.4. Haematology blood count for lamb fed Canola meal as a replacement for soyabean meal

	CM0	CM25	CM50	CM75	CM100	Ref range
RBC ($9.45 \times 10^{12}/L$)	11.22	9.54	11.87	12.82	9.74	9-15
HCT/PCV (%)	34.25	30.40	30.40	38.45	29.30	27-45
Hgb (g/dL)	14.50	11.20	13.10	14.85	13.40	9-15
MCV (fl)	30.40	31.80	32.00	30.00	30.15	28-40
MCH (pg)	12.75	11.80	11.00	11.45	14.05	8-12
MCHC (g/dL)	38.20 ^b	37.00 ^b	34.40 ^a	33.30 ^a	38.60 ^b	31-34
RDW (%)	21.25	20.65	20.00	20.45	20.25	16-22
WBC ($4.81 \times 10^9/L$)	2.59	4.81	9.11	7.93	6.27	4-12
%NEU	0.79	1.24	1.14	1.34	1.21	10-50
%LYM	1.61	4.51	3.15	7.27	6.09	40-75
%MONO	0.08 ^a	0.21 ^b	0.31 ^c	0.28 ^c	0.30 ^c	0-6
%EOS	0.10 ^a	0.18 ^b	0.13 ^a	0.17 ^b	0.23 ^c	0-10
%BASO	0.02	0.03	0.07	0.05	0.04	0-3
PLT ($\times 10^3/\mu L$)	2.00	0.99	0.99	2.95	2.00	250-750

*P<0.05; **P <0.001

RBC=red blood cell; HCT= Haematocrit; PCV= packed cell volume; Hgb= haemoglobin; MCV= mean corpuscular volume; MCH = mean cell haemoglobin; MCHC =mean cell haemoglobin; RDW = Red cell distribution width; NEU = neutrophil; LYM =lymphocyte; MONO = monocyte; EOS =eosinophil; BASO =basophil; PLT =platelet; Ref=reference (Merck manual, 2012); CM0 = 0% Canola meal; CM25 = 25% Canola meal; CM50 = 50% Canola meal; CM75 = 75% Canola meal; CM100 = 100% Canola meal.

When the white blood cell count falls within the normal range it means that the feeding pattern did not affect the immune system (Ameen *et al.*, 2007). Of particular interest are the observed significant differences in EOS among the treatment groups. Notably, as the inclusion levels increased from 25% Canola to 100% Canola, the amounts of EOS also increased significantly. The EOS are a group of white blood cells that are responsible for boosting the defence systems of the body.

The increased concentrations of EOS observed in treatment groups containing Canola, may therefore indicate that there are some components of Canola that boosted the immune system of the lambs. Indeed, Canola contains phytochemicals, such as isoflavones, which influence the immune system of the animals (Rumsey *et al.*, 1997). Isoflavones influence the signal transduction process of macrophages and other phagocytic cells and the activity of cytotoxic T lymphocytes, thus influencing both non-specific and specific immune responses (Stewart & Hoskin, 1997). Any harmful effect(s) of Canola on the lambs, if any, would have been reflected by lower levels of hematological parameters (Bawala *et al.*, 2007; Minka & Ayo, 2007; Etim *et al.*, 2014).

3.6 Conclusion

A linear and steady increase in live weights was observed in all treatment groups. Live weight gains; ADG, ADFI, FCE and slaughter weights were all similar across treatments. Most haematological parameters fell within the recommended ranges for healthy animals. The results of the current study, therefore, show that Canola meal can replace soyabean meal in lambs' diet without any significant negative impact on growth performance and health of the lambs.

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CHAPTER 4: EFFECT OF REPLACING SOYABEAN MEAL WITH CANOLA OILCAKE ON MEAT QUALITY CHARACTERISTICS OF MUTTON MERINO LAMBS

Abstract

The study was carried out to determine the effect of replacing soyabean meal (SBM) with Canola meal (CM) on carcass measurements, meat quality and sensory characteristics of the Mutton Merino lambs. Nineteen lambs with an average body weight of $23\text{kg} \pm 2.64\text{kg}$ were used. The lambs were randomly assigned to five dietary treatments in a completely randomized block design and fed in individual cages for 60 days. The soyabean meal (SBM) in the control ration was replaced with Canola meal at 0%, 25 %, 50%, 75% and 100% inclusion levels. There was no significant effect ($P > 0.05$) of dietary treatment on carcass weight (CWT) (16.5 – 18.7kg), cold carcass weight (CCWT) (16.2 – 18.2kg), carcass length (78.7 – 83.7cm), ultimate meat pH (pH_u) (5.70 – 5.81) and temperature (9.07-10.7 °C). All lamb carcasses had a fat score of 2 and all the carcasses' conformations were graded 3. Lamb meat from different dietary regimens showed no difference in water holding capacity (0.36 – 0.38), cooking loss (10.8 – 13.6%), drip loss (2.27 – 3.67 %), evaporation loss (8.53 – 10%) and thaw loss (0 – 0.13%). The shear force measurements were also the same (1.67 – 2.17kg). There was no significant effect of diet on the lightness (L^*) (33.5 – 35.8), redness (a^*) (11.35 – 12.7), yellowness (b^*) (13.4 – 14.8), chroma (C^*) (17.6 - 19.6) and the hue angle (h) (47.8 - 50.2). For all the treatment groups, lambs meat was rated similarly by the sensory panels for overall lamb flavor (5.71 – 5.89), aroma (5.78 – 6), roast lamb (5.33 – 5.52), metallic (2.22 – 2.70), animal like (1.60 – 1.85), sour meat (6.22 – 6.74), impression juicy (5.41 – 5.89) and first bite (6.22 – 5.89). The muscle fibres (5.96 – 6.30) and the amount of connective tissue (5.70 – 6.07) also showed no significant differences. Canola meal can therefore replace soyabean meal in fattening lambs diets resulting in good quality meat that is highly acceptable.

4.1 Introduction

Meat forms a very important part of the human food chain. Currently, the growing meat consumption in the world, particularly in emerging countries, including South Africa, is not being matched equally by the growth of the local livestock production. This is causing imbalances (lower self-sufficiency level in meat and meat products) in South Africa 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 is exacerbating the problems of high livestock and meat prices (Smit *et al.*, 2014). In most sheep feeding systems, soya bean meal is the most popular protein supplement and hence requires consistent supply (Cromwell, 2000). However, the shortages of soybean meal in South Africa and the associated high prices of soya bean meal require that alternative protein sources be investigated. Among other sources, Canola meal (oil cake) has shown great promise (Widyaratne & Zijlstra, 2007; Little *et al.*, 2014, Smit *et al.*, 2014).

Recently research has shown that the use of oilseed such as Canola in the nutrition of ruminants, including sheep, can be an effective way of improving the quality of animal food products, particularly meat (Borys *et al.*, 2006). However, the efficacy of oilseeds depends on their partially rumen-protected nature and their fatty acid composition (Rizzi *et al.*, 2002). Although the current Canola variety (**CM-HP**) has less crude protein (35-40%) than SBM (48.5%) and about 3 times as much fiber, it is thought to have a greater concentration of digestible energy (AOF, 2007; Maison, 2013; Little *et al.*, 2014). In South Africa, Canola is a relatively new commercially cultivated oilseed crop produced mainly in Western and Southern Cape (Mosiane *et al.*, 2003; de Kock & Agenbag, 2009). Nevertheless, Canola production in South Africa has increased significantly over the years.

Several studies have been done in evaluating the effect of replacing soyabean meal with Canola in pigs (Ekpe *et al.*, 2000), poultry (Leeson, 1986), aquaculture (Plaipetch & Yakupitiyage, 2013), small ruminants (Leupp *et al.*, 2006), and large stock (Murphy *et al.*, 1995). However, the influence of Canola meal on meat quality characteristics in sheep is largely unknown in South Africa. Indeed there are no comparative data for SBM and Canola meal on meat quality of lambs. Additionally, in view of feed processors' and knowledge that nutrition of an animal can affect some meat quality aspects (Hopkins *et al.*, 1995, 2001), this study was designed to determine the effect of feeding Canola meal on meat quality attributes of mutton Merino lambs.

4.2 Materials and Methods

4.2.1 Study site, diets and experimental treatments

The description of the study area is explained in section 3.2.1, the experimental design and treatments are explained in section 3.2.2 while animal management and feeding is explained in section 3.2.4.

4.2.2 Slaughter procedures

Lambs were slaughtered at the end of the feeding trial at about seven months of age. Twenty four hours prior to slaughter, lambs were weighed and taken to Zeerust abattoir (80km from the North-West University, Mafikeng campus). At the abattoir, lambs were deprived of feed over night while were given free access to clean, fresh water. Lambs were electrically stunned to render them unconscious. Stunned lambs were hanged by shackling below the hock of one hind leg and hoisted with the head down. Bleeding was done by inserting a knife through the neck behind the jaw bone and below the first neck bone. Skinning was done by hand, followed by evisceration. The grading of the meat for fat and conformation was done by trained personnel

according to South African mutton board standards (The agricultural product standards act 1998). The carcasses were then washed and chilled overnight in a cold room at 2°C.

4.3 Measurements

4.3.1 Carcass traits

Immediately after slaughter, the hot carcass weight (HCW) was recorded. After chilling for 24 hours, the carcasses were reweighed to obtain the cold dressed weight (CDW). Carcass length was measured by the use of a tape from the neck downwards. After CDW measurements, the carcasses were sawn down at the middle line through the center of the vertebral column, according to dissection procedure described by Fisher & de Boer (1994). The left hand side (LHS) of each carcass was used to measure the carcass length. The sirloin and loin muscle were then removed starting from the 3rd vertebrae to the lumbar region for qualitative meat analysis. The meat samples were vacuum-packed and transported to the Meat Industry Centre at the Agricultural Research Centre (ARC), Irene, South Africa for meat quality evaluation.

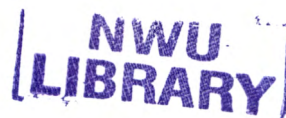
4.3.2 Dressing-out percentage

The dressing out percentage was determined by using the following equation:

$$\text{Dressingout \%} = \frac{\text{carcassweight}}{\text{slaughterweight}} \times 100\%$$

4.3.3 pH and temperature measurements

Ultimate pH (pH_u) and temperature were measured 24 hours post slaughter on the *Longissimusdorsi muscle* (central area of the loin) using a Corning Model 4 pH-temperature meter (Corning Glass Works, Medfield, MA) equipped with an Ingold spear-type electrode (IngoldMesstechnik AG, Udorf, Switzerland) (Stanford *et al.*, 2003). The carcasses were identified in slaughter sequence for temperature sampling (T₁₅) and pH_u.



4.3.4 Meat colour

Colour of the meat (L^* = Lightness, a^* = Redness and b^* = Yellowness) was determined using a Minolta colour-guide 45/0 BYK-Gardener GmbH machine, with a 20 mm diameter measurement area and illuminant D65-day light, 10° observation angle. There were three readings taken and this was done by rotating the Colour Guide 90° between each measurement, in order to obtain a representative average value of the colour. The guide was calibrated before measurements using the green standard. The muscle slices, 4cm in length, were allowed to bloom for 1 hour on a polystyrene tray. They were then overwrapped with polythelene film at 4 °C. Hue angle, $\tan^{-1} (b^*/a^*)$, and chroma, the square root of $a^{*2} + b^{*2}$, were then calculated (Priolo *et al.*, 2000)

4.3.5 Drip, cooking and evaporative loss

Meat was first prepared by boiling. It was then cooled to room temperature and the drip loss, cooking loss (CL) and the evaporation loss was determined. They were computed as:

$$\% \text{ Drip loss} = \frac{\text{Initial weight of meat}}{\text{final weight of meat}} \times 100$$

$$\text{Cooking loss \%} = \frac{\text{wt of raw steak after thawing} - \text{wt of cooked meat}}{\text{wt of steak after thawing}} \times 100$$

$$\text{Evaporation loss \%} = 100 - (\text{wt after cooking} - \text{raw weight}) \times 100$$

4.3.6 Meat tenderness

Meat tenderness (shear force measurements) was determined using Instron (3344, Universal Testing cross head speed at 400mm/min, one shear in the centre of each core). Following cooking, sub samples of specified core diameter were cored parallel to the grain of the meat. The samples were sheared perpendicular to the fibre direction using a Warner Bratzler (WB) shear device mounted on an Instron 3344 (Universal Testing) and mean maximum load (kg) was recorded for each sample (Xazela *et al.*,2012).

4.3.7 Sensory evaluation

Fifteen lamb loin chops from five dietary treatments were evaluated. The samples were cut into smaller pieces for easy preparation. A Type K thermocouple (Omega Engineering Inc., Stamford, CT) was placed in the geometric center of each chop and internal temperature was monitored during cooking using a microprocessor thermometer (model HH21, Omega Engineering Inc., Stamford, CT). Meat was cooked by grilling it in an electric grill (model GGR64, Salton, Inc., Mt. Prospect, IL), up to a temperature of 70°C. The meat samples were also boiled and salt was added for taste. Cooked meat was then wrapped in aluminum foil and maintained at 60°C using a heated pan carrier (Model UPCH400-110, Cambro MFG. CO., Huntington Beach, CA) until served to trained taste panelists. Meat qualities were rated for tenderness, juiciness, meaty flavor, overall flavor and overall acceptability. A 9 point Hedonic scale (1= Dislike extremely, 2= Dislike very much, 3= Dislike moderately, 4= Dislike slightly, 5= Intermediate, 6= Like slightly, 7= Like moderately, 8= Like very much, 9= Like extremely) was used to award meat from different heat and dietary treatments.

4.4 Statistical analysis

General linear models procedure (SAS, 2008) was used to determine the effect of diet on linear measurement, slaughter weight, cold dress mass, dressing out percent, cooking loss, meat colour (L^* , a^* , b^*) parameters, pH, carcass temperature, WB shear force and sensory characteristics. Sensory scores were log transformed [$\log (x + 1)$] to achieve normality before analysis. The sensory results were then reported as back-transformed means. The following SAS model was used:

$$Y_{ij} = \mu + D_i + E_{ij},$$

Where: Y_{ij} = observation (carcass traits, pH, colour, drip loss, cooking loss, shear force values, sensory scores), μ = population mean constant common to all observations; D_i = effect of dietary treatment; E_{ij} = random error term, assumed to be normally and independently distributed with mean 0 and variance equal to δ^2 . Mean separations was done using the PDIFF option in SAS (2008).

4.5 Results and discussion

The results of the effects of diet on carcass measurements are presented in Table 4.1. Dietary treatment had no effect on the carcass measurements. All lamb carcasses had a fat score of 2 and all the carcasses conformations were graded 3. This kind of fat is highly acceptable and indicates that both Canola meal and soyabean meal can yield carcasses with the same fat content. According to Clerk *et al.* (2003), high fat content is associated with coronary heart diseases and health/diet conscious consumers may be willing to sacrifice palatability for lower fat in meat to reduce this risk. Kerry *et al.* (2002) indicated that the increase of fat from less than 1% to 3% leads to improved palatability. Both the hot and cold carcass weights were statistically similar for all the treatment groups. This might be attributed to similar slaughter weights. The carcasses length ranged from 78.7cm to 83.7cm. The results indicate that there

was no significant effect of dietary treatment on the meat quality attributes of lamb meat. Similar results were also reported by several authors with different animal species (Ponnampalam *et al.*, 2005; Montazer-Sadegh *et al.*, 2008; Okrouhlá *et al.*, 2012).

The ultimate meat pH (pH_u) of the meat from all dietary treatments ranged from 5.7 - 5.8. This could be because of similar management of the lambs at the farm and during the experimental period. The pH of meat is regarded as the measure of acidity and the ultimate pH is determined by the extent of the pH decline 24 hours after slaughter (Klont 2005). The pH_u in all treatment groups were, however, slightly higher than the recommended pH of a good quality meat, which is usually from 5.4 to 5.7. This might have been due to lower glycogen reserve pre-slaughter caused by fasting such that the pH did not decline at the normal rate upon the onset of rigor mortis. High glycogen level at slaughter is essential for optimum meat quality. During rigor mortis, the substrate glucose, which is derived from glycogen, is converted to lactic acid. The built up of lactic acid is then responsible for post-mortem pH decline in the muscle. If the post mortem pH decline does not proceed normally (greater than 6.0), then the ultimate pH values will be higher than normal and the resultant meat is dark, firm and dry (DFD) which is described as being tougher and the muscle is firm due to the high water holding capacity and the surface feels dry as the water is tightly held within the muscle (Kerry *et al.*, 2002; Klont 2005).

Table 4.1: Effect of replacing soyabean meal with Canola meal in lambs diet on carcass measurement of the lambs

Carcass measurement	Dietary treatment ¹					SE	P-values
	CM0	CM25	CM50	CM75	CM100		
SLW (kg)	34.63	34.73	33.62	33.20	33.48	0.9	0.60
Carcass weight (kg)	18.7	18.7	17.7	17.7	16.5	0.76	0.30
Carcass conformation	3	3	3	3	3	0.00	0.00
Fat	2	2	2	2	2	0.00	0.00
Cold carcass weight (kg)	18.2	17.8	16.8	16.9	16.2	0.77	0.41
Length (cm)	83.7	83.3	79.5	80.7	78.7	1.96	0.32
pH _u	5.81	5.73	5.70	5.78	5.78	0.07	0.79
Temperature (°C)	10.3	9.40	9.07	10.2	10.7	1.71	0.96

¹Dietary treatment: CM0= 0% Canola meal; CM25=25% Canola meal; CM50= 50% Canola meal; CM75= 75% Canola meal; CM100= 100% Canola meal; SLW = slaughter weight;

²pH_u = ultimate pH at 24 hours

The meat temperature was also similar for all the groups. The cold carcass weight was also statically insignificant because lambs had the same carcass weight. Lamb meat from different dietary treatments did not differ in terms of water holding capacity, cooking loss, drip loss, evaporation loss, and thaw loss (Table 4.2). The shear force measurements were also similar. Drip loss is regarded as the amount of water that is lost during storage while cooking loss is the amount of water that is lost during cooking. Both the thaw and evaporative losses are components of cooking loss. The similarity in the water holding capacity of the lamb was attributed to the lack of differences in the pH of the meat as well as the fat content. The myofibrillar protein contains ionic charges that are capable of binding water and the most abundant of the proteins in the muscle fibre are the actin and myosin. The higher pH values indicated that there was an increase in the negatively charged ions that resulted in increased water holding capacity.

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). Since fat content was the same in the current study, then no difference could be expected in terms of shear forces. As fat is lower in density than heat – denatured protein in cooked meat, as the, percentage fat increases the overall meat density decreases and as bulk density decreases with a given bite of meat, the meat becomes more tender (Kerry *et al.*, 2002; Clark *et al.*, 2003). Meat from lambs was tender since the shear force values ranged from 1.7 to 2.1 kg, which is lower than the threshold values for shear force of 4.5 kg. This could further be explained by the similarities in the amount of connective tissues and muscle fibre. The higher the amount of connective tissues, the tougher the meat.

Table 4.2: Effect of dietary treatment on carcass characteristics of lamb meat

Carcass characteristics	Dietary treatments ¹					SE	P-values
	CM0	CM25	CM50	CM75	CM100		
Cooking loss (%)	13.6	10.8	11.4	10.8	13.2	1.53	0.56
Drip loss (%)	3.67	2.27	2.77	2.67	3.43	0.69	0.50
Evaporation loss (%)	10	8.57	8.60	8.53	9.73	1.03	0.74
Thaw loss (%)	0.07	0.07	0.13	0.00	0.13	0.05	0.30
Shear Force (kg)	1.67	2.17	1.90	1.87	1.89	0.28	0.80
Water holding capacity	0.36	0.38	0.38	0.38	0.37	0.03	0.98

¹Dietary treatments: CM0=0% Canola meal; CM25=25% Canola meal; CM50= 50% Canola meal; CM75= 75% Canola meal; CM100= 100% Canola meal

The effect of replacing soyabean meal with Canola oilcake on meat colour is presented in Table 4.3. There was no significant effect of diet on the colour of carcass. Meat from lambs fed control diet and those that received Canola meal had the same colour. Meat colour is the most important factor affecting consumer acceptance, purchasing decisions and satisfaction of meat products (Muchenje *et al.*, 2009). Colour was evaluated in the L^* , a^* , b^* system, where L^* measured the relative lightness, a^* the relative redness and b^* the relative yellowness. Mallia *et al.* (2000) classified regular meat at L^* : 45-53, Barbut (1996) at $L^* < 50$ and Owens *et al.* (2000) at $L^* < 53$. The L^* threshold for PSE meat is given as 50 by Joo *et al.* (1999) while Barbut, (1996) reported it as $L^* > 50$. PSE is a pale, soft and exudative meat that results from a short-term stress such as improper pre-slaughter handling. The meat has a lower than normal pH (5.4 – 5.7) and is capable of losing high amount of moisture during cooking and a resultant meat will be drier, tougher and not as flavorful (Kerry *et al.*, 2002).

But values of $L^* > 53$ for regular meat and $L^* < 45$ for DFD meat were also reported by Owens *et al.*, (2000). The Chroma and the hue angle also showed no difference between meat from lambs fed the control and those that received Canola meal. Since meat colour is determined by the content of myoglobin and its derivatives as well as the meat pH (Sebsibe, 2012), this similarity could be due to the fact that both the groups had no difference in the muscle pH. Higher meat pH results in lower L^* values, suggesting that high meat pH result in darker meat than normal meat pH, which is why the colour was not visibly dark in this study. Prioli *et al.* (2002) indicated that the more the hue angle is close to 90° , the more the colour corresponds to yellowness and in the current study the values were lower than that. Consumers are less likely to purchase yellow meat.

Table 4.3: Effect of dietary treatments on colour of lamb meat

Colour parameter ²	Dietary treatment					SE	P-values
	CM0	CM25	CM50	CM75	CM100		
L*	35.4	35.8	34.3	33.5	34.8	1.19	0.66
a*	12.6	12.7	12.4	12.5	11.4	1.06	0.90
b*	14.4	14.8	13.6	13.6	13.4	0.60	0.42
C*	19.1	19.6	18.5	18.5	17.6	1.09	0.75
H	48.9	49.4	47.8	47.8	50.2	1.73	0.82

CM0= 0% Canola meal; CM25=25% Canola meal; CM50= 50% Canola meal; CM75= 75% Canola meal; CM100= 100% Canola meal; L*=lightness, a*=redness, b*=yellowish, c*=chroma, h=hue angle

Results on sensory perception of mutton from lambs fed Canola oilcake are shown in Table 4.4. There was no significant difference in the sensory attributes of the lambs. The meat from all treatment groups was rated similarly for overall lamb flavor, aroma, roast lamb, metallic, animal like, sour meat, impression juicy, first bite and tenderness.

The 9-point hedonic scale used in these evaluations, the value of 5.0 corresponds to neither like nor dislike and all values above that indicates acceptability. The fact that sensory evaluation gave means greater than 5.0 indicated that the lamb meat was acceptable for all the treatments and the control diets except for metallic-like, animal-like and sour meat. Cooked meat is the result of a reaction between lean meat and lipids and is more aromatic compared to raw meat. Flavour aromatics are perceived by the olfactory senses during chewing and basic receptors on the tongue. Oral sensations are detected from the trigeminal receptor in the mouth that provides astringent and metallic sensory attributes and aftertastes are perceived after swallowing (Kerry *et al.*, 2002; Clark *et al.*, 2003). It then shows that both lamb meat from soyabean meal and Canola meal could be accepted at the same percentages. This similarity could be due to the fact that lambs had the same amount of fat. Juiciness is the capacity of the muscle to release both its constitutive water, regarded as the initial juiciness, and the infiltrated fat content, regarded as sustained juiciness. This, together with water and the melted lipid, constitutes a broth that when retained in the meat, is released upon chewing. This broth may also stimulate the flow of saliva and thus the meat's apparent juiciness (Dryden & Marchellow 1970; Clark *et al.*, 2003). Similarities in the first bite mean values could be attributed to similar shear force values for both the control and the treatment groups.

Table 4.4: Effect of replacing soyabean meal with Canola meal in finishing diets on consumer sensory perceptions of lamb meat

Sensory attributes	Dietary treatment					SE
	CM0	CM25	CM50	CM75	CM100	
Aroma	6.00	6.00	5.78	5.96	5.82	0.16
Roast lamb	5.37	5.52	5.33	5.34	5.41	0.30
Metallic like	2.70	2.22	2.63	2.33	2.48	0.29
Animal like	1.71	1.60	1.85	1.71	1.78	0.15
Sour meat	1.33	1.37	1.26	1.66	1.67	0.25
First bite	6.63	6.74	6.22	6.30	6.70	0.24
Impression of juiciness	5.41	5.89	5.44	5.41	5.41	0.23
Muscle fiber intensity	6.15	6.22	6	5.96	6.30	0.20
Amount of connective tissue	5.89	6.07	5.85	5.70	6.04	0.20
Overall lambflavour	5.74	5.89	5.74	5.78	5.71	0.11

CM0 = 0% Canola meal; CM25 = 25% Canola meal; CM50 = 50% Canola meal; CM75 = 75% Canola meal; CM100 = 100% Canola meal

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4.6 Conclusion

The results of the current study indicated that Canola meal can completely replace soyabean meal in the weaner lambs diet without any negative effect on the quality of the meat. Even though there was no difference in the conformation of the carcasses and the fat cover, but all the carcasses were of good quality. The lamb meat was tender and acceptable to consumers with a good colour.

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CHAPTER 5: GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 General discussion

The objective of the current study was to determine the possible effects of replacing soyabean meal with Canola meal in finishing diets offered to Mutton Merino lambs on growth performance, hematological and meat quality characteristics. Nineteen lambs with an average body weight of 23 ± 2.64 kg were used in a feeding trial. The lambs were randomly allotted to the five dietary treatments in which the soyabean meal (SBM) in the control ration (100% SBM) was replaced with Canola oilcake (CM) at 0%, 25%, 50%, 75% and 100% levels.

In chapter 3, the hematological characteristics and growth performance were determined. There was no significant difference in the rate of gain and weights of the lambs for all the treatments. The results showed no significant difference in the whole blood haematological count for all the treatments except for the mean corpuscular haemoglobin concentration (MCHC) and the monocytes (MONO) (both the absolute and the percentage). The red blood cell counts of the lambs were within the normal range ($9 - 15 \times 10^{12}/L$) reported for sheep (Cheesbrough, 2004; Merck Manual, 2012). The PCV values obtained in the present study (29.3 - 38.5%), were within the normal range (27 - 45%) reported for sheep (Merck Manual, 2012). The PCV counts were however closer to the higher levels (45%). The results of the haemoglobin (Hgb) counts (11.2 - 14.9 g/dL) showed no difference amongst the groups and were within the normal ranges (9 - 15g/dL) reported for sheep (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 highlighted that when

haematologic values fall with the normal range reported for lambs, it shows dietary treatments had no adverse effect on the health of the animals during the trials (Egbe *et al.*, 2000). There was no significant difference in the MCV and MCH counts of the lambs. The MCV values (30 – 32fl) were within the normal reference (28 – 40 fl) range while the MCH counts (11 – 14.1pg) were slightly above the normal range (8 – 12pg). There was a significant difference ($P < 0.001$) in the MCHC values between the treatment groups. The results showed that 75% level of inclusion of Canola meal in lambs' diets produced the highest red blood cell count.

The findings on the red blood cell distribution width counts obtained in the current study were within the normal range (16 – 22%) and the values were much closer to 22% than being closer to 16%. There was no significant difference for the white blood cell count and the values fell within the normal range. The white blood cell differential counts showed that the neutrophils counts (0.8 – 1.3%) were lower than the normal range (10 - 50%) for sheep (Coles, 1986; Merck manual, 2012) but were not significantly different from each other. The lymphocytes percentages were also lower than the normal ranges (40 – 75%). There was no significant difference for both percentage and absolute eosinophil and basophil. This similarity could be due to similar management of the lambs as the animals had minimal stress. The increase in the ratio of neutrophil to lymphocytes is an indicator of nutritional stress (Awodi *et al.*, 2005; Addas *et al.*, 2010). There was a significant difference ($P < 0.05$) between the groups for the percentage and absolute monocytes. The monocytes counts however were within the normal ranges (0 – 6). The lowest percentage was obtained with the control diet while highest was obtained in 50% Canola meal.

This shows that the percentage lymphocytes can only be increased when soyabean meal is replaced with the same amount of Canola meal. The same was recorded for the absolute

monocytes (Njidda *et al.*, 2014). There was no significant difference for both percentage and absolute eosinophil and basophil. The platelets had no significant difference.

Chapter 4 was based on determining the effects of replacing soyabean meal with different levels of Canola meal on meat quality characteristics and sensory attributes. There was no significant effect of the diet on the carcass measurements, water holding capacity, meat colour and sensory attributes of the lambs. The replacement produced carcasses with a fat score of 2 and all the carcasses were graded 3 indicating meat of a good quality. Meat had a pH of 5.7 – 5.8 indicating that the meat was juicy, tender with an intense flavor (Okrouhlá *et al.*, 2012). The tenderness was also described by the shear force value being lower than the threshold values of 4.5kg. The results of the sensory evaluation revealed that lambs meat was acceptable.

5.2 Conclusion

The replacement of soyabean meal with Canola oilcake did not have a negative impact on the growth performance, hematological and meat quality characteristics. It was found that growth performance, health and meat quality of the lambs was similar when fed either soyabean meal or Canola meal. The inclusion of Canola meal can also produce meat of good quality which is tender and juicy and that is highly acceptable to consumers.

5.3 Recommendations

- ✓ Farmer and feed companies can completely replace soyabean meal in the diets of lambs with Canola meal to improve the performance of the animals
- ✓ Further studies need to be carried out to determine the effect of replacing soyabean meal on fatty acids and antioxidants stability of the lambs.

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