

**EFFECT OF LOCATION AND DRYING METHODS ON NUTRIENT COMPOSITION,
APPARENT DIGESTIBILITY, GROWTH PERFORMANCE AND CARCASS
CHARACTERISTICS OF SOUTH AFRICAN MUTTON MERINO LAMBS FED DIFFERENT
LEVELS OF DRIED MARULA FRUIT PEELS**

BY

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A dissertation submitted to the department of Animal Science, Faculty of science, engineering,
and agriculture, University of Venda in fulfilment of the requirement for degree of Master of
Science in Agriculture (AGMAAS).



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Declaration

I, **Ronewa Murovhi** (student number: 15000963), hereby declare that this proposal for Master of Science in Agriculture (AGMAAS) submitted to the Department of Animal Science, School of Agriculture, at the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and in execution, and all reference material contained therein has been duly acknowledged.

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Abstract

The purpose of this study was to determine the effect of location and drying methods on nutrient composition of dried marula fruit peels and apparent digestibility, and growth performance as well as carcass characteristics of South African mutton merino lambs fed different levels of dried marula fruit peels. Marula (*Sclerocarya birrea*) is a medium sized tree belonging to the Brachystegia genus. Several experiments were conducted to evaluate the chemical composition of dried marula fruit peels where the DM, OM, CP, CF, ADF, NDF, and GE were determined. All the data in this experiment were subjected to analysis of variance for a 2x2 factorial in a completely randomised design using a GLM procedure of Minitab 19(Minitab, 2019). Tukey's studentised multiple range test determined statistically significant differences among the means. The dry matter of fresh marula fruit peels has shown a significant difference ($P < 0.01$). The dry matter of fresh marula fruit peels from Tzaneen using freeze and oven-drying methods was higher than those from Phalaborwa. The dry matter, crude protein, ash, ether extract, acid detergent lignin, and gross energy contents of dried marula fruit peels for both locations and drying methods were not significantly different ($P > 0.05$). The crude fibre, Acid detergent fibre, and nitrogen detergent fibre results for both location and drying methods were significantly different ($P < 0.01$). The crude fibre and nitrogen detergent fibre from Tzaneen were found to be higher than those from Phalaborwa when a freeze-drying method was used. However, when using an oven-drying method, the crude fiber, nitrogen detergent fiber, and acid detergent lignin contents were higher in Phalaborwa.

Apparent digestibility of DM, CP, and OM of the diet was determined in a completely randomised design and the means were compared using a Tuckey method at a 95% confidence level. The experiment was conducted in the last ten days of growth trial. A total of 9 male South African mutton merino sheep of approximately 35kg of weight were used in this experiment. The results revealed that the inclusion levels of dried marula fruit peels in the animal diet did not affect ($P > 0.05$) the CP intake. However, a significant difference ($P < 0.01$) was observed in the OM intake by the lambs. The inclusion levels of dried marula fruit peels in the diet did not affect ($P > 0.05$) the faecal excretion of nutrients by lambs. A non-significance difference ($P > 0.05$) was observed in the digestibility of nutrients.

The determination of growth performance and carcass characteristics of the lambs fed different levels of dried marula fruit peels was conducted, where the ADFI, ADG, FCR and hot carcass weight, cold carcass weight, dressing percentage were measured respectively. A completely randomised design was used in this experiment with seven animals per treatment. Before the trial, the lambs were vaccinated against brucellosis, pulpy kidney and treated for internal parasites. The inclusion levels of dried marula fruit peels had no significant impact ($P>0.05$) on the growth performance and carcass characteristics. This research has revealed that dried marula fruit peels can be used as a potential energy source for lambs without negatively affecting the growth and carcass characteristics of lambs at up to 10% inclusion level.

Keywords: By-products, Growth performance, Apparent digestibility, Carcass characteristics, Chemical composition, SA merino lambs, Dried marula fruit peels.

Dedications

I want to dedicate this work to my husband and kids, for their strength, understanding, support and encouragement when I confronted setbacks during the study.

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List of abbreviations

%	Percentage
°C	Degrees Celsius
am	After morning.
ANOVA	Analysis of variance
ADF	Acid detergent fibre
ADFI	Average daily feed intake
AWG	Average weekly gain
DMFP	Dried marula fruit peels
DCP	Dried citrus pulp
DM	Dry matter
CP	Crude protein
EE	Ether extract
NDF	Nitrogen detergent fibre
CF	Crude fibre
OM	Organic matter
FCR	Feed Conversion Ratio
FBW	Final body weight
GIT	Gastrointestinal tract
EBW	Empty body weight
HCY	Hot carcass yield
IBW	Initial body weight

CCW

Cold carcass weight

CL

Chilling loss

CCY

Cold carcass yield

DCP

Dried citrus pulp

DMFP

Dried marula fruit peels

CHAPTER ONE

INTRODUCTION AND BACKGROUND

This chapter provides an overview of the research and its context. The problem statement is outlined, as are the study's motivation and objectives.

1. Introduction

1.1 Background of the study

The most used energy source for animals in South Africa and some other parts of Africa is maize and some of the alternative energy sources that have been used in animal nutrition are citrus pulp and popcorn waste (Oladejo *et al*, 2012; Steyn *et al*, 2017; Nkosi *et al*, 2010). According to Nkosi *et al*, (2010) approximately 66% of maize produced around the world is used in animal nutrition while 25% is for human consumption. Due to the increase in population and rise in competition for maize between livestock and humans, it is important to look for an alternative energy source for animals. The amount of nutrients that an animal receives determines how well it will grow and develop, which is balanced energy and protein in their feed (Sayed, 2009; White and Hegarty, 2014). Energy is the most limiting factor in sheep, energy deficiency may result in reduced conception rate, lambing rate, milk production, and rate of gain and in severe situations it can result in loss of weight and death (Johnson, 1997). Energy and protein are the major dietary elements that affect growth performance, quantity of carcass as well as productivity in sheep (Sayed, 2009). A significant amount of the marula fruit waste produced during the production of marula beer are found in the lowveld of the province of Limpopo. Some of these wastes are consumed by ruminants at the disposal locations, the majority of the wastes remain unutilized, which poses a risk of land pollution. The marula fruit contains a significant amount of carbohydrates roughly 14% (Dube *et al*, 2012). Fruit waste has a high energy content that makes it a viable alternative to maize meal for ruminants, particularly in feedlots. Thus, this study's objective was to evaluate the use of dried marula fruit peels for feedlot lambs' consumption as an energy source.

1.2 Problem statement

The lowveld of Limpopo province has a considerable amount of marula fruit waste generated during marula beer making. This waste is made up of marula seeds and marula fruit skins. Some quantities of this waste are eaten by ruminants at their disposal sites, however, most of the waste remains unutilized and this creates a possible land pollution danger, and the nutritive value of marula fruit skin remains unknown. Marula fruits are seasonal, ripen quickly, and contain a high percentage of moisture of about 85% (Ndlovu, 2016). Fresh Marula fruit peels only last two to three days due to their high moisture content. However, they can be preserved for use in feeding by drying. The earliest industrial processing technique for fruit preservation is drying (Doymaz, 2008). According to Nkosi et al, (2010) approximately 66% of maize produced around the world is used in animal nutrition while 25% is for human consumption. However, an increase in human population creates even more competition between man and animals for maize. Due to the increase in human population, the competition between animals and humans for maize should be minimized.

1.3 Justification

In the literature, there is no information on the nutritive value of marula fruit peels as feed for ruminants. Marula fruits can be used as feed for goats and pigs (Shackleton *et al.*, 2002), however, no research has been conducted about the use of dried marula fruit peels as a source of energy for lambs. Feeding animals with marula fruit peels will help prevent land pollution, and this will also prevent the animals from being common food for humans. In times when maize is expensive, dried marula peels which are preserved can be used as the energy source for the lambs.

1.4 Main objectives

To evaluate the nutritive value of marula fruit peel-based sheep grower diet.

1.4.1 Specific objectives

To determine

- Impact of drying methods and location on the chemical composition of marula fruit peels (DM, OM, CP, CF, ADF, NDF AND GE).
- Apparent digestibility of DM, CP, and GE of the diet.
- Growth performance of lambs (AFI, ADG, FCR).
- Carcass characteristics of the lamb (hot carcass weight, cold carcass weight and dressing percentage).

1.4.2 Null hypothesis

1. Different sampling areas and drying methods have no significant effect on:
 - a) Chemical composition
2. Marula fruit skin inclusion in the diets of lambs has no significant effect on:
 - a) Apparent digestibility
 - b) Growth performance
 - c) Carcass characteristic

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CHAPTER TWO

LITERATURE REVIEW

2. Introduction

This chapter reviews marula fruit peels as a source of energy for South African mutton merino lambs. However, arguably, there is little literature available regarding the use of marula fruit peels as the source of energy for South African mutton merino lambs that has been conducted in South Africa. Therefore, citrus pulp will be used in this literature review. The chapter will give the little information available that has been documented about marula fruit and detailed information about the chemical composition of citrus pulp, the apparent digestibility of DM, CP, and GE of the diet containing citrus pulp, the effect of feeding citrus pulp on the growth performance and carcass characteristics of the animal. Lambs can also be fed dried citrus pulp as an energy source. In contrast to starch-rich cereals, citrus pulp has a high amount of digestible fibre, making it a high-energy feedstuff that can be used to prevent ruminal pH drop and adverse effects on forage digestibility in ruminants (Salami *et al.*, 2020). South African farmers prefer South African merino sheep because of its multiple rearing ability (Hoffman *et al.*, 2003). Merino sheep are considered to be important due to their economic value (Van Graan *et al.*, 2018).

2.2 Different drying methods that can be used in preserving food

- 2.2.1 Sun drying method is a type of a method used to preserve food by placing food on a tray under the sun, however, this method can be risky because weather is uncontrollable as it may lead to spoilage (Ahmed *et al.*, 2013).
- 2.2.2 Ramya and Jain (2016) defined osmotic dehydration as a simultaneous mass transfer process that primarily encourages the flow of water molecules from the food to the osmo-active solution and some migration of solutes from the solution into the food. Osmotic dehydration is known to improve shelf life of fruits, however if it is overdone the fruits can lose nutrients. Ahmed *et al.* (2013) defined Osmotic dehydration as the technique of removing water from a solid biological material that contains water by immersing it in a concentrated aqueous solution.
- 2.2.3 Oven drying method it involves heating of fruits in a controlled environment. If the oven is not properly controlled, the fruits may lose water soluble vitamins (Coklar *et al.*, 2018)
- 2.2.4 Freeze drying method is a technique that preserves biologically active chemicals in great amounts by operating at a low temperature (Radojčin *et al.*, 2021). According to Orak *et al.* (2019) freeze drying method is best as it keeps the nutritional value of the fruits.

2.3 Marula fruit (*sclerocarya birrea*)

2.3.1 Description and uses of the fruit

Marula fruit is the size of a small plum which is high in vitamin C (Ndlovu, 2016). It ripens from December to March. This fruit has a thick light-yellow skin, with an aromatic smell and sweet-sour taste when ripe. Fruit juice and pulp are known for making alcoholic beverages, and jam, and the fruit kernel is used for the extraction of marula oil. Marula seed cake has been successfully used as a protein supplement for goats (Mlambo, 2011). Geographic factors such as climate and soil type have an effect on the availability and quality of marula fruits because marula fruits thrive in areas that are warm, dry and with low humidity and they prefer well drained soil (Petje, 2008).

2.3.2 Nutritional composition

The pulp of the marula fruit is rich in macro and micronutrients, including the most common organic acids, ascorbic and citric acid, and the most common amino acids, glutamine, arginine, and asparagine (Mdluli and Owusu-Apenten, 2003). Muhammad et al. (2016) reported that marula fruit has a high protein content of 20%-35%, an energy value of 25 MJ/Kg and an average of 30.96 % CP. The crude protein value of marula fruit reported by Muhammad et al. (2016) is the same as the crude protein reported by Aganga and Mosase (2001) which is 36.96%. Hiwilepo (2013) reported that the moisture content of marula flesh ranges between 79 – 92 g/100g.

The energy values of marula fruit flesh, the nuts and the kernel are approximately 130kj/100g, 3138kj/100g, 2699kj/100g – 2703kj/100g, respectively. The dietary fibre has been reported to be more than 2.9% of the fresh weight of the fruit (Hiwilepo, 2013).

2.4 Chemical composition analysis of other energy sources for ruminants

2.4.1 Chemical composition of citrus pulp

The ash content of the dried citrus pulp was found to be between 5% and 16.85% (Fegeros *et al.*, 1995, Caparra *et al.*, 2007, Sharif *et al.*, 2018). The fat content was found to be 2.4% (Caparra *et al.*, 2007). However the fat content of the fresh orange peel was found to be 2.78 ± 0.01 (Adewole *et al.*, 2014). Fats in feed are important since it improves animal performance.

Fats supplements help improve the absorption of fat-soluble vitamin (Çetingül and Yardımçı, 2008). NDF, ADF, OM and DM of the dried citrus pulp were found to be between 19% - 21%, 12% -25.7%, 83%-95% and 87%-91% respectively (Fegeros *et al.*, 1995, Sharif *et al.*, 2018, Steyn *et al.*, 2017). Fegeros et al, 1995 found that the DCP is a bulky concentrate rich in pectin that has a low CP of about 7% and a high NDF of about 23%. Its energy content is considerable, and some

of its characteristics are similar to those of roughage, which helps to maintain a reasonably high ruminal pH of 10. The chemical composition of the dried citrus pulp showed that it is a great ingredient for ruminants and the results of CP, NDF, and ADF reported by Ibrahim et al, (2011) are similar to the findings of Sharif et al, (2017), where the values were 6.40%, 26.21% and 20.35% respectively. Citrus pulp's high level of easily fermentable carbohydrates suggests that it has a high nutritional value based on its nutritional chemical makeup; nevertheless, its protein content is minimal and has little biological value and digestibility (Caparra *et al.*, 2007). The results of the analysis of DCP in Sharif et al, (2017) showed that DCP metabolisable energy content was 3056 kcal/kg DM.

2.5 Apparent digestibility

In a digestibility trial, a known amount of food under investigation is given to animals and faecal output is measured (McDonald *et al.*, 2011). Ranilla et al, (2018) found that Citrus pulp substituted for maize in the diet enhanced the apparent digestibility of dry matter and had no detrimental effect on ruminal fermentation in Rusitec fermenters. The study's findings suggest that by-products from the juice industry enhance ruminal fermentation, ruminant diets may benefit from including them. Sharif et al, (2017) have reported that feeding lambs with DCP did not have a significant effect on the DM digestibility. The higher the level of DCP in the diet of the sheep, the higher the digestibility (Sudweek, 1977). Bueno (2002) stated that feeding DCP to Saanen kids did not affect the nitrogen balance.

2.6 Gross Energy

Singh and Oosting (1993) defined gross energy as the energy content of the feed. DCP has high amounts of fibre (15.69% for CF, 23.37% for NDF, and 21.49% for ADF), low levels of gross energy (3.60 Mcal/kg), CP (6.17%), and amino acids (0.02 to 0.54%); in feed practice, DCP should be used in conjunction with high-energy or protein feed ingredients. (Wang *et al.*, 2017).

2.7 Growth performance and carcass characteristics

(Sharif *et al.*, 2018) discovered that lambs can safely consume up to 40% of their diet as DCP, with no negative effects on feed intake or growth performance. The usage of DCP in the diet led to the creation of an affordable feed formulation. Bueno *et al.*, (2002) shared that the DCP improved growth performance in Saanen kids. This proves that DCP is suitable to be fed to ruminants since it does not bring about negative effects but rather good results. Ahooui *et al.*, (2011) reported that feed containing DCP can increase the daily weight gain and feed conversion ratio of fattening male calves. Carparra *et al.*, (2007) revealed that only 30% inclusion of DCP in the diet of lambs causes positive results, however more than that for example 40% of DCP in the diets negatively affects the feed conversion efficiency, carcass characteristics and dressing percentage. Carcass characteristics such as slaughter weight have an affect the overall yield and quality (Park *et al.*, 2002). Some of the key attribute of carcass quality includes yield grade, tenderness, color uniformity, and fat content (Corazzin *et al.*, 2019).

2.8 Summary of literature review

It can be concluded that dried marula fruit peels can be successfully fed to lambs without any negative effect on feed intake, growth performance and carcass characteristics. Some of the nutritional composition of marula fruit pulp and citrus pulp are not different, and ruminants have been effectively fed citrus pulp without experiencing any negative effects on growth, digestibility, or intake.

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CHAPTER THREE

CHEMICAL COMPOSITION OF MARULA FRUIT PEELS

3.1 Introduction

Some parts of South Africa receive rain only in the summer, resulting in a shortage of pastures used as a source of energy for ruminants (Mikasi, *et al.*, 2018). Therefore, looking for an alternative source of energy for ruminants that can be used during a time of need is essential. South Africa is one of the tropical countries which provides favourable environmental conditions for marula trees (*sclerocarya birrea*) to grow naturally. Marula fruits are used for various purposes, which include making Amarula cream liquor and homemade beer, and its kernel oil is used for pharmaceutical and cosmetic industries (Nwonwu, 2007). Marula fruit peels that remain after removing the kernels can be used as feed for ruminants. Marula fruits are available in the

summer, and most remain unutilised, which may lead to the wastage of possible feed sources. Preserving marula fruit peels can mitigate this challenge. Marula fruits are seasonal, and their peels can be preserved through drying during fruiting seasons.

Drying is the oldest way of preserving food by lowering the moisture content to prevent spoilage by microorganisms (Ndlovu, 2016). There is a need to investigate the chemical composition of these marula fruit peels before incorporating them into animal feed as a source of energy since there is very little information about the chemical composition of these peels. Different locations have different environmental conditions that may influence marula fruits' chemical composition. This is supported by the data obtained from Agricultural Research Council (ARC), which shows that Tzaneen receives more rain than the Phalaborwa area. A study by Soro *et al*, (2011) revealed that the shea fruit yield increases as the average monthly rainfall increases. This study aims to evaluate the effect of location and drying methods on the nutrient composition of dried marula fruit peels.

3.2 Material and method

3.2.1 Description of the study area

The agriculture experimental farm served as the study's location (22° 58' 32" S, 30° 26' 45" E; Altitude of 596 above sea level), and the samples were analysed in the animal science nutrition laboratory, University of Venda, Thohoyandou. The daily temperatures at Thohoyandou range from a minimum of 18°C to a maximum of about 31°C (Rambau et al., 2016). The area receives an average annual rainfall of ±500 mm that falls predominantly in summer.

3.2.2 Sample collection and preparation.

Marula fruit peels were collected from Phalaborwa and Tzaneen from people who brew marula beer. A subsample from the samples collected from the abovementioned areas was dried using two different drying methods, freeze-drying, and oven-drying, before chemical composition analysis in the animal science and biochemistry lab at the University of Venda, Thohoyandou.

3.3 Chemical Composition Determination

3.3.1 Nutrient analysis

3.3.1.1 Determination of dry matter

The Association of Official Analytical Chemists' method was used in determining the DM (AOAC, 2000 method 934.01). Then, 5g of Fresh marula fruit peels were dried using an oven at 60°C until constant weight was achieved. The peels were ground using a Retsch ZM 200 grinder to pass through a 1mm sieve for chemical analysis. The DM was calculated by dividing the mass of the crucible containing the dried samples by the mass of the crucible containing fresh samples multiplied by 100:

$$\% \text{ DM} = \frac{\text{mass of dried sample}}{\text{mass of fresh samples}} \times 100$$

3.3.1.2 Determination of ash content and calculation of OM

According to the Association of Official Analytical Chemists (AOAC, 2000 official method 942.05), The sample was ignited at 500°C for six hours in a muffle furnace in order to determine the ash content. Two hours was given for the samples from the furnace to cool. The crucibles were then placed in the desiccator for 30 minutes. Ash content was calculated as follows:

$$\text{Ash \%} = \frac{\text{weight of test portion}(g) - \text{weight loss on ashing}(g)}{\text{weight of the test portion}(g)} \times 100$$

Then OM was calculated from the ash content of the sample as follows:

$$\% \text{ Organic material on DM basis} = 100 - \% \text{ Ash on DM basis}$$

3.3.1.3 Determination of ether extract (EE)

The EE was determined according to the Association of Official Analytical Chemists (AOAC, 2002 official method 920.39) using the VELP® SCIENTIFICA SER 148 Solvent Extractor. An extraction vessel was placed in an oven overnight at 100°C. it was then cooled for 30 minutes in a desiccator,

and its weight was recorded. Then, 2g of sample was weighed and transferred to the extraction thimble. A small, defatted cotton wool was inserted in a thimble to keep the sample in place during the extraction. After the extraction unit has completed extracting fat, and ether has been evaporated, the extraction vessels were placed in an oven for 2 hours at 100°C. After 2 hours, the extraction vessels were placed in a desiccator for 30 minutes, and weight was taken. Then, 10 ml diethyl ether was added to the used cup to remove fat.

The % EE was calculated as follows:

$$\%EE = \frac{\text{Weight of the extraction vessel with fat} + \text{Weight of empty vessel}}{\text{Wt of the sample}} \times 100$$

3.3.1.4 Determination of crude protein

The nitrogen content of marula fruit peels was determined using the Dumas method with a LECO FP 528 based on AOAC,2002; method 984.13). The sample was combusted at a high temperature of about 900°C in the presence of oxygen. The instrument was first calibrated by analysing a pure material with a known nitrogen concentration. The sample of 0.1000g dried marula fruit peels was weighed and placed in a foil.

The foil was folded with a sample, and the weight was taken. The foil containing the sample was then placed in a carousel for a Leco instrument to analyse the sample automatically. Once the analysis was complete, the system was switched off and all three gas bottles were closed.

%percentage crude protein was calculated as follows:

$$\%Crude\ Protein = \%Nitrogen \times \text{Protein conversion factor (6.25)}.$$

3.3.1.5 Determination of crude fibre (CF)

The CF was determined according to AOAC (2000, method 978.10). Samples were boiled first with 1.25% sulphuric acid (H₂SO₄) and subsequently with 1.25% sodium hydroxide (NaOH) for 30 min. The residues containing crude fibre were dried to a constant weight, and the dried residues were then ignited in the muffle furnace. The crude fibre content was estimated as follows:

$$\%Crude\ Fibre = \frac{\text{pre-ash weight} - \text{post-ash}}{\text{weight of the sample}} \times 100$$

3.3.1.6 Determination of Neutral Detergent Fibre (NDF)

The Determination of NDF was done according to the method of Robertson and van Soest (1981) (Method 968.06). Then, 1g of dried sample was dried and ground to pass through a 1mm sieve. The samples were transferred into a 500ml beaker containing an NDF solution and 0.5g sodium sulfide and heated on a hot plate. After 1 hour of heating, the sample mixture was allowed to cool for 10 minutes, and samples were filtered using hot water to remove residues. Following collection of the samples into a crucible, they were put in the oven for six hours at 105°C.

3.3.1.7 Determination of Acid Detergent Fibre (ADF)

The ADF was determined according to the method of (AOAC, 2000 Method 968.06). Samples of marula fruit peels were digested in a pepsin-acid solution and acid detergent solution.

3.3.1.8 Determination of Acid Detergent lignin (ADL)

The ADL was determined according to the method of (Goering and Van Soest, 1970). Samples of marula fruit peels were subjected to the ADF procedure, and the residues were further digested in sulphuric acid.

3.3.1.9 Gross energy (GE)

The GE was determined by ignition of the sample using a Bomb MC-1000 modular Calorimeter.

3.4 Experimental design

A 2 x 2 factorial design was used, where 2 represents the sample sites (Phalaborwa and Tzaneen), and the other 2 represents the drying methods (freeze and Oven drying).

3.5 Data analysis

All the data in this experiment were subjected to analysis of variance for a 2x2 factorial in a completely randomised design using a GLM procedure of Minitab 19 (Minitab, 2019). Tukey's studentised multiple range test determined statistically significant differences among the means at a 95% significance level.

The statistical model used was as follows:

$$Y_{ij} = \mu + \alpha_i + G_j + (\alpha G)_{ij} + e_{ij}$$

Where y_{ij} = is the observations: OM, DM, CP, NDF, ADF, ADL, Fat, Ash,

μ = overall mean

α_i = the effect of sample sites

G_j = effect of the drying methods

$(\alpha G)_{ij}$ = sample sites x drying methods interaction

e_{ij} = random error

3.6 Results

Table 1: Chemical composition analysis (%) of marula fruit peels from two locations (Phalaborwa and Tzaneen) using two drying methods (Oven and Freeze-drying method)

Location	Drying Method	DM (fresh peels)	DM (dried peels)	ASH (dried peels)	CP (dried peels)	EE (dried peels)	CF (dried peels)	ADF (dried peels)	NDF (dried peels)	ADL (dried peels)	ENEG (Mj/100g)
TZN	FM	38.37 ^b	89.95 ^a	8.43 ^a	4.28 ^a	2.44 ^a	18.13 ^b	22.30 ^d	25.64 ^b	5.63 ^b	1.431 ^a

	OM	49.81 ^a	88.89 ^a	7.24 ^a	4.06 ^a	1.91 ^a	18.88 ^b	28.61 ^b	26.29 ^b	7.10 ^{ab}	1.442 ^a
PLB	FM	35.99 ^b	88.91 ^a	8.21 ^a	4.30 ^a	1.93 ^a	17.57 ^b	25.43 ^c	24.98 ^b	7.41 ^{ab}	1.442 ^a
	OM	35.14 ^b	85.54 ^a	9.12 ^a	4.09 ^a	2.35 ^a	20.01 ^a	30.65 ^a	28.03 ^a	9.11 ^a	1.421 ^a
SEM		0.640	2.00	0.368	0.794	0.243	0.440	0.421	0.709	1.090	8.440
Location Means											
TZN		44.09 ^a	89.42 ^a	7.83 ^a	4.17 ^a	2.17 ^a	18.00 ^b	25.45 ^b	25.96 ^b	5.37 ^b	1.437 ^a
PLB		35.56 ^b	87.22 ^a	8.66 ^a	4.44 ^a	2.14 ^b	19.59 ^a	33.04 ^a	31.98 ^a	9.22 ^a	1.421 ^a
SEM		0.452	1.550	0.260	0.562	0.172	0.311	0.298	0.501	0.773	5.970
Drying method means											
FM		37.18 ^b	89.42 ^a	8.32 ^a	4.29 ^a	2.18 ^a	17.45 ^b	23.87 ^b	25.31 ^b	5.52 ^b	1.426 ^a
OM		42.48 ^a	87.22 ^a	8.18 ^a	4.07 ^a	2.13 ^a	19.75 ^a	34.63 ^a	32.64 ^a	9.06 ^a	1.432 ^a
SEM		0.452	1.550	0.260	0.562	0.172	0.311	0.298	0.501	0.773	5.970
Significance											
Location(L)		*	Ns	Ns	Ns	Ns	*	**	**	*	Ns
Drying methods(D)		*	Ns	Ns	Ns	Ns	*	**	**	*	Ns
LXD		*	Ns	Ns	Ns	Ns	**	**	**	Ns	Ns

*: significantly different ($P < 0.05$); **: significantly different ($p < 0.01$) ; Ns: non-significant ($P > 0.05$) ; FM: Freeze-drying method; OM: Oven-drying method; TZN: Tzaneen ; PLB: Phalaborwa ; SEM: standard error means; DXL: Location X Drying methods; DM: Dry Matter; CP: Crude Protein; EE: Ether Extract; CF: Crude Fiber; ADF: Acid Detergent Fiber; NDF: Neutral Detergent Fiber; ADL: Acid Detergent Lignin

3.6.1 Description of Results

Table 1 shows the results of the chemical composition of marula fruit peels of the interactions between locations (Phalaborwa and Tzaneen) and drying methods (oven and freeze-drying method). The dry matter of fresh marula fruit peels has shown a significant difference ($P < 0.01$). The dry matter of fresh marula fruit peels from Tzaneen using freeze and oven-drying methods was higher than those from Phalaborwa. The dry matter, crude protein, ash, ether extract, acid detergent lignin, and gross energy contents of dried marula fruit peels for both locations and drying methods were not significantly different ($P > 0.05$). The crude fibre, Acid detergent fibre, and

nitrogen detergent fibre results for both location and drying methods were significantly different ($P < 0.01$). The crude fibre and nitrogen detergent fibre from Tzaneen were found to be higher than those from Phalaborwa when a freeze-drying method was used. However, when using an oven-drying method, the crude fibre, nitrogen detergent fibre, and acid detergent lignin contents were higher in Phalaborwa.

3.7 Discussion

3.7.1 Chemical Composition Analysis Data

The DM content of fresh marula fruit peels from this study ranged between 35g and 45g. However, Makhamedzha (2017) reported the DM of marula peels to be 16g/kg, which was lower than the DM found in this study. The difference in these DM results could be the locations where the peels were found. There was similar CP and EE content of dried marula fruit peels for both the locations and drying methods. Alnaimy *et al.* (2017) reported a CP of 6.9% and EE of 3.8% of dried citrus pulp, which was higher than the CP and EE content of dried marula fruit peels. The difference in the CP and EE content could be the difference in plant species, weather, and location where the plants are found. ARC (2020) results show that different locations may receive different annual rainfall; hence, the annual rainfall received in 2020 in Phalaborwa was reported to be lower than that received in Phalaborwa the same year.

The non-significance difference in the gross energy of dried marula fruit peels in this study may be attributed to the similar EE and crude protein content. The fat content contributes to the energy content of the feed (Mikasi *et al.*, 2018). The chemical composition of dried marula fruit peels from Phalaborwa and Tzaneen in this study contradicts with the chemical composition of dried citrus pulp obtained by Rahmahn (2023), who observed 90.63% DM, 7%CP, 21.6%NDF, and 15.9% ADF.

The DM and CP content contained in DMFP are lower than those obtained from DCP; however, the ADF and NDF content of dried citrus pulp were greater than those in dried marula fruit peels. The difference in these results could be that the peels came from different fruits and how the samples were processed.

Muhammad *et al.* (2016) reported that fresh marula fruit's average crude protein content was 30.96%, much higher than the crude protein of dried marula fruit peels in this study. The crude protein content of dried citrus pulp obtained by Fegeros *et al.* (1995), Ibrahim *et al.* (2011), and Alsaied *et al.* (2019) was found to be higher than the CP found in this study. The CF and ash

content reported by Alnaimy *et al.*, (2017) was 12.68% and 3.71%, lower than the CF and ash content found in this study.

The NDF, ADL, and ADF content from both locations using the freeze-drying method were lower. These results concur with the results found by Jancik *et al.* (2017), who reported that freeze-dried samples had lower NDF, ADF, and ADL content than those that were dried using a forced air oven. This shows that; indeed, drying methods influence the nutritive value of samples.

3.8 Conclusion

The dry matter of fresh marula fruit peels in this study was found to be low, which suggests that its moisture content is high. Therefore, it can be concluded that there is a need to preserve marula fruit peels to prevent spoiling.

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CHAPTER FOUR

APPARENT DIGESTIBILITY OF MARULA FRUIT PEELS-BASED DIET

4 Introduction

According to Robbins (2012), apparent digestibility can be defined as the ratio of the amount of matter or energy that is consumed to that through digestion. Apparent digestibility increases asymptotically as feed intake increases, but at a low intake level, endogenous losses remains constant which results in decreased apparent digestibility (Robbins, 2012). When an animal is presented with an unfamiliar meal and its intake is low, the apparent digestibility estimate may be highly skewed (Sibbald, 1975, 1976; Sibbald and Kramer, 1977). The availability of energy and nutrients is generally indicated well by apparent digestibility, which offers a logical foundation for designing diets that satisfy certain requirements for the available nutrients (Bureau, 1999). It is crucial to employ alternative energy sources in sheep nutrition to lower the cost of producing animals and provide a good home for agricultural output leftovers. Since food accounts for more than 70% of all expenses related to animal production, most of the recent research has concentrated on agro-industrial items in feed, which can be utilised as a substitute for ruminant nutrition due to their availability (Ajila *et al.*, 2019).

4.1 Material and methods

4.1.1 Description of the study area

The study was conducted at Suikerboschfontein at a farm in Bronkhorstspuit 50km east of Pretoria, Gauteng, South Africa-(25°48'18" S, 28°44'47" E). Bronkhorstspuit falls under Kungwini municipality in Tshwane Metro. The area has an average annual temperature of 16.8°C and an average annual rainfall of 625mm (Swanepoel, 2006).

4.1.2 Management of animals

The apparent digestibility trial was conducted towards the end of the growth trial, on the last ten days, when animals were approximately 35kg. A total of 9 male South African mutton merino sheep were used in this experiment. A diet for the sheep was formulated to be isocaloric and isonitrogenous. There were three diets: one with maize serving as control, one with 5% dried marula fruit peels, and the third one was having 10% dried marula fruit peels. Three animals were randomly allocated to each diet. The animals were fed *ad libitum daily* at 9 a.m. Clean water was always available. Animals were placed in metabolism cages individually designed to collect feces, which were 117.5L x 57.8b x 83.9h in size. These animals were given a 3-day adaptation period before data collection. The metabolic crates were fitted with feeders and drinking bowls. Sheep were fitted with harnesses and faeces collection bags.

4.1.3 Data collection

The collection of faecal samples took seven days with the first three days serving as the adaptation period of lambs to the faecal bags. Faeces and orts were weighed daily in the morning immediately after collection, and 20% of representative samples were taken and frozen at -20°C and pooled over the collection period for each animal to be later analysed at the University of Venda laboratory.

4.1.4 Laboratory analysis

Before chemical analysis, the faeces and feed samples were thawed and dried in the oven at 60°C for 48h and ground to pass through a 1 mm sieve. The DM of the feed and faeces samples was determined according to the association method of the official analytical chemist (AOAC, 2000 Method 934.01). They were dried using an oven at 60°C for 48 hours. The ash content of the feed and faecal samples was determined by ashing the samples in a furnace at 500°C overnight (until all carbon was removed from the ash). The organic matter was calculated by subtracting the ash from dry matter content of the respective samples. The feed and fecal samples were analysed for OM and nitrogen to estimate nutrient intake and digestibility. The apparent digestibility of nutrients was calculated as indicated below:

$$\%Nutrient\ digestibility = \frac{\text{nutrients consumed} - \text{nutrients in faeces}}{\text{nutrient consumed}} \times 100$$

4.1.5 Experimental design

A completely randomised design was used with three animals per treatment.

4.1.6 The statistical analysis

Data were subjected to analysis of variance (ANOVA) for a complete randomised design using Minitab 19(2019) (GLM). The treatment means were compared using a Tukey method at a 95% significance level.

The following model was used in this experiment: $Y_{ij} = \mu + D_i + \epsilon_{ij}$

Where: Y_{ij} = is the experimental observation (Nutrient intake, faecal output, and nutrient digestibility)

μ = is the mean

D_i = is the effect of the inclusion level in the diet (i =control diet, i =10% marula fruit skin, 20%marura fruit skin)

ϵ_{ij} = random error

4.2 Results

Table 4.1: Chemical composition of three animal feeds

The chemical composition of diets (0% DMFP, 5% DMFP, and 10% DMFP) is presented in **Table 4.1**. most of the nutrient composition of the diets were the same, however, there was no statistical analysis conducted to determine the significance difference amongst the mean.

Nutrients (%)	0% DMFP diet	5% DMFP diet	10% DMFP diet
Dry matter	94.35	89.54	94.33
ASH	21.33	22.73	20.04
Organic matter	73.02	66.81	74.29
Crude protein	13.83	14.33	13.31

DMFP; Dried marula fruit peels; %: percentage

Table 4.2: Nutrient intake (%) by lambs fed dried marula fruit peel diet.

Energy source	Inclusion level	No of animals	Nutrient intake		
			DM	CP	OM
Dried marula fruit peels	0%	3	94.35a	13.83 ^a	73.02 ^a
	5%	3	89.54a	14.33 ^a	66.81 ^b
	10%	3	94.33a	13.31 ^a	74.29 ^a
SEM			Ns	Ns	**
Significance			1.50	0.587	0.630

CP: Crude protein; OM: Organic matter; SEM: Standard error mean; Ns: Non-significance difference($P>0.05$); **significantly difference($P<0.01$)

Table 4.3: Nutrient output (%) from faecal of lambs fed different levels of marula fruit peels diet.

Energy source	Inclusion levels	No of animals	Fecal output		
			DM	OM	N
Dried marula fruit peels	0%	3	34.01 ^a	22.61 ^a	1.71 ^a
	5%	3	36.84 ^a	23.79 ^a	1.86 ^a
	10%	3	36.11 ^a	24.34 ^a	1.82 ^a
SEM			1.42	1.55	0.092
Significance			Ns	Ns	Ns

DM: Dry matter; OM: Organic matter; N: Nitrogen; SEM: standard error mean; Ns: Non-significance difference ($P>0.05$)

Table 4.4: Nutrient digestibility (%) by lambs fed different levels of dried marula fruit peels diet.

Energy source	Inclusion levels	No of animals	Digestibility		
			DM	OM	CP
Dried marula fruit peels	0%	3	63.95a	69.04a	22.09a
	5%	3	58.74a	64.34a	18.36a
	10%	3	61.71a	67.24a	14.17a
SEM			1.89	2.23	6.63
Significance			Ns	Ns	Ns

SEM: standard error mean; DM: dry matter; OM: Organic matter; CP: Crude protein; Ns: Non-significance.

4.3 Description of results

4.3.1 Nutrient intake and faecal output

Data on crude protein and organic matter intake for the three groups of lambs are presented in Table 4.2. The results show that the inclusion levels of dried marula fruit peels in the animal diet did not affect ($P>0.05$) the CP intake. However, a significant difference ($P<0.01$) was observed in the OM intake by the lambs.

The data on faecal output (g/day) of Nitrogen (N), Organic matter (OM), and Dry matter (DM) for the three groups are presented in Table 4.3. The inclusion levels of dried marula fruit peels in the diet did not affect ($P>0.05$) the faecal excretion of nutrients by lambs.

4.3.2 Nutrient digestibility

Data on DM, OM, and CP digestibility of the diets for the three groups of lambs are presented in Table 4.4. There was no significant difference ($P>0.05$) observed in the digestibility of nutrients.

4.4 Discussion of results

4.4.1 Nutrient intake

The nutrient intake of crude protein and by the lambs given the three diets was not significantly different, however the lambs that were assigned a diet with a 5% inclusion level had a numerically high intake, followed by a 0% inclusion level, and lastly 10% inclusion level. This indicates that a 5% inclusion level of dried marula fruit peels resulted in higher CP intake than the other inclusion levels. For the nutrient intake of OM (organic matter), the lambs with a 5% inclusion level had the lowest intake, followed by the lambs with a 0% inclusion level and then the lambs with a 10% inclusion level. This suggests that OM intake decreased with the increased inclusion level of dried marula fruit peels in the diet of lambs.

Regarding DM (dry matter) intake, the lambs with a 5% inclusion level had the lowest intake, followed by the lambs with a 10% inclusion level, and then the lambs with a 0% inclusion level. This shows that the DM intake was the lowest, with a 5% inclusion level of dried marula peels. A study by Guimaraes *et al*, (2014), who evaluated the intake, digestibility, and performance of lambs fed with diet containing different levels of cassava, reported that the dry matter and organic matter intake was not affected ($p>0.05$) by the inclusion level of cassava peels in the diet. This study concurs with the current study; both studies show that at a 0% inclusion level, the DM and OM intake was numerically higher than those at a 10% inclusion level.

This indicates consistency in the impact of including dried peels in animal diets on DM and OM intake. Ramírez-Rivera *et al.* (2010) reported that there was a significant difference among the treatments; the total Nitrogen intake increased with the increase in the inclusion levels of Tithonia in the diet of sheep which is contradictory to the findings of the current study. This suggests that different types of dried peels may have different effects on nutrient intake in animal diets.

4.4.2 Faecal output

The nutrient output (faecal output) of dry matter, organic matter, and nitrogen for the inclusion levels of 0%, 5%, and 10% dried marula peels were found to be similar. This concurs with the study by Mikasi *et al.*, (2018), who evaluated the digestibility of Macadamia oil cake and Marula seed cake and found that the nutrient in the faecal output was not significantly different for all the diets. Based on these results, it can be observed that the nitrogen output increased slightly with the inclusion of dried marula peels in the diet, reaching its highest value at a 5% inclusion level (1.86 g/kg). However, at a 10% inclusion level, the nitrogen output decreased slightly to 1.82 g/kg. This could be the result of the non-significant difference observed in the CP intake.

There was a gradual increase in organic matter output with the inclusion levels of dried marula peels. The 0% inclusion level resulted in the lowest OM output, while the 10% inclusion level had the highest OM output.

4.4.3 Digestibility of nutrients

The digestibility values for dry matter, organic matter, and crude protein were significantly the same for all the treatments. These findings suggest that the inclusion of dried marula fruit peels did not negatively affect the digestibility of DM, OM, and CP in the lamb diet, which could have an impact on their overall nutritional efficiency. Supporting this observation, Mikasi *et al.*, (2018) reported a non-significant effect on the digestibility of nutrients by lambs fed different levels of MOC and MSC. However, Ajagbe *et al.*, (2020) contradicted these results; they reported that the digestibility values for DM, OM, and CP differed significantly among the treatments. This contradiction could be the result of different feeds given to the animals and the type of animals used in the experiments. Factors such as animal species (sheep and goats), breed, and feed composition affect nutrient digestibility (Khashkheli *et al.*, 2020).

4.5 Conclusion

This study revealed that incorporating dried marula fruit peels into the sheep's diet does not affect nutrient intake and digestibility; therefore, dried marula fruit peels can be a potential energy source for sheep.

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CHAPTER FIVE

**THE EFFECT OF INCLUSION LEVEL OF DRIED MARULA FRUIT PEELS ON THE
GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF SOUTH AFRICAN
MUTTON MERINO LAMBS**

5.1 Introduction

During winter seasons the tropical and subtropical countries undergo a decline in quality and quantity of forage (Mikasi *et al.*, 2018). Chikwanha *et al.* (2019) have indicated that most farmers globally are using agricultural byproduct-based diets for their livestock to have a successful sustainable ruminant livestock system without affecting the performance and meat quality. Dried citrus pulp as an agro-industrial by-product has been successfully used as an energy source for lambs without negatively affecting the performance of lambs (Sharif *et al.*, 2018). The alternative way of ruminant feeding system is based on locally available by-products feedstuffs which contain nutrients that may be useful for maintenance, growth, reproduction, and production (Halmemies-Beauchet-Filleau *et al.*, 2018). Dried marula fruit peels have the potential to be used as an alternative energy source for ruminants because ruminants are able to consume fresh marula fruits as feed.

High energy diet improves the growth performance of finishing lambs (Carrilo-Muro *et al.*, 2023). Marula by-products are produced in large amounts in many parts of the world after brewing marula beer. The marula fruits can be fed fresh to ruminants but due to their rapid spoilage, it is important to preserve them through drying. Previous studies show that high dietary energy levels improve average daily gain, however, this can also result in resource wastage (Wang *et al.*, 2020). A study by Mlambo *et al.* (2011) marula seed cake has been used as a protein supplement for goats however, in literature there is no information about the use of dried marula fruit peels as feed for lambs. This study was therefore undertaken to evaluate the effect of different inclusion levels of dried marula fruit peels on the growth performance and carcass characteristics of South African mutton merino lambs.

5.2 Material and Methods

5.2.1 Description of the study area

A farm mentioned in 4.2.1 served as the study's location.

5.2.2 Management of animals

A total of 21 male lambs were used in the experiment with an average weight of 20kg at the beginning of the experiment, and they were fed until they were about 42kg on average. The duration of the experiment was 3 months. The lambs were put individually in separate pens of 117.5L x 57.8b x 83.9h by size. Animals were randomly assigned to three treatment diets with seven animals in each diet.

They were fed *ad libitum* daily at 9 in the morning and there was always access to clean water. The adaptation period for this experiment was 14 days. All lambs were dewormed with Prodose orange, vaccinated against pulpy kidney with Pulpy vax and treated for internal and external parasites with Ivemax before entering the feedlot.

5.2.3 Animal diets and treatments

A diet for the lambs was formulated to be isocaloric and isonitrogenous. The experiment had 3 diets thus one with 0% marula fruit peels serving as control, one with 5% dried marula fruit peels, and the third one was having 10% dried marula fruit peels.

5.2.4 Chemical analysis of feed material

The feed samples (0%,5%, and 10% dried marula fruit peel-based diets) were determined as indicated in Chapter 3 section 3.3.1.

Table 1: Three lamb diets with 0%, 5%, and 10% dried marula fruit peels as an energy source

Feed	Treatment 1 0%	Treatment 2 5%	Treatment 3 10%
Soya	10	10	10
Crashed maize	10	0	0
Wheat bran	10	10	10
Hominy chop	43.5	50.5	47.5
Hay	10	10	10
Molasses	10	8	6
Feed lime	5	5	5
Salt	1.5	1.5	1.5
Dried marula peels	0	5	10
Nutrient density of diets			
Dry matter	94.37%	89.06%	94.29%
Crude protein	10.11%	11.77%	11.39%
Ash	91.77%	91.98%	92.10%

5.3 Data collection

The lambs were weighed at the beginning of the trial, during the adaptation period and at the beginning of data collection. Feed offered and refusals were weighed and recorded once daily before offering fresh feed, to determine the average feed intake. Lambs were weighed once a week before feeding to calculate the average daily gain and feed conversion ratio was calculated using the daily feed intake and daily live weight gained.

The following equations were used:

$$ADFI = \frac{\text{total feed consumed}}{\text{number of days on feed}}$$

$$ADG = \frac{\text{weight gain}}{\text{number of days on feed}}$$

$$FCR = \frac{\text{daily feed intake}}{\text{daily live weight gained}}$$

All of the experiment's lambs were slaughtered at a commercial abattoir when it was concluded. Captive bolt stunning was used to make lambs unconscious and insensitive to pain and dressed as per industry-accepted procedure. Immediately after dressing, the carcass was weighed to obtain hot carcass weight. The carcasses were then chilled for 24 hours at $\pm 3^{\circ}\text{C}$ and reweighed to determine cold carcass weight. Dressing percentage was calculated using hot carcass weight and live weight as follows:

$$\text{dressing percentage} = \frac{\text{hot carcass weight}}{\text{live weight}}$$

The chilling loss was calculated using hot carcass weight and cold carcass weight using the following equation:

$$\text{Chilling loss \%} = \frac{\text{Hot carcass weight} - \text{Cold carcass weight}}{\text{Hot carcass weight}} \times 100$$

5.4 Experimental design

A total of 21 lambs were used in a completely randomised design with 7 lambs in each diet. Animals were randomly allocated to three diets (0% dried marula fruit peels, 5% dried marula fruit peels and 10% dried marula fruit peels).

5.5 The Statistical Analysis

Data was subjected to analysis of variance (ANOVA) on a complete randomized design using Minitab 19 (Minitab, 2019). Means were compared using the Tuckey pairwise method at a 95% confidence level.

The following model was used.

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

Where y_{ij} = is the observations: IBW, FBW, ADFI, AWG, FCR and Carcass measurements

μ = overall mean

α_i = the effect of inclusion level

e_{ij} = random error

5.6 Results

Table 2: Effect of marula fruit peels-based diet on growth performance of South African mutton merino lambs

Treatments	IBW(kg)	FBW(kg)	ADFI(kg)	ADG(kg)	FCR
0%	21.429a	41.857a	1.199a	0.244a	5.249a
5%	21.286a	42.714a	1.285a	0.258a	4.979a
10%	21.286a	39.143a	1.192a	0.250a	5.438a
SEM	0.84	2.20	0.08	0.03	0.46
Significance	NS	NS	NS	NS	NS

IBW: Initial body weight, FBW: Final body weight, ADFI: Average daily feed intake, ADG: Average daily gain, FCR: Feed conversion ratio, SEM: Standard error mean, NS: Non-significant ($P > 0.05$).

Table 3: Effect of dried marula fruit peels on the carcass characteristics of South African mutton merino lambs

Treatments	SLT MASS	HOT C MASS	COLD C MASS	DRESSING %	CHILLING LOSS
0%	41.857 ^a	16.871 ^a	16.500 ^a	39.414 ^a	2.201 ^a
5%	42.714 ^a	17.743 ^a	17.343 ^a	40.557 ^a	2.220 ^a
10%	39.143 ^a	15.929 ^a	15.614 ^a	40.000 ^a	1.999 ^a
SEM	2.20	1.01	0.991	0.698	0.149
Significance	NS	NS	NS	NS	NS

SLT MASS: Slaughter mass, HOT C mass: Hot Carcass Mass, COLD C MASS: Cold carcass mass, DRESSING %: Dressing percentage, NS: Non-significant ($P>0.05$)

5.7 Data description:

5.7.1 Growth performance

The growth performance of lambs' results is shown in Table 1 above. The inclusion levels of dried marula fruit peels had no significant impact ($P>0.05$) on the growth performance.

5.7.2 Carcass characteristics

Carcass characteristics results are shown in Table 2 above. There was no significant difference in all the parameters (slaughter mass, hot carcass mass, cold carcass mass, dressing percentage and chilling loss) among treatments ($P>0.05$).

5.8 Discussion

5.8.1 Growth performance

The non-significant difference observed in this study may be due to the non-significant effect observed for Crude protein intake obtained in the apparent digestibility trial. The results obtained in this study mirror the results found in the study which has shown that the inclusion levels of dried citrus pulp in the diet of sheep did not influence the dry matter intake and body weight gain (Bakr, 2019). Yang et al. (2020) and Barreto et al. (2010) indicated that the level of nutrients contained in the diet affects the growth performance of livestock.

However, the results of the current study shows that maize meal can be replaced by marula fruit peels at 5% and in this study replacement of maize with 5% and 10% dried % levels of the diet. Lambs fed high-energy diets containing more than 14% protein have not demonstrated improved growth performance (Rios-Rincon et al., 2014). This study contradicts the current study because the diet of the lambs contained low protein content and the growth performance was not negatively affected. Menezes et al. (2018) reported an average daily gain for Santalne lambs of 0.0717kg per day which was found to be lower than the average daily gain reported in this study.

Feed intake is positively correlated with body weight gain as it is generally acknowledged that lambs fed more feed picked up more weight each day (Mikasi, et al., 2018). Sayed (2009) reported that feeding lambs with diets which is high in energy significantly affects the average daily feed intake. However, lambs allocated on low energy diets consume less feed and have a low conversion ratio compared to other treatment groups. This study contradicts with the current study since a non-significant effect on feed intake and feed conversion ratio among all the treatment groups was observed.

Hu lambs were fed a diet containing metabolisable energy ranging from 9.17MJ/kg to 10.82MJ/kg and their average daily gain ranged from 0.1081kg/d to 0.1527kg/d (Wang, 2020). These results were found to be lower than the results obtained in this study, where the metabolisable energy were ranging from 14.26 MJ/kg to 14.42 MJ/kg and average daily gain were ranging from 0.244kg to 0.258kg. The difference in the two study may be due to the level of metabolisable energy in the diets and the difference in sheep breed used in both experiments. However, the study by Wang (2020) show that increasing metabolisable energy results in increased average daily gain of lambs.

5.8.2 Carcass characteristics

The non-significant difference amongst the parameters under investigation in this study suggests that the inclusion of dried marula fruit peels did not affect the lambs' overall carcass characteristics. The report published by Takele *et al.*, (2011) shows that the Horro lambs had a dressing percentage of between 36.7% and 42.5%. The results published by Mulugeta *et al.*, (2021) show that the dressing percentages of sheep were found to be (33.5% - 35.7%). The results from both the above-mentioned studies were found to be lower than the results observed in the current study.

The difference in these results could be the type of feed fed to these lambs and the type of sheep breed used. Increasing energy level in the diet results in increased dressing percentage (Hosseini

et al., 2008; Sayed, 2009, Chikwanha *et al.*, 2019). These three studies contradict with the current study.

5.9 Conclusion

Based on the findings in this study, dried marula fruit peels can be added to lamb diets as a feed ingredient to provide an alternate energy source for the animals without compromising the animals' growth and carcass characteristics. However, additional studies with longer higher levels of marula fruit peels in the diets would contribute to a more robust evaluation of the effects of dried marula fruit peels on the growth performance of lambs.

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CHAPTER SIX

GENERAL DISCUSSION, CONCLUSION AND FUTURE WORK

6 General discussion

The moisture content of fresh marula fruit peels was found to be high in this study which means that it is important to preserve them through drying so that they can last longer. The protein and fat content found in the dried marula peels were lower than the recommended amount required by the animal for their growth. This suggests total replacement of maize in the diet of sheep may not have a positive influence on the growth and digestibility by the lambs as compared to when a certain percentage is incorporated in the diet.

The nutrient intake and faecal output by the lambs were found to be similar. These similarities suggest that the inclusion of dried marula fruit peels in the diets of South African mutton merino lambs possessed no adverse impact on the nutrient intake and faecal output. The non-difference observed in the apparent digestibility trial has led to the non-significance difference in the growth trial. The lack of difference in the carcass measurements follows the same trend of the growth performance in terms of feed intake and weight gain. An animal's consumption of feed increases its weight gain and eventual carcass output (Masiza *et al.*, 2018). In the current study, lambs which gained more weight were found to have heavier carcasses.

6.2 General conclusion

It is possible to conclude that both oven and freeze-drying are efficient ways to preserve the nutritional qualities of marula peels, given the data showing that drying both methods and locations had no effect on the chemical composition of the peels. This implies that, depending on availability and viability, any of the two method of drying can be employed. Inclusion of dried marula fruit peels in the diet of South African mutton merino lambs did not have a negative impact on the digestibility and growth performance of lambs, therefore, dried marula fruit peels can be included in the diet of lambs at up to 10%.

6.3 Recommendation

It is recommended that further investigation on the chemical composition of marula peels that are dried using other methods such as sun drying is also implemented and collect the peels from different locations as the chemical composition of the peels may be influenced by the environment. Since the inclusion level of dried marula fruit peels in the diet of lambs at up to 10% did not negatively affect digestibility, growth and carcass characteristics it is therefore recommended that further investigation should be undertaken with higher inclusion levels to find out if increasing the inclusion level to more than 10% cannot affect digestibility, growth and carcass characteristics of lambs.

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