EVALUATION OF THE *MORINGA OLEIFERA* LEAF MEAL EFFECTS ON MILK YIELD, MILK QUALITY AND THE HELMINTHIC LOAD OF SAANEN DAIRY GOATS IN RANGELAND CONDITIONS AT NEUDAMM FARM

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Abstract

Capra aegarus hircus (Goats) are popular small ruminants kept mainly for meat and milk. Over time, goat milk became popular and a substitute for cow milk. Researchers have focused their studies on alternative and cheaper methods of increasing milk yield, milk quality and improved animal health. This study aimed to assess the effects of *Moringa oleifera* inclusion in the diet of Saanen dairy goats on their milk yield and quality as well as the reduction of gastrointestinal parasite egg load. The study used a 3x3 Crossover Latin square Design to determine the effects of 0g, 10g and 30g/day *Moringa oleifera* leaf meal on the milk yield and quality whilst a completely randomised design was used to determine the effects on the parasite egg load. The evaluation of milk yield was done by hand milking the goats daily, whereas milk quality was conducted using a Lactoscan SP. The parasite egg load was assessed using the quantitative faecal flotation method complemented by the McMaster Egg Counting Technique. The Statistical Package for Social Science (SPSS®) version 27 (IBM, 2020) software was used for data analysis. Milk yield and quality data were analysed using the General linear model and the parasitic egg counts were analysed using the generalised linear model (Poisson regression model). The comparison of means was done using Duncan's new multiple range test at $P<0.05$ significance. The goat milk yields significantly differed at $P<0.05$ in the first period at 3.178 kg/day (30 days) and the yield reduced in the second at 2.848kg/day and 2.831kg/day for the third period (30 to 90 days of the trial). The moringa supplement had no significant effect on the goat milk yield. The treatment did not affect the milk fat, non-fat solids, density, protein, lactose, added water, temperature, freezing point, salts, total solids or pH of the goat milk. The gastrointestinal parasite egg load assessment found the presence of three genera; *Strongyloides, Moniezia and Coccidia*. The study treatment levels of 10g and 30g of moringa leaf meal/day were effective in the reduction of the egg loads. In conclusion, the study findings showed no positive response in the milk yield and milk quality for the treatment levels of 10g and 30g/day, however, a positive response of parasites to moringa leaf meal was observed due to the reduction of parasitic egg load with 10g and 30g/day treatments. The results from this study show that moringa leaf meal could be used in Saanen dairy goats in the reduction of gastrointestinal helminths. This study would recommend the use of 10g/day moringa leaf meal supplementation for dairy goats for ecological management of gastrointestinal tract parasites.

Keywords: *Moringa oleifera*, Saanen goats, Milk yield, Milk quality, Parasite egg load.

List of Publication(s)/Seminar/Conference presentations

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List of Acronyms

AASIKS	African Association for the Study of Indigenous Knowledge Systems
ADF	Acid detergent fibre
CF	Crude Fibre
CP	Crude Protein
CRD	Completely randomized design
CT	Condensed Tannins
DM	Dry Matter
DMI	Dry Matter Intake
DNA	Deoxyribonucleic acid
EPG	Eggs per gram
FMD	Foot and mouth disease
GIPs	Gastrointestinal parasites
Ha	Hectare
MLM	Moringa leaf meal
NCAs	Northern Communal Areas
Nd	No date
NDF	Neutral detergent fibre
OM	Organic Matter
SCFA	Short-chain fatty acids
SD	Significant difference
SNF	Solids-non-fat
SPSS	Statistical Package for Social Sciences
TMR	Total mixed Ratio
VCF	Veterinary Cordon Fence

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Dedication

The author dedicates this work to the entire Shea family who supported me during my study by believing in me. This work is also dedicated to my little sister Martha Shea as a motivation for her future academic work.

Declaration

I, Immanuel Mayday Kauluma Shea, at this moment declare that this study titled "Evaluation of *Moringa oleifera* leaf meal effects on milk yield, milk quality and the helminthic load of Saanen dairy goats in rangeland conditions at Neudamm Farm" submitted for the requirements of the degree Master of Science in agriculture at the University of Namibia, is my original work and haven't previously been submitted to any institution of higher learning. All sources cited or quoted in this research paper are indicated and acknowledged with a comprehensive list of references. No part of this thesis may be reproduced, stored in any retrieval system, or transmitted in any form, or by means (e.g., electronic, mechanical, photocopying, recording and or otherwise) without my prior permission, or that of the University of Namibia acting on my behalf. I, Immanuel Mayday Kauluma Shea, grant the University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which the University of Namibia may deem fit.

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CHAPTER ONE: INTRODUCTION

1.0. Summary of the Chapters

The study is organized in six chapters. Chapter one comprises the introduction to the overall study, followed by the background, the problem statement, objectives, hypotheses, the significance and limitations of this study. Chapter Two covers the literature review, with chapter three covering the chemical composition of the feedstuff used in the study. Chapter three includes the proximate analysis of *Moringa oleifera* Leaf Meal (MLM) and the commercial custom-made dairy goat pellets used in the study. Chapters one, two and three serve as preliminary chapters to chapters four and five, which are dedicated to the moringa leaf meal as a treatment alongside the commercial pellets to achieve individual objectives. In this regard, Chapter Four details the first and second objectives that evaluate the effects of moringa leaf meal dietary supplement to Saanen goats on their milk yield and milk quality. Chapter five, like the preceding chapter, focuses on the use of moringa leaf meal effects on the anthelmintic gastrointestinal parasites (GIPs) of the goats. Chapters four and Five are concluded by the final chapter, Chapter Six where the overall conclusions, recommendations and limitations of both objectives are summarized.

1.1. Study Background

Goats (*Capra aegarus hircus*) are popular small stocks that are mainly kept for meat and milk. The study by Mazinani and Rude (2020) on goat and sheep products noted that goats are amongst the earliest animals that were domesticated by nomads for meat, milk, fleece, mohair, hide and processed dairy products such as yoghurt and cheese. According to Aziz (2010), dairy goats are considered to be the "cow of the poor." Goats consume less feed, occupy less space and produce enough milk for an average unitary family when compared to cows. In Namibia, the Directorate of Veterinary

Services (DVS) reported a total of 1.3 million goat heads in the 2021 National Census. Despite this high goat headcount; dairy goats are rarely reared in Namibia, although most farmers cannot afford to farm with dairy cattle. Nonetheless, farming with dairy goats would be a good alternative. Leitanthem *et al*. (2022) stated that goat farming is practiced under semi-intensive production systems, and only a few farmers provide concentrates for their goats for supplementation. They also found that challenges faced by animal producers include a shortage of concentrated feed and where they are available, they are expensive. Poor feed quality is a leading factor in limiting animal productivity in tropical countries (Leitanthem *et al*., 2022). As easy as it is for the common goat farmer to keep dairy goats, few farmers keep dairy goats and those that farm with them need to optimize farming outputs in terms of produced milk yield, milk quality and offspring (Mendieta-Araica *et al.*, 2011).

Animal genetics play an important role in their ability to grow, produce and reproduce (Mazinani and Rude, 2020). The domestication, selection and controlled mating of goats also played a big role in the shaping of the animal’s genetics into categories that provide more of the desired products such as dairy, meat, fibre or their combinations (Korsor, 2018). Ishag *et al.* (2012) also reported that genetic characteristics form an important socio-economic role in many local areas of the world by contributing to food and nourishment. The same author gave the assumption that the Saanen breed of goats is the most evolved genetically among the goat breeds. Monteiro *et al.* (2017) demonstrated goat’s good ability to thrive in difficult environmental conditions, whilst Vatta *et al*. (2001) countered this argument by highlighting the sensitivity of goats to internal parasites amongst other factors that can cause lowered fertility, high susceptibility to diseases, abortion, and death.

Skapetas and Bampidis (2016) highlighted that the nutrition of goats is mainly composed of browsing, grazing and feeding of supplements. One of the ways to improve goat production is improving their nutrition to include energy and protein-rich feed, as well as minerals which are crucial for growth, maintenance and production (Kholif *et al.*, 2015). Due to high commercial feed costs, researchers have increasingly focused on the use of available alternative feed sources. This led to intensive studies on the various effects of feed sources on the animals' health and production potential. Moringa is a worldwide and drought-tolerant tree, which has been researched as an animal protein feed source for animals such as goats and fish (Manh *et al.,* 2005; Egwui *et al.,* 2013; Zhang *et al.,* 2018; Su and Chen, 2020). Bryan (2011) emphasized the plant's ability to sustain and improve the feed quality of small and medium-scale farmers. Studies on moringa have shown positive results from increased animal feed intake in goats (Zeng *et al*., 2018), subsequent increase in milk yield of goats and cattle (Kholif *et al.,* 2015; Dong, Zhang and Diao, 2019), improved milk fat composition and decreased somatic cell count (Zhang *et al.,* 2018), although Mendieta-Araica *et al.* (2011) found no change in the milk chemical composition while Novianti *et al*. (2021) also did not notice any change in milk production within animals fed with moringa. Korsor *et al*. (2017) reported that the use of moringa led to increased milk production, improved milk quality, and increased anthelmintic effects against gastrointestinal parasites in Boer goats.

Although goats are kept for their meat at the household level in Namibia, goat milk is known for its high nutritive value and health benefits (Togarepi *et al.,* 2018). Araújo *et al*. (2006) reported that the Saanen and Alpine dairy goat breeds are prominent and well adapted to semiarid conditions. Aziz (2010) reported the largest amount of goat milk produced in India followed by Bangladesh and Sudan. In developing countries such as Namibia, where most of small stock farming produce is used for family consumption, research demonstrates that dairy goat farming has great potential for community growth, especially where goat milk has the potential to improve human nutrition. Saanen goats are locally adapted in Namibia and are mainly kept for milk production as in the climatical environments described by Monteiro *et al*. (2017).

1.2. Problem Statement

Farmers constantly need alternative nutrient-rich feed that is readily available and of high biomass. In the absence of this feed, animals tend to produce poorly, lose weight, and be more susceptible to illnesses. However, Barkema *et al*. (2015) found that dairy farmers are challenged with other aspects such as maintaining production, keeping their herds healthy, obtaining optimum growth and reaching maximum reproduction due to the nature of their farming. Dairy goat farms are not different from other dairy farms, even though goat diets are obtained primarily from browsing and grazing (Skapetas and Bampidis, 2016). Another issue that dairy goat farmers have to deal with is the health of their animals as goats suffer from helminths. There is a need for dairy goats to supplement the dairy cattle milk production to meet the required milk demand. In Namibia, the dairy goat industry has an untapped potential with the ability to uplift the nation at large as done in Sudan (Ishag *et al.,* 2012).

The purpose of this study was to determine the nutritional effect that *Moringa oleifera* leaf meal supplement will have on the milk production and composition and helminth load in dairy goats kept in rangeland conditions at Neudamm farm.

1.3. Study Objectives

1.3.1. Overall Objective

To evaluate the effects of *Moringa oleifera* leaf meal as a nutritional and ethno-medicinal supplement to Saanen goats in rangeland conditions of Neudamm.

1.3.2. Specific Objectives

1. To assess the chemical composition of *Moringa oleifera* leaf meal.
2. To evaluate the effects of supplementing *Moringa oleifera* leaf meal on the milk yield of Saanen dairy goats kept in rangeland conditions of Neudamm.
3. To evaluate the effects of supplementing *Moringa oleifera* leaf meal on the milk quality of Saanen dairy goats kept in rangeland conditions of Neudamm.
4. To assess the effects of *Moringa oleifera* leaf meal on gastrointestinal parasites of Saanen dairy goats in rangeland conditions of Neudamm.

1.4. Hypotheses

$H_0$1: *Moringa oleifera* leaf meal is not chemically rich

$H_0$2: *Moringa oleifera* leaf meal supplementation does not significantly enhance dairy goats' milk yield.

$H_0$3: Supplementation of *Moringa oleifera* has no significant effect on the quality of dairy goat milk.

$H_0$4: *Moringa oleifera* leaf meal supplementation does not have significant effects on gastrointestinal parasite load and composition of parasite eggs in dairy goats.

1.5. Significance of the study

The study has great potential to stimulate farmers not only to farm with dairy goats in Namibia but also to improve milk yield and quality. It would also benefit the Namibian population to get access to goat milk, especially in regions or families where it is costly to farm dairy cattle. The study will inform farmers about the benefits of moringa as a multipurpose plant with great nutritional and ethno-medicinal properties. The study will introduce farmers to the use of moringa as an anthelmintic substance, thus helping them to manage intestinal parasites in small ruminants while increasing profits by eliminating the loss of milk during commercial deworming drug withdrawal periods. Finally, the study will set a basis for research in the Namibian dairy goat industry.

1.6. Study Limitations

The limitation of the study included the size of the flock, which dictated the experimental design due to a limited number of replicates. The availability of moringa leaf meal during the year proved to be a limitation causing a delay in the commencement of the experiment. Finances proved to be a constraint for required proximate analyses of the milk and animal feed that was used in the research.

1.7. Scope of the Study

The study was carried out at Neudamm farm. The study only used the Saanen breed of goats, where only does in their second parity and early stage of lactation were supplemented with moringa leaf meal.

CHAPTER TWO: LITERATURE REVIEW

2.1. Overview of Namibian Livestock Farming

2.1.1. Namibia's Socio-demographic information

Namibia has a total of 388,080 square kilometres used for agriculture, with just 1% of that area being classified as arable (FAO, 2013). According to Smit *et al*. (2017), 40% of Namibia's smallholder farmers grow grain crops primarily for household consumption, while about 70% of the country's population relies entirely or partly on agriculture for their livelihood. According to Mendelsohn *et al*. (2012), the majority of households have additional income from non-agricultural or off-farm sources such as pensions, business revenues and salaries. With over 20% of the total labour force, the agriculture industry was found to have the highest labour force according to the 2016 National Labour Force Survey (NSA, 2017). The agriculture and forestry industries have contributed an average of 4.26 per cent to the Namibian gross domestic product (Smit *et al*., 2017). The sector is vulnerable to different conditions, which can be linked to a variety of causes such as inadequate rainfall brought on by climate change, restricted access to appropriate technology and a lack of technical experience. Namibia imports around 70% of its food needs, which demonstrates the difficult agricultural conditions (Smit *et al*., 2017).

Goats, cattle, sheep and poultry are the main livestock farmed, with a few pigs and donkeys. Cattle, goats, sheep, and pigs make up 76% of Namibia's agricultural output value (Thomas *et al*., 2014). According to the 2012 livestock census, Namibia had 2.9 million cattle in total, with 1.4 million in the Northern Communal Areas (NCAs), the Zambezi region had 136 221; the rest resided south of the Veterinary Cordon Fence (VCF), also known as the Foot and mouth disease (FMD) free zone (World Organization for Animal Health, 2012). Sheep and goat farming are concentrated in the more arid southern regions, with cattle rearing predominantly in the centre and northern regions of the country (GIZ, 2022). Some of the cattle breeds raised include Brahman, Afrikaner, and Simmental breeds. This forms the majority of commercial farming income. In the commercial sector, sheep breeds are mostly the Karakul, bred for its pelt, and the Dorper and Damara kept for their meat production. They are largely concentrated in the drier south. The Boer goat and Angora breeds of goats are the most prevalent and most extensively distributed (Jim, 2000). The majority of the country's "communal land" is characterized by roaming cow herds used for subsistence farming. Over a third of Namibian homesteads don't have livestock, while livestock owners have fewer than 30 cattle and goat heads. In total, this farming system has about 600,000 cattle and 950,000 goats (GIZ, 2022).

The majority of young people are least engaged in farming activities (Cheteni, 2016). A study by Motiang and Webb (2015), suggests that formal education may increase the likelihood that young people will participate in or accept new agricultural innovations and technologies that will increase agricultural output. According to Adesina (2016), female-headed households owned fewer heads of goats but sold more goats while male-headed households owned more goats. In Table 1 below, the major sociodemographic traits of Northern Namibia farmers are enumerated (Togarepi *et al*., 2018).

Table 1: Household socio-demographic characteristics of Northern Namibian farmers

Characteristics		Frequency (%)	Number of goats owned (%)	Number of goats sold (%)
Gender	Male	42 (56)	1486	21
	Female	33 (44)	1094	31
Education Level	Primary	21 (28)	776	12
	Secondary	35 (46.7)	1173	27
	Vocational	9 (12.0)	315	7
	Tertiary	10 (13.3)	318	12
Age	30-40	10 (13.3)	323	14
	41-50	25 (33.3)	885	18
	51-60	21 (28)	697	16
	61+	19 (25.3)	693	10
Marital status	Single	24 (32)	796	29
	Married	51 (68)	1786	29

Source: Togarepi *et al*. (2018).

2.1.2. Agro-pastoral and pastoral systems

Pastoralism and agro-pastoralism are the foundations of the production systems in the communal regions, and the majority of households are subsistence-oriented rather than economically focused (Ibrahim and Tajuddin, 2021). In contrast to commercial livestock production, animal ownership has changed goals and outputs, such as draft power, milk, manure, meat, financial security, and sociocultural status. Jim (2000) elaborated on the importance of higher production per hectare rather than per head as this maximization increases turnover in communal area livestock production.

Due to recurrent droughts, there is a tendency to have higher concentrations of people and livestock close to permanent water sources; this practice leaves other areas underutilized. The number of animals is more dependent on the quantity of reliable water than on the quantity of forage, so the effects of drought tend to be more severe in communal than in commercial areas (Ali *et al*., 2011).

In Namibia, there are two distinct sub-sectors within the agriculture industry: the commercial sub-sector, which is capital-intensive, relatively more developed, and export-oriented. The communal sub-sector is primarily subsistence-based, labour-intensive, and low-tech. Togarepi *et al*. (2018) reviewed the importance of livestock farming for many farmers including goat farming.

2.1.3. Mixed crop-livestock farming system

Umar (2011) reported that communal farmers integrate crop and livestock activities for their convenience. The supply of grazing areas to animals and animal manure play a decisive role in the production of cropland. The grazing animals have an important role in the tillage of land, while animal manure is used for crop field fertilization. During the dry season, animals in this production system depend upon extensive grazing of natural veld and crop residues. This is a closed system in which waste products of crops are used by livestock, which in turn return its waste (manure) to the crop field (Umar, 2011).

2.1.4. Livestock marketing system

According to Marius *et al*. (2021), access to meat markets in Namibia is controlled by the veterinary cordoned fence (VCF) which separates the south, which is a foot and mouth disease-free zone, from the north-central, which is FMD protected, and the northeast, which is FMD-prone.

Livestock farmers can choose between selling their livestock to MeatCo, which is the primarily formal market, or to the informal market (Thomas *et al.*, 2014). The Meat Board is in charge of enforcing all laws governing the distribution of stock brands, the issuance of export licenses, and the marketing of red meat (de Lange, 2008). In the official market, goats are sold to established markets, dealers pay tax, and prices are publicly posted and set by supply and demand. Goats are sold both formally and informally in Namibia, both directly to consumers, in farm markets that are overseen by the Meat Board of Namibia, or via middlemen (Marius *et al.*, 2021).

NCA cattle farmers may be eligible to sell their cattle to formal markets, such as MeatCo after their animals have been subjected to quarantine for 21 days so that meat products from the NCAs can be sold in the markets of Namibia, South Africa, and the European Union (Thomas *et al.*, 2014).

Approximately 95% of the goats, mostly of the Boer breed, are sold live on hoof to markets in South Africa, with sporadic selling to markets in Angola and other countries like Botswana (Marius *et al.*, 2021). Due to a lack of goats on the market and excessive demand, prices are high in South Africa (Directorate of Marketing, 2018). As a result of live exports of goats, there is little to no value enhancement in Namibia (Togarepi *et al.*, 2016). This leads to an underdeveloped formal and informal goat market in Namibia to the extent that markets as such do not exist in some parts of the country (Togarepi *et al.*, 2018).

Marketing data are not kept on record in the NCAs. This results from the fact that livestock trading is not organized in the informal market, marketing facilities and institutions are underdeveloped, and buyers and sellers negotiate prices (Marius *et al.*, 2021). According to the Meat Board Annual Report (2014), communal farmers only sell for emergency money or to open market vendors who barbecue meat for sale; therefore, marketing is need-based. As a result, livestock prices on the local market become undesirable for the farmers (Marius *et al.*, 2021).

Thus, the majority of subsistence farmers sell their livestock on the open market to friends and other people, particularly during the peak festive seasons (Togarepi *et al*., 2018), while farmers in the southern and central regions of the country sell their livestock through organized markets with information shared among participants for local goat sales, through auctions and international exports (de Lange, 2008). Since many farmers prefer to sell directly from their farms rather than incurring transportation costs to auction pens and commission fees from auctioneers, auction sales have recently decreased (Meat Board, 2019).

2.2 Goat Farming

2.2.1. Generalities

Goat farming is perceived to be a smart alternative farming activity that may support farmers' resilience to climate-related hurdles (Mbuku *et al*., 2015 and Waineina *et al*., 2021). The Namibian goat population stands at 1.9 million as reported by Marius *et al*. (2021) most of these goats are found in the northern parts of Namibia and are mainly kept for subsistence purposes. The same author further stated that the best-established breed of goats found in Namibia is the Boar goat kept for its meat production. The indigenous goats, despite being the most abundant in numbers, have no uniform character or one pure breed to identify them (Krause, 2006). Goats are mainly browsers with a high preference for bush over grass; they have a robust adaptability capacity to different ecological zones and can be reared under different production systems starting from extensive, semi-intensive and intensive systems (Waineina *et al*., 2021).

Due to varying production activities and available resources, farmers have formed different production systems targeting different trait preferences for raising goats

(Ouma *et al*., 2004; Duguma *et al*., 2010). After defining the production system, the farmer selects suitable breeds of goats that produce optimally under that production system with minimal improvement strategies (Kosgey, 2004). Breed improvement programmes work best when farmers' production systems are put into consideration when choosing qualities to target (Getachew *et al*., 2010). Initiating programmes to increase goat productivity, such as genetic improvement programmes, requires a solid understanding of a production system (Kosgey *et al*., 2006).

On a farm, goats frequently fill biological and economic gaps. Holcomb (1994) reported that goat meat is produced more frequently than beef or pork worldwide and goat farming is an important component of sustainable farming. A farm's economic, environmental, and genetic variety can be increased by integrating animals, as this has a significant impact on the sustainability of the farm (Marius *et al*., 2021).

Goats are kept under different systems to minimize economic input and maximize the goat's output. Ogola *et al*. (2010) stated that different breeds of animals are differently adapted to produce products, over time the goats have been selected to genetically improve the products of their genetic line. The breeds produce different main products with the examples of the Boer goat and Kalahari red breeds for meat production, the Saanen and Toggenburg as dairy breeds and the Angora goat for mohair (Kandiwa *et al*., 2020)

Approximately 200 different goat breeds exist today, and they offer a range of products including milk, meat, and fibre such as mohair and cashmere (Togarepi *et al*., 2018). The first wild goat to be tamed and one of the first animals in the world to form a link with humans was the wild Bezoar Goat of the Middle East (Kilpatrick, 2017). More than 1000 goats from nine well-known commercial breeds were used by Brito *et al*.

(2017) in a study of genetic diversity. Goats are better able than other farm-raised ruminants to effectively convert conventional feed sources into milk and meat (Darcan and Silanikove, 2018); this helps them to survive in arid and drought-prone environments. Despite the goat's great adaptability, farmers face production concerns such as poor nutrition, diseases and livestock predation (Togarepi *et al*., 2018). The feed scarcity is attributed to droughts and soil erosion. Without good nutrition animals will have low carcass weights which have a direct link to the profitability of goat production (Musara *et al*., 2013). In the study conducted by Togarepi *et al*. (2018), diseases like those transmitted by ticks, lumpy skin disease and internal parasites were common in goats and were associated with poor- and low-quality nutrition, which led to high mortality rates.

Throughout domestic goat breeding in the world, more than 50 dairy goat breeds have been developed (Deniskova *et al*., 2020). One of the breeds was developed using the technique of long-term folk selection in the Swiss Zaanental Valley in the middle of the 19th century, giving it the name Saanen breed (Devendra and Haenlein, 2011; Dunin and AG, 2013). The Saanen goat breed has high milk production between 300 and 2000 kg in a lactation period of 150–300 days and is the Holstein cattle of the goat breeds (Devendra and Haenlein, 2011). This breed adapts well to various housing and feeding situations without experiencing a major drop in milk production. Their cross-breeds with regional goat populations are promising, in addition to the use of pure-bred Saanen goats for dairy production (Deniskova *et al*., 2020). Saanen sires are of high quality and good for improving low-productive mongrel goat groups with a milk yield of 200-250 kg for 305 days of lactation into dependable milk producers (Deniskova *et al*., 2020). Domestic goats have not been the subject of as many genomic investigations as other livestock animals (Ajmone-Marsan *et al*., 2014).

2.2.2 Supplementary feeding of goats

Poor quality feeds are the main obstacle limiting farm animal productivity (Sultana *et al*., 2015). In the dry season, natural pastures have poor nutrition due to high fibre and low crude protein content (Oni *et al*., 2010). According to Gerbregiorgis *et al*. (2012), due to farmers' inability to provide the necessary amount of protein and energy, they often feed low-quality hay and crop residues high in fibres with little to no vitamins and minerals; as a result, there is low digestibility and voluntary intake which significantly reduces the production. Supplementation with concentrate feeds improves animal DM intake and digestion of low-quality roughages consumed by the animals (Nurfeta, 2010).

Moyo *et al*. (2012) reported that trees offer a decent and cheap supply of protein and minerals. Alternative protein sources from forage trees and shrubs that goats browse have increased recently in research studies. These include *Pterocarpus lucens, Acacia Senegal* (Sanon *et al*., 2008), *Acacia etbaica, Dichrostachys cinerea* (Yayneshet *et al*., 2008), *Acacia karroo* (Marume, 2010), *Manihot esculenta* (Oni *et al*., 2010) and *Moringa oleifera*, *Sauropus androgynous* and *Coleus amboinicus* (Novianti *et al*., 2021).

The use of moringa leaf meal has been given more attention as a source of protein and feed component in ruminant production (Murro *et al*., 2003; Mendieta-Araica *et al*., 2011 and Gerbregiorgis *et al*., 2012), particularly in goat production (Sarwatt *et al*., 2002; Asaolu *et al*., 2010, 2011& 2012; Moyo *et al*., 2012). Using moringa leaf as a protein source has numerous benefits, including that it is a perennial plant that may be harvested multiple times during one season. Mendieta-Araica *et al*. (2011) stated that dried moringa leaf can be kept for longer periods without losing any of its nutritional content, whilst there is no to little difference in its intake when feeding the leaves fresh or dried (Sultana *et al*., 2015).

Alebel *et al*. (2020) listed the feed resources that farmers frequently employ over the various seasons. The common feed resources employed include natural communal grazing land, commercial grazing lands, grasses (cut and carry system), browses (shrubs, trees), crop leftovers, concentrate, and local brewery by-products. Animal feed availability, both in terms of quantity and quality, is largely influenced by climatic and seasonal conditions (Edea, 2008).

According to Alebel *et al*. (2020), community grazing was discovered to be the primary source of feed during all seasons, while hay and browses are the second sources of goat feed, followed by crop residues in the dry season. Solomon (2007) and Amelaml (2011) both claim that natural pasture serves as the primary source of feed for goats.

The energy content of the roots or the wholesome green tops of alternative feeds such as roots and tubers like sugar beets, mangels, sweet potatoes, and turnips may be fed as energy sources (Ibrahim and Tajuddin, 2021).

Goats are frequently fed a variety of milling by-products. Other concentrates that are offered to goats most frequently are grain; and cereal grains including oats, corn, barley, and wheat; these have high energy (carbohydrate/fat) contents (Guide, 2004).

Moyo *et al*. (2012) asserted that grains such as buckwheat and amaranth are less popular as feed sources due to their conflict with human use. High protein feed includes soy and cottonseed meals. Animals consuming high-quality forages need a greater energy concentration to use the protein found in the forages, which is adequate or even excessive protein (Coffey *et al*., 2004). The goats' need for protein needs to be met by feeding a higher-protein supplement when the pasture or hay is of lower quality. For dairy goats to thrive during periods of maximum lactation or growth, they require both high-quality fodder and extra grain (Guide, 2004).

Since moringa possesses high quantities of crude protein in its leaves, it has been suggested as an additional feed for dairy cows, goats, and fish (McKenna *et al*., 2005 & Sánchez *et al*., 2006). Additionally, it has a lot of antioxidant chemicals (Siddhuraju and Becker, 2003). which may affect the quality of the meat (Mielnik *et al*., 2003). Crossbred Xhosa lop-eared goats were given *Moringa* leaf meal in a study by Moyo *et al*. (2014) and the results showed that the chevon had the highest physiochemical features and consumer sensory impacts when compared to grass hay and sunflower seed cake. Goats fed moringa had meat with lower shearing and cooking loss values than other goats that had received another treatment (Abdoun *et al*., 2022).

2.2.3. Meat goats

One of the motivations for early animals' domestication by humans was their meat. Meat goats develop and build more muscle than other purpose goats due to their larger frames. The Boer goat breed of meat goat is the most popular amongst farmers. According to Mdladla *et al*. (2016), selective breeding completely optimized the Boer goat for meat consumption as a source of food for everyone who farms with them. Boer goats have been developed over many generations to have the characteristics that would increase the ability to produce meat that has the anticipated characteristics (Rahmatalla *et al*., 2017). Meat goats develop into larger, heavier animals than typical goats. People throughout the world can get their protein and nourishment from goats (Kilpatrick, 2017).

2.2.4. Dairy goats

Many species have been selectively bred to produce milk including goats. Dairy goats are created from goat breeds that have undergone selective mating (Ajmone-Marsan *et al.*, 2014). Numerous characteristics set dairy goats apart from meat goats. Although meat goats can also produce milk, it is incomparably inferior to that of a dairy goat in terms of both quality and quantity. Most people consume goat milk and it is mostly the best source of nutrition available, as most people around the world farm with goats (Kilpatrick, 2017).

In various regions and cultures, goat milk is frequently consumed and is very beneficial to human health (Mahanjana and Cronjé, 2000). Goat milk is frequently used as a safe alternative to conventional milk from cows due to its lower levels of lactose. Dairy goats are often thinner and more tamed than meat goats since most of the nutrition consumed is channelled to milk production. Dairy goats have more flexibility for diverse body shapes and sizes because they don't need to be as physically strong or hefty (Mdladla *et al*., 2016).

2.2.5. Dairy Goat Breeds

Ali *et al*. (2011) attest that the population of goats present in developing countries increased by more than 95% between 1969 and 2010, while global trends in the evolution of the goat population and its products show a steady and rapid expansion in comparison to both cattle and sheep. There are over 500 different goat breeds in the world; however, about a dozen of them are raised for their milk, and there are between 600 and 700 million dairy goats worldwide (Getaneh *et al*., 2016). Dairy goat environments range from deserts to high-altitude mountains. Dairy goats can be used in diverse pastures as weed and brush control. When the land is turned into pasture, erosion on row crop land decreases (Coffey *et al*., 2004). Goats, like other ruminant animals, transform unfit-for-human-consumption plant material into premium animal products (Guide, 2004).

The main varieties of dairy goats include Saanen, Toggenburg, British Alpine, and Anglo-Nubian. The greatest breed for milk production is the Toggenburg; it is not unusual for one goat to produce 7.57 litres of milk each day. In Ethiopia, goats are primarily kept for the following three uses: breeding, milk production, and meat production (Getaneh *et al*., 2016). Pasteurized goat milk, goat milk colostrum, goat milk powder for pets, goat cheese, flavoured goat milk powder, goat milk yoghurt, and bottled milk juice are all examples of items made from goat's milk (Sahlu and Goetsch, 2005).

2.2.5.1 Alpine Goat

There are various types of Alpines, including the most known French Alpine and a few British, Rock, and Swiss Alpines. The Alpine goat's sizes range from medium to large, and colours range from pure white to fawn, grey, brown, black and mixtures in the same animal (Harris *et al*., 1996). One thing they all share is a black line that goes down the back of each Alpine (Kilpatrick, 2017).

2.2.5.2 Nubian Goat

The Anglo-Nubian is a distinctive and hardy breed that has its origins in Africa but later became prevalent in Europe. Being taller than the other major breeds gives the Nubian a very distinctive appearance. Additionally, Nubians have long ears and a more rounded nose bridge (Kilpatrick, 2017). The Nubian is a dairy goat of Oriental descent that is quite large, proud, and graceful and is renowned for its high-quality milk. Long, drooping ears, convex noses, and a short, shiny hair coat are traits that define them. Since any colour or pattern is acceptable, the breed is only recognized by its distinctive convex facial profile between the eyes and the muzzle and its long bell-shaped ears. They have a nice stature and a medium to huge size (Harris *et al*., 1996).

2.2.5.3 Saanen Goat

The Saanen breed originates in Switzerland. This breed is renowned for its high level of output. The Saanen breed is popular among many farmers due to their great milk production. Their transparent white coat makes them simple to identify (Kilpatrick, 2017). White or pale cream are the preferred colours for Saanens. There is no prejudice against goats that have skin spots. It is acceptable but not preferable to have a few discreet colour patches in the hair. They range in size from medium to large, have strong bones, and are all female throughout. The ears are upright and of medium size. Goats of this breed are negatively judged if they have a predisposition for a Roman nose (Harris *et al*., 1996).

2.2.5.4 Toggenburg Goat

One of the heaviest breeds is the Toggenburg, which has its origins in Switzerland. Over time, they have undergone selective breeding to increase milk production. A Toggenburg goat is built bulkier and their colour might be used to identify them. The colour of all pure-bred Toggenburg goat is a distinctive light brown/grey (Kilpatrick, 2017). The Toggenburg goats are strong, robust, and of average size. The Toggenburg goat may have white markings and be any shade of brown. These white marks can be seen on the face, from the eye area to the nose, around the outside of the ears, from the foot to the knee, from the foot to the hock, and as a triangular patch on either side of the tail, covering the pin bone area. These goats have medium-sized ears that are carried alertly (Harris *et al*., 1996).

In the table 2 below the average milk yield and chemical compositions of the Alpine, Nubia, Saanen and Toggenburg dairy goat breeds are shown.

Table 2: Average milk yield and composition of dairy goat breeds

Breed	Milk Yield (Kg)	Fat (%)	Protein (%)
Alpine	903	3.56	3.06
Nubian	713	4.61	3.66
Saanen	942	3.52	3.02
Toggenburg	869	3.35	3.01

Source: Getaneh *et al*. (2016)

2.2.6. Factors Affecting Dairy Goat Production

Dairy goat varieties from Europe have much greater milk production potential than native breeds that haven't been developed for it (Park, 1994 and Peeters *et al*., 1992). The correlation between body weight and milk output is favourable for dairy goats. Although larger does produce more milk, only around 10% of the variance in milk supply can be attributed to body weight (Peacock, 1996). The age of animals also has an impact on milk production, but it closely relates to body weight. Most of the increase in body weight can be attributed to ageing. Between the ages of four and eight years, the doe reaches its highest milk production peak (Peacock, 1996). Age and parity (number of lactations) are tightly correlated since milk output is influenced by both (Getaneh *et al*., 2016). The body mass may increase until the age of six years and then decline. Milk production also varies, reaching its peak between the ages of four and eight years. According to research on Alpine goats, the second lactation produced the highest yields (960 kg), while the seventh lactation produced the lowest yields (634 kg) (Browning *et al*., 1995). Although the udder volume and milk yield are closely connected, poor udder attachment has been regarded as a serious problem (Alawa and

Oji, 2008). Animals with a flat growth curve that mature later are likely to be more productive (Ciappesoni *et al*., 2004).

Numerous research findings suggest that mammary growth occurs throughout pregnancy. More milk is required, which makes sense (Zumbo and Di Rosa, 2007). The season of kidding has some bearing on milk production. Early lactation yields have lower yields than lactations that start later in the year (Zeng *et al*., 1997). This could be attributed to different feed resources available during the year. To create lactose, which in turn significantly regulates the passage of water into milk, the mammary gland needs glucose. Since the body stores very little glucose, a decrease in feed intake quickly reduces milk production (Park, 1994). Milk output can be impacted by the kidding season, which is frequently confused with age-related effects. Cold temperatures can lower milk output (Mourad, 1992). Despite having heat-resistant traits, goats that are giving milk are vulnerable to heat stress (Lu, 1989). Extremely cold temperatures can lower milk output (Mourad, 1992). The temperature plays an important role in the goats that are lactating as they have less milk secreted when exposed to cold. However, it has been found that the milk output from goats at a temperature of 20 ^{o}C was roughly 30% lower than that at -0.5 ^{o}C (Butswat *et al*., 2000).

Diseases and illnesses such as mastitis and brucellosis reduce milk supply, with the extent of the impact depending on the type and severity of the particular illness. Clinical illnesses are less hazardous to goat milk production than subclinical illnesses (Zeng *et al*., 1997).

2.3. Goat Milk

2.3.1. Generalities

The lactation period is the phase of the secretion or production of milk. Lactation lasts between 200 and 350 days, depending on the breed and environmental circumstances and natural lactation ends after 305 days (Getaneh *et al*., 2016). The lactation period has three lactation stages mainly the early (less than 80 days), mid (80–140 days), and late (more than 140 days) (Ibrahim and Tajuddin, 2021).

Zailan and Yaakub (2018), found that the peak milk production of Jamanapari goats in Malaysia occurred during the middle of lactation, followed by early lactation and late lactation. The average milk yield of Saanen goats was 2.55 kg per day, according to a prior study conducted in Europe (Ferro *et al*., 2017). The Saanen goat milk output varied depending on the stage of lactation. The data in Table 3 shows that mid-lactation does yield the most abundant milk, followed by early and late-lactation does.

Table 3: Saanen goat milk yield and composition of lactation stages

Stages	Milk Yield (g/day)	SNF%	Fat%	Protein%	Lactose%
Early	$226.20^{b} \pm 49.10$	$7.84^{a} \pm 0.12$	$2.97^{c} \pm 0.12$	$2.87^{a} \pm 0.06$	$4.27^{a} \pm 0.06$
Mid	$833.10^{a} \pm 177.70$	$7.79^{a} \pm 0.09$	$4.40^{a} \pm 0.00$	$2.87^{a} \pm 0.06$	$4.27^{a} \pm 0.06$
Late	$142.50_{b} \pm 36.90$	$7.26^{b} \pm 0.02$	$3.50^{b} \pm 0.00$	$2.60^{b} \pm 0.00$	$3.97^{b} \pm 0.06$

Source: Ibrahim and Tajuddin (2021)

Morand-Fehr *et al*. (2007) found that Saanen goats produce 700 to 900 g/day of milk during the late lactation period in Turkey. Due to the perfect environmental conditions for dairy goats to produce milk, these results appeared higher in comparison to recent findings (Gokdai *et al*., 2020). The milk yield differences could be attributable to various farm management practices and environmental conditions. However, a fairly recent study found that heat stress in dairy goats plays a significant impact in predicting daily milk yield (Zhu and Wang, 2020).

The lactation phase has the largest impact on the composition of milk as it influences the milk contents within that stage (Park, 1994). Like in cow's milk, many components of goat's milk, particularly fat and protein, are higher in colostrum; early in lactation but fall off significantly after that until they sharply increase at the end of lactation, when yields are low (Getaneh *et al*., 2016).

2.3.2. Goat Milk Yield

The process of milk extraction from the udder has to be done to measure the goat milk yield (Etgen and Reaves, 1978). Milk yield has been found to decrease when goats are milked less frequently each day, thus goats milked only once a day resulted in a one-third decrease (Meinert *et al*., 1989). It is recommended that goats be milked twice daily on a regular schedule, ideally every 12 hours (Getaneh *et al*., 2016). Tropical non-dairy goat breeds can produce up to 0.5 litres of milk per day, whereas specialized dairy goat breeds like the Nubian, Saanen, Alpine and Toggenburg can produce 2-4 litres per day of milk (Peacock, 1996).

Earlier studies show that Saanen goats' milk output grew steadily with age (Mioč *et al*., 2008). Goats typically reach their maximum lactation between the ages of 4 and 8 years, according to Getaneh *et al*. (2016). The increase in milk yield was brought on by previous alveoli that have not totally regressed and are now contributing more to milk production (Lérias *et al*., 2014). The table 4 below demonstrates the average milk yield and milk composition of Saanen goats at the different ages of 2, 3 and 4 years.

Table 4: Average milk yield and milk composition of Saanen goats at different ages.

Age (years)	Milk yield (g/d)	Fat%	SNF%	Protein%	Lactose%
2	$571.1^{b} \pm 89.7$	$2.87^{b} \pm 0.10$	$7.78^{a} \pm 0.04$	$2.80^{a} \pm 0.00$	$4.23^{a} \pm 0.03$
3	$850.5^{a} \pm 155.0$	$2.77^{b} \pm 0.06$	$7.80^{a} \pm 0.03$	$2.80^{a} \pm 0.00$	$4.27^{a} \pm 0.03$
4	$943.9^{a} \pm 168.0$	$3.33^{a} \pm 0.06$	$7.53^{b} \pm 0.11$	$2.77^{a} \pm 0.03$	$4.1^{a} \pm 0.06$

Source: Ibrahim and Jalil (2022).

The high nutritional value of plant material such as moringa is essential for the increase of milk yield and quality in ruminants (Babiker *et al*., 2017). As a result of their high protein content, there has been an increase in the production of microbial proteins in ruminant forestomaches (Soliva *et al*., 2005). Moringa has been used to increase milk production in goats, sheep, and cows testified by many researchers both in partial or complete replacement of feedstuffs (Mendieta-Araica *et al*., 2011; Babiker *et al*., 2017; Choudhary *et al*., 2018 and Zeng *et al*., 2018). Research on using moringa leaves in place of alfalfa hay demonstrated increased goat milk yields as well as higher milk fat, lactose, solid-non-fat, and calorie contents (Babiker *et al*., 2017).

Similarly, Choudhary *et al*. (2018) reported that lactating Bengal goats had increased milk yields and milk with higher fat, protein, lactose, and solid-non-fat contents when the concentrate combination was partially replaced by 50% moringa leaves. The inclusion of moringa leaves in diets has improved milk quality and yield, when replacing a diet of alfalfa (Abdoun *et al*., 2022). Higher dry matter intake and milk yield were obtained when moringa leaves were substituted for *Trifolium alexandrinum* hay in the diet of creole dairy cows (Sánchez *et al*., 2006). In another study, moringa was used to substitute alfalfa either entirely (100%) or partially (50%) and cows fed the moringa diet produced more milk than those fed an alfalfa-based diet (Khalel *et al*., 2014). Additionally, when compared to alfalfa-based rations, moringa-based rations enhanced the solid and solid-non-fat, protein, and ash contents of cow's milk (Khalel *et al*., 2014). However, milk yield was increased without having a significant impact on milk composition when cotton seed cake was substituted with moringa leaves meal at 10, 20, or 30% dry matter content in dairy cows' rations (Sánchez *et al*., 2006).

Replacing wheat silage and hay in the total mixed ration (TMR) of lactating cows with a mixture of moringa leaves, chopped wheat hay, and sugar cane molasses at a rate of 180 g/kg dry matter resulted in higher milk yield and milk fat content despite the reduction of digestible dry matter intake (Cohen-Zinder *et al*., 2016). Nevertheless, cows' milk production and serum biochemical profile were unaffected by the replacement of alfalfa hay and maize silage with moringa silage (Zeng *et al*., 2018). Moringa leaves have been found to improve milk quality and yield; this could be due to the plant's favourable effects on rumen microorganisms and its beneficial rumen bypass properties (Abdoun *et al*., 2022).

2.3.3. Goat Milk Quality

2.3.3.1 Fats

Butterfat is the name for the suspended globules of fat that are present in milk. Goat milk is mostly distinguishable by its lipid composition (Devendra and McLeroy, 1982). Goat's milk has a higher proportion of fat than cow's milk, the typical total fat content in milk is comparable to that of other ruminant species (Getaneh *et al*., 2016). A variety of factors, including genetics, season, lactation stage, and diet quality and quantity, affect the typical proportion of goat milk fat. Cow's milk includes an average of 14 to 17 mg of cholesterol per 100 grams of milk, whereas goat's milk is more frequently documented at 11 to 25 mg per 100 grams of milk (Auld *et al*., 2000).

2.3.3.2 Proteins

The percentage of milk protein has been reported to be similar in both cow and goat milk (Getaneh *et al*., 2016). The casein fractions of the milk from goats and cows have similar amounts and distributions of amino acids, but the order of assembly is virtually different (Bruhn and Schutz, 1999). The lactalbumin component also appears to have a comparable difference; however, it may have more clinical implications (Getaneh *et al*., 2016). Many people experience allergic reactions to the lactalbumin in cow's milk, compared to that in goat milk, especially for young children (Mendieta-Araica *et al*., 2011).

2.3.3.3 Vitamins

Compared to conventional cow's milk, goat milk contains 47% more vitamin A, 25% more vitamin B6, and vitamin A2 (Devendra and McLeroy, 1982). Goat milk in comparison to cow's milk, contains significantly less thiamine (B1) (Getaneh *et al*., 2016). A study by Bruhn and Schutz (1999), illustrates that it is remarkable that goat milk, which has a higher casein content than cow milk, gets its vitamin A content entirely from the vitamin itself and not carotenoid pigments that are present in cow milk.

2.3.3.4 Lactose

Lactose has been proven to be the main free carbohydrate in goat milk with its concentration lower than that of cow's milk, although the extent of the difference is difficult to measure (Getaneh *et al*., 2016). There is no consensus on whether to analyse lactose in its mono- or non-hydrated form, and this lack of hydration can cause a five per cent difference in the concentration recorded for a given amount of lactose (Auld *et al*., 2000).

2.3.3.5 Mineral Salts

Goat milk is a natural source of minerals with excellent health benefits. Major and trace minerals found in goat's milk include Ca, Na, Mg, P, K, Zn, Mn, Se, Co, and Fe (Ambrosoli *et al*., 1988). Goat milk is a rich source of calcium as it contains 34% more K element and 13% more calcium per serving than cow's milk, making it one of the most common natural minerals in milk (Auld *et al*., 2000).

2.3.3.6 Enzymes

Despite some variations, the goat's milk contains similar enzymes to those in cow's milk (Devendra and McLeroy, 1982). The peroxidase activity in the milk of both animals is identical in every way, however, the goat's milk has less xanthine oxidase (Bruh and Schutz, 1999). The enzyme alkaline phosphatase has the same amount of heat susceptibility as that seen in dairy cattle and it functions equally effectively as a pasteurization marker (Getaneh *et al*., 2016).

The table 5 below compares the milk composition parameters of goats, cattle and sheep species.

Table 5: Average milk composition of goat, cow and sheep.

Composition	Goat (%)	Cow (%)	Sheep (%)
Total Solid	13.9	13.5	19.3
Fat	4.8	4.8	7.6
Protein	3.7	2.8	5.5
Lactose	5.0	4.5	-
Ash (minerals)	0.85	0.74	-

Source: Devendra and McLeroy (1982).

2.4. Different ruminant feed sources

2.4.1. Generalities

In dry and semi-arid pastoral areas, grazing and browsing is the primary source of animal feed. Crop residues may be used to supplement the total feed supply, especially in integrated crop-livestock systems (Tolera *et al*., 2000). Seasonal variations can be seen in the quantity and kind of fodder available from natural pastures. Dube *et al*. (2017) noted the need for dry season supplementation due to the severe low-quality available feed supply. Tolera *et al*. (2000) reported that low output, stunted growth, poor condition, illnesses and parasite susceptibility are some of the negative effects of poor nutrition.

Therefore, there is a necessity to address the nutritional issues of goats to effectively utilize the available feed resources (agricultural and agro-industrial by-products, natural pastures, and browse) and appropriate supplementation of poor-quality natural pasture and crop residue-based diets (Marius *et al*., 2021). The type, availability, and cost of supplemental feeds are factors to consider to ensure a consistent supply of feed and strategies for its conservation to be adapted. To improve fodder utilization, studies focus on the nutritional value of naturally occurring tree leaves and pods frequently browsed (Tolera *et al*., 2000).

2.4.2. Feed Intake and Nutrient Digestibility

According to McDonald *et al*. (2011), animal diets should have a minimum of 11.2 g/kg DM of CP to support rumen microbial activity. This highlights the importance of feed intake in fulfilling both the animal's nutritional and quantity needs as have been primarily studied (Grant *et al*., 1995 and Dado and Allen 1996). Baloyi *et al*. (2008) demonstrated that legume supplements improved fibre digestion in the animal rumen, while Mupangwa *et al*. (2022) reported that animal gender affected the DM and NDF digestibility of forage legumes. They reported the highest DM digestibility in male animals with the female goats having improved digestibility.

Daily dry matter consumption of goats in experiments ranged from 2.6 to 4.0% as reported by Dzakuma *et al*. (2004) and Awuk and Tamir, (2007). Quigley and Heitmann (1991) reported a high dry matter intake in Lablab as a protein source which Mupangwa *et al*. (2022) recently confirmed with animals consuming more lablab fodder than Vigna fodder. Askar *et al*. (2016) reported that NDF levels in feed directly correlate with animal feed intake. According to McDonald *et al*. (2011), high NDF content causes an increase in the microbial population and increases the rate of fibre digestion; this results in a rise in feed intake, however, this is not the case when iNDF content exceeds 15% of total dietary dry matter (Harper and McNeill, 2015). However, Robinson and McQueen (1997) reported that cowpea dietary NDF had no negative effect on the animal dry matter intake. A higher NDF concentration may also cause saliva to be produced, which acts as a buffer and reduces feed intake (Washaya *et al*., 2017).

According to McDonald *et al*. (2011), high-quality forages with low DMI have longer rumination periods, which results in highly digestible forage. According to Kholif *et al*. (2014), forage legumes have poor NDF and ADF values and are exacerbated by anti-nutrients, particularly tannins. Meanwhile, Kholif *et al*. (2015) demonstrated that the administration of undegraded protein enhances DMI and improves digestibility to overcome low digestibility.

Farmer *et al*. (2014) observed that Holstein cows fed corn and silage showed 49% *in-vivo* NDF digestibility, 34% ADF, 67.9% CP, 62% DM, and 64% OM. Serment *et al*. (2011) found that goats fed concentrates had higher ADF digestibility. When goats were fed potato vines, Malecky *et al*. (2017) showed low NDF digestibility.

2.4.3. Fodder Selection Characteristics of Goats

It can be difficult to interpret whether a goat is a grazer or a browser based on different grazing patterns under different environmental conditions (Togarepi *et al*., 2018). Goats' diet conformation was influenced by their choice of fodder (Solanki, 1994). The majority of research on grazing animals and their behavioural aspects were based on weather and ingestion behaviour (Tixier *et al*., 1997), climate and active hours (Lee *et al*., 2019); grazing interactions with other areas had been studied by Washaya *et al*. (2021) and Solanki and Naik (1998).

Throughout the year, pasture convenience affects the diet choice of herbivores (Dumont *et al*., 1995). Due to their bipedal position, which helps in consuming food, goats can choose plant leaves from the upper surface layer (Decandia *et al*., 2008).

According to Pisani *et al*. (2000), the springtime grass is selectively fed to goats in semi-arid areas due to its quantity and quality during the season.

According to Aharon *et al*. (2007), goats prefer herbaceous plant species. Wild plants are expected to have a poor forage selection pattern given the availability of herbaceous grass species (Manousidis *et al*., 2016). Goats are accustomed to having access to feed and can adapt to their preferences hence they prefer herbaceous grasses if available (Osoro *et al*., 2013).

Most of a goat's day is spent feeding and ruminating (Katsande *et al*., 2016). According to Mupangwa *et al*. (2022) grazed goats spent a lot of their time resting, while 30.5% of their time was spent eating. Unni *et al*. (2014) reported that goats are selective and spend the more time choosing feeds, moving and eating frequently. According to Provenza (2005), goats consume 60% shrub, 30% grass, and 10% large leaves while sheep consume 20% shrub, 50% grass, and 30% large leaves with about 34% and 66% of the total plant, wild and herbaceous plants, respectively. Goats have an unusual lip and tongue that is well-developed, allowing them to consume a variety of vegetation, including short grass, large leaves, and wild shrubs (Gusha *et al*., 2015). Goats prefer fresh grass to dry grass and leaves on stems (Mupangwa *et al*., 2022).

2.5. Uses of Moringa

2.5.1 Moringa Biological Characteristics

Moringa originates in India and has since expanded to numerous semiarid, tropical, and subtropical regions of other countries due to its ability to grow well in a range of temperatures between 25 and 35 °C (Gopalakrishnan *et al*., 2016). Moringa has an average height of 10-12m an average diameter of 45cm and a bark of light grey colour, while the young shoots are purple or white-greenish (Raja *et al*., 2016). The fruit of the perennial, evergreen *Moringa oleifera* tree matures to a brown colour and contains 10 to 50 seeds (Vlahof *et al*., 2002).

Numerous countries began cultivating moringa on a big scale (Makkar and Becker, 1996). Similarly, moringa was brought to Egypt and produced using a variety of land-use techniques (Abd and Baroty, 2013). Moringa typically has five uneven, lightly veined, yellowish-white, bisexual flowers that are fragrant and these are about 2.0 cm in width and 1.0–1.5 cm in length (Raja *et al*., 2016).

Moringa is grown in semi-arid, tropical, and subtropical regions. Although the moringa plant may grow in a variety of soil types, it favours neutral to slightly acidic soil (pH 6.3 to 7.0) (Thurber *et al*., 2010). Moringa roots rot in water-logged locations and require that it is cultivated using rainwater due to their low water need (Korsor *et al*., 2018). Since it prefers warm temperature conditions, moringa is especially suited to dry areas. Moringa leaves can produce approximately 100 tons of dry matter (DM)/ha of biomass when grown under intense circumstances (Foidl *et al*., 2002). Moringa has the potential for nutritional use for multiple species all over the world (Gopalakrishnan *et al*., 2016).

Moringa seeds are planted directly in the ground or by seedlings that have been grown in nurseries (Price, 2007). According to Manduwa *et al*. (2017), temperature affects how well moringa performs during its flowering stage. Although moringa grows best at high temperatures, suboptimal conditions can result in low growth and a low yield (Muhl *et al*., 2011). Moringa output improves significantly if grown in a cold climate, but it is important to fully comprehend the effects of the cold climate before planting (Abdoun *et al*., 2022).

NPK fertilization allows maximum development and a high leaf yield with favourable nutritional characteristics of moringa plants cultivated in sandy soil (Darwish *et al*., 2019 and Aslam *et al*., 2020). When treated with N at a rate of 521 kg/ha/year, moringa can produce up to 27 tons of dry matter per hectare at a planting density of 167,000 plants per ha (Mendieta-Araica *et al*., 2013). Nitrogen fertilization appears to change moringa's chemical composition by raising its protein content (Mouchili *et al*., 2019).

Moringa trees in arid and semi-arid tropical climates shed their leaves during the dry season and begin to grow again during the rainy season (Palada and Chang, 2003). The general consensus is that pruning accelerates the growth of vegetative elements, especially the leaves, resulting in a dense growth of extra leaves and lateral buds (Abdoun *et al*., 2022). If the tree is not pruned, it may develop an upright, quickly-growing shoot with few leaves and fruits on the main stem (Palada and Chang, 2003). To improve branching and boost yield moringa should be pruned (Bosch *et al*., 2004). According to Vijayakumar (2000), pruning moringa plants early, after 60 days of sowing, is preferable since it speeds up the plant growth and produces more fodder.

A study by Raja *et al*. (2016) shows that moringa can be grown as a perennial or annual plant. When cultivated perennially, moringa benefits areas that are less favourable for cash crop environments by reducing erosion and maintaining agroforestry. Raja *et al*. (2016).

2.5.2. Nutrients and phytochemical compounds in *Moringa oleifera*

There have also been found nutritionally valuable functional molecules such as carbohydrates, proteins, lipids, and vitamins in the plant (Gopalakrishnan *et al*., 2016). Yaméogo *et al*. (2011) reported moringa leaves had lower protein and fat concentrations in comparison to the plant seeds (27.2%) and roots (17.1%). The average crude protein content of dry leaves ranged from 28.7 to 30.3% and contained 19 amino acids (Moyo *et al*., 2011). The protein content (on a dry basis) of dried leaves was also reported to be between 25.0% and 29.0% (Abdoun *et al*., 2022), while the protein and fat content of moringa seeds was estimated to be 34% and 33.23%, respectively (Anwar *et al*., 2005). Moringa leaves have a high protein content, which makes them a viable source of supplemental protein for animal feed between 16% and 40% of the protein content was reported in other investigations (Sarwatt *et al*., 2002 and Sánchez *et al*., 2006). Table 6 below illustrates the *Moringa oleifera* nutritional composition per 100mg, while Table 7 shows the *Moringa oleifera* leaf-meal phytochemical composition.

Table 6: *Moringa oleifera* nutritional value per 100mg

Composition	Units	Composition	Units
Energy	64kcal (270kj)	MINERALS	
Carbohydrates	8.28g	Calcium	185mg (19%)
Dietary Fibre	2.0g	Iron	4.00mg (31%)
Fat	1.40g	Magnesium	147mg (41%)
Protein	9.40g	Manganese	0.36mg (16%)
VITAMINS		Phosphorus	112mg (16%)
Vitamins A	378µg (47%)	Potassium	337mg (7%)
Thiamine (B1)	0.257mg (22%)	Sodium	9mg (1%)
Riboflavin (B2)	0.660mg (55%)	Zinc	0.6mg (6%)
Niacin(B3)	2.220mg (15%)		
Pantothenic Acid (B5)	0.125mg (3%)		
Vitamin (B6)	1.200mg (92%)		
Folate(B6)	40µg (10%)		
Vitamin C	51.7mg (62%)		

Source: Raja *et al*. (2016).

Table 7: *Moringa oleifera* leaf-meal phytochemical composition

Parameters	Composition (%)
Dry Matter	90.46
Crude Protein	18.38
Crude Fibre	14.04
Ether Extract	14.58
Ash	8.38
Organic Matter	91.62
Nitrogen Free Extract	44.71
Neutral Detergent Fibre	25.68
Acid Detergent Fibre	14.78
Acid Detergent Lignin	8.11
Hemicellulose	10.90
Cellulose	6.67

Source: Tona *et al*. (2014).

2.5.3. Moringa as a feed source

A couple of studies suggest that moringa affects ruminal fermentation due to its tannin and saponin content (Dewangan *et al*., 2010; Zhao *et al*., 2012 and Batista *et al*., 2014). According to Singh *et al*. (2006), it can be speculated that the numerous antibacterial compounds can be isolated from different parts of the moringa tree, which is crucial to consider given the rumen bacterial biodiversity that is crucial to the ruminants' ability to utilize their feed (Forsberg and Cheng, 1992).

Therefore, integrating moringa into ruminant diets would impact ruminal microbial activity, which in turn would impact ruminal fermentation, digestibility, and overall animal performance. This would be true for both its protein content and bioactive components (Soltan *et al*., 2017).

Moringa has good nutritional qualities; this explains its worldwide pasture use alongside other pastures such as alfalfa (Criscioni *et al*., 2016). Moringa exhibits excellent green matter productivity, and with a planting density of one million plants per hectare, the biomass yield can be maximised (Makkar and Becker, 1996). In the creation of rations for animal feeding, moringa leaves and the press cake from its seeds may be utilized (Pérez *et al*., 2010). The index of digestible protein of moringa leaves in the intestine is higher than that of several conventional protein supplements, such as coconut press cake, cotton, sesame, and sunflower seeds (Makkar and Becker, 1996). The press cake of six Cuban non-traditional oil plants was studied, and moringa proved to have the greatest protein content (68.6% of dry weight) among all of them (Martin *et al*., 2010). This shows that the plant has a high potential as an animal feed source.

Moringa leaves make a good protein supplement due to their high quantities of crude protein, lack of tannins, lectins, trypsin inhibitors, or factors that cause flatulence and their low levels of saponin and phytate (Makkar and Becker, 1996). Along with its use in vermiculture and fish farming (Cova *et al*., 2007), a combination of moringa leaves with molasses and sugarcane straw has shown excellent results as animal feed (Radovich, 2011). Ben *et al*. (2009) fed moringa cake to 24 lambs and reported improved ruminal fermentation and weight gains.

Moringa also contains other elements, such as lactogogue, which is formed of phytosterols and serves as a precursor to hormones important for reproductive growth. Phytosterols like stigmasterol, sitosterol, and kampesterol, which are hormone precursors, are abundant in moringa (Soltan *et al*., 2017). These phytochemicals, in combination with the high amino acid content, can increase the excretion of oestrogen, which in turn increases the growth of the milk-producing mammary gland ducts (Gopalakrishnan *et al*., 2016).

It was recently discovered that adding moringa leaves to ruminant diets improved milk output and composition while reducing oxidative damage to the milk and serum of ewes and goats (Babiker *et al*., 2017). According to Gopalakrishnan *et al*. (2016), moringa leaves, pods, and flowers contain amino acids amounting to up to 440, 300, and 310 g/kg DM, respectively. Moringa was also suggested as a source of minerals because it contains 25 times more iron than spinach and 25 times more vitamin C than oranges. It also contains 10 times more vitamin A than carrots, 9 times more protein than yoghurt, 15 times more potassium than bananas, and 7 times more vitamin C than oranges (Rockwood *et al*., 2013). According to Babiker *et al*. (2017), the functional effect of phenolic acids and antioxidant activity of moringa leaves may be responsible for the lowered cholesterol level in the milk of ewes and goats fed on these plant leaves.

According to Marhaeniyanto1 and Susanti (2014), short-chain fatty acids (SCFAs), ammonia (NH_3), methane (CH_4), carbon dioxide (CO_2), and microbial protein are the main products of ruminal fermentation. Moringa leaves were discovered to be a methanogen inhibitor, so it was suggested to be an alternative to replace essential antibiotic feed additives to alternate the ruminal fermentation pathways (Soliva *et al*., 2005).

Soliva *et al*. (2005) noticed that diets including moringa leaves had an organic matter *in vitro* degradability that was comparable to or even higher than diets containing rapeseed meal or soybean meal. On the other hand, Dey *et al*. (2014) reported that a buffalo diet supplemented with wheat straw and moringa leaves, increased total gas production and improved the *in vitro* degradability of organic matter. There is proof that the benefits of moringa leaves on ruminal fermentation may not be due to their high protein content (Dung *et al*., 2005; Van, 2006 and Soltan *et al*., 2017).

Babiker *et al*. (2017) switched the alfalfa in lactating ewes and goats' diets with moringa leaves and concluded that it had a positive impact on milk yield, composition, and quality as well as on the growth performance of kids and lambs. Additionally, moringa leaves increase the amount of vitamin C and total antioxidant capacity in goats' and ewes' milk and serum (El-Desoky *et al*., 2017). Table 8 below illustrates the moringa leaf meal effects on goat rumen metabolites and particular microbial enzyme activity.

Table 8: Effects of moringa leaf feeding on goat rumen metabolites and particular microbial enzyme activity.

Attributes	Control	ML10	ML20	SEM	P-Values		
					T	P	T*P
pH	6.6	6.7	6.7	0.08	0.85	0.42	0.95
Concentration of rumen metabolites							
TVFA mmol/dl	7.59	7.63	7.58	0.35	1.0	0.17	0.60
Acetate %	65.4	64.5	63.7	0.92	0.78	0.62	0.09
Propionate%	20.8	22.5	23.1	1.16	0.70	0.79	0.17
Butyrate%	12.8	12.3	12.4	0.30	0.78	<0.001	0.38
A:P ratio	3.2	3.2	2.8	0.17	0.60	0.94	0.10
Ammonia-N (mg/dl)	12.4	14.5	13.3	0.99	0.70	0.43	0.42
Rumen enzymes Activities (units/mg protein)							
Carboxymethyl cellulase	0.64	0.59	0.54	0.10	0.92	0.06	0.89
Avicelase	0.46	0.57	0.41	0.04	0.27	0.44	0.06
Xylanase	1.37	1.96	1.06	0.15	0.76	0.10	0.95
Acetyl esterase	0.47	0.46	0.49	0.10	1.00	0.30	0.47
Urease	0.37	0.40	0.55	0.04	0.15	0.15	0.58
Protease	8.73	8.94	7.28	0.38	0.21	0.14	0.34

ML10: moringa at 10% of DM, ML20: moringa at 20% of DM

Source: Jadhav *et al*. (2018).

2.5.4. Moringa as an ethnomedicine source

Drug-active ingredients in plants create a vast variety of secondary metabolites to protect themselves against infections and herbivores, among other uses (Wube *et al*., 2005). Numerous of these substances have found widespread application in human and veterinary medicine, and many contemporary medications are either directly extracted from plants or produced as synthetic analogues (Dharani, 2010). The key factor used to categorize secondary metabolites is how they are created from primary metabolites. The main classes are Polyketide Derivatives, Alkaloids and Flavonoids (Dharani *et al*., 2015). Several medications are made of alkaloids, which are commonly present in plants and are well-known for their pharmacological characteristics (Manguro *et al*., 2003).

Due to the widespread moringa use for both feeding and therapeutic reasons in many tropical countries, a lot of conventional uses have been experimented it (Saini *et al*., 2017). The leaves, fruits, roots, and seeds can be used to treat a variety of conditions such as anaemia, anxiety, asthma, paralysis strokes, bronchitis, chest congestion, diabetes, diarrhoea, erectile dysfunction, lack of desire for sex in women, swollen glands, high blood pressure, skin infections and sores to mention few (Fuglie, 2001).

Hoffmann *et al*. (2003) discovered that while many of moringa's medicinal properties have already undergone thorough research vetting, there are still others that need clinical trials to back them up. Despite the information on moringa’s therapeutic abilities being widely circulated, it typically relies on empirical data rather than referring to specialized literature (Askar *et al*., 2016). A high portion of the information originates from businesses that manufacture and/or distribute moringa nutritional supplements and other products made from the plant whose all added value is mostly in the form of advertising (Martin *et al*., 2013).

2.5.4.1 *Moringa oleifera* antimicrobial bioactive compounds

Moringa oleifera can be used to treat a variety of illnesses and research findings have supported this claim (Fuglie, 2001). The effectiveness of different plant parts against pathogenic microorganisms has been demonstrated through experiments. Studies demonstrate that aqueous extracts from the leaves can prevent the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Cáceres *et al*., 1991). Chuang *et al*. (2007) demonstrated the antifungal efficacy of alcoholic extracts from the seeds and leaves as well as essential oils from the leaves against dermatophytes like *Trichophyton rubrum* and *Trichophyton mentagrophytes*.

Studies demonstrated the antibacterial action of moringa seed extracts, which flocculate Gram-positive and Gram-negative bacteria similarly to how they flocculate water colloids (Fahey, 2005). Their ability to inhibit vital enzymes causes rupture of the cell membrane, which has bactericidal properties (Suárez *et al*., 2003). The microbiological activity of moringa seed extracts against bacteria such as *Salmonella typhii, Vibrio cholerae*, and *Escherichia coli*, which cause typhoid fever, cholera, and gastroenteritis, respectively, was demonstrated in a study conducted in Kenya (Walter *et al*., 2011).

Due to moringa extracts being natural antibacterial agents, which form an affordable and sustainable technique for disease prevention and improve the quality of life in underdeveloped areas, the authors of this review believe that this result can have a positive effect on their lives (Bharali *et al*., 2003). It has been noted that many rural areas of developing countries lack cheap water treatment options due to the high costs of chlorine and other disinfectants, which leads to diseases caused by contaminating bacteria (Guevara *et al*., 1999). According to Martin *et al*. (2013), medicines made from the leaves, flowers, and roots of moringa have been shown to prevent cancer.

The most researched aspect of moringa is its antimicrobial action against opportunistic illnesses (Brilhante *et al*., 2015). There are a variety of bioactive substances found in leaves that are assumed to be specifically responsible for the antibacterial action (Shah *et al*., 2016). Moringa leaves have been discovered to be a valuable natural source of antimicrobial compounds against resistant germs, particularly in light of the development of drug resistance among many virulently pathogenic bacteria (Wang *et* *al*., 2016). Other plant parts show strong antibacterial activity against *Cladosporium cladosporioides, Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus and Penicillium sclerotigenum* (Oluduro *et al*., 2010) due to the high content of 4-benzyl isothiocyanate, methyl N-4-benzyl carbamate, and 4-benzyl thiocarboxamide of moringa seed (Martin *et al*., 2013).

2.5.4.2 *Moringa oleifera* antioxidant activity

According to Morsy *et al*. (2015), ruminal microorganisms are primarily strict anaerobes with less developed antioxidant capacities than facultative anaerobic and aerobic microbes. According to Shah *et al*. (2016), moringa seeds and leaves may be a source of natural antioxidants. Therefore, adding antioxidants to ruminant diets would reduce oxidative stress, encourage the channelling of more nutrients towards optimal microbial growth, and improve microbial protein synthesis (Soltan *et al*., 2017). Moringa leaves show strong antioxidant activity against free radicals, protect important biomolecules from oxidative damage, and offer considerable protection against oxidative damage (Sreelatha and Padma, 2009).

Due to the presence of ascorbic acid and flavonoids, which have antioxidant activity, moringa leaves contain up to 8% natural antioxidants on a dry matter basis (Nadeem *et al*., 2013). Different antioxidants present in moringa leaves were identified by Anwar *et al*. (2003) and were found to be efficient in preventing autooxidation and enhancing the oxidative stability of sunflower oil over 90 days at room temperature.

Numerous human diseases' ethology is linked to the build-up of free radicals. The use of antioxidants in pharmacology is widely researched. Antioxidants are compounds that can delay or prevent the generation of free radicals (Martin *et al*., 2013). Antioxidant chemicals found in plants, such as carotenoids, tocopherols, ascorbates, and phenols, can reduce oxidative damage either directly by neutralizing free radicals or indirectly by activating cell defences (Ogbunugafor *et al*., 2011). More than 40 chemicals with antioxidant activity can be found in moringa's various sections.

2.5.4.3 Phenolic compounds

Kaempferol, gallic and ellagic acids are among the phenols that have free radical capture activity and because of their ability to chelate metal ions are both found in the seeds of moringa (Lalas and Tsaknis, 2002). The extracts from moringa leaves, fruits, and seeds were found to inhibit lipid peroxidation and moringa was also suggested as an ideal candidate for the pharmaceutical, nutraceutical, and functional food industries (Singh *et al*., 2009). These extracts also protect living cells from the oxidative damage of DNA associated with ageing, cancer, and degenerative diseases (Tang *et al*., 2020).

The fraction extracted with ethyl acetate, which is high in phenolic acids and flavonoids, has the greatest antioxidant capacity as reported by Verma *et al*. (2009). According to seasonal and agroclimatic factors, moringa leaves' antioxidant capacity changes (Iqbal and Bhanger, 2006).

Arsenic and other heavy metals have been affected by the plant's antidote effect in rats as demonstrated by Gupta *et al*. (2007). It has been demonstrated that the moringa seed powder can lower the concentration of arsenic and protect against the haematological effects and oxidative stress that metal can cause, both of which have been linked to many phytochemicals with antioxidant and chelating potential (Martin *et al*., 2013).

The moringa seed's natural coagulants, high concentration of amino acids like methionine and cysteine, and antioxidants like vitamins C and E and beta-carotene are what allow arsenic-induced oxidative stress to be reversed (Flora and Pachauri, 2011).

2.5.4.4 *Moringa oleifera* anthelmintic activity

The moringa tree gains the additional recognition of being an anthelmintic for ruminants as a result of its enrichment in phenolics (Soltan *et al*., 2017). In many developing countries, gastrointestinal parasites continue to hinder ruminant productivity by causing severe anaemia, anasarca, and sudden death (Mortensen *et al*., 2003). Cabardo and Portugaliza (2017) noticed that the ethanolic and aqueous extracts of moringa seed have numerous methods for killing the gastrointestinal parasites with a low possibility of anthelmintic resistance developing.

Overall, *Moringa oleifera* exhibits a strong potential for controlling parasites, which may prevent their related diseases (Cabardo Jr. and Portugaliza, 2017). Asaolu *et al*. (2012) and Moyo *et al*. (2013) showed that supplementing with moringa leaves may reduce the burden of strongyle parasites in naturally infested West African Dwarf goats and cross-bred Xhosa lop-eared goats. The effectiveness of moringa leaves in inhibiting the behaviour of gastrointestinal parasites eggs and larvae was corroborated by Tayo *et al*. (2014) who used aqueous and ethanolic leaf extracts in their study.

Berkovich *et al*. (2013) and Soltan *et al*. (2017) discussed the possible use of moringa seeds, leaves, and gum extracts in nematode parasite control due to their tannins, saponins and alkaloids responsible for over 90% of the egg hatch inhibition. The impact of tannins on internal nematodes in ruminants has received the greatest attention in recent years. In addition to acting directly through their antiparasitic activity, tannins may also operate indirectly by enhancing host resistance (Hoste *et al*., 2006).

Tannins are known to decrease the parasite larvae motility, which may imply paralysis and interfere with the larvae's ability to coordinate their neuromuscular movements (Hoste *et al*., 2006). According to Ali *et al*. (2011), saponins are a good source of cytotoxic and anthelmintic components, making their extraction and purification necessary for the creation of novel drugs.

Moringa seeds are effective at reducing helminth eggs not only in ruminants' gastrointestinal tracts but also in the process of purifying water from helminth parasites and their eggs (Wang *et al*., 2016). Urban farming uses irrigation water often in many impoverished countries across the world, which is susceptible to contamination by the helminth parasite and its eggs. To reduce helminth eggs and turbidity in irrigation water, moringa seeds were utilized (Sengupta *et al*., 2012).

2.5.5. Conservation strategies and efficient use of indigenous medicinal plants

Demisse (2001) stated that conservation efforts should focus on preserving the greatest amount of genetic variation within each species to guarantee that its genetic potential is preserved in the future. The reliance on traditional medicine for healthcare causes sustainable management of traditional medicinal plant resources crucial (Cunningham, 1993). There have been various conservation initiatives implemented globally to prevent additional harm to threatened medicinal plants (Pramanik *et al*., 2016).

Due to their difficulty in domestication and management, several traditional medicinal plants must be preserved in their natural habitat (Legesse and Ababa, 2010). Saini *et al*. (2016) stated that medicinal plants can be preserved by assuring and promoting their growth in their designated areas, this is conceivable in places like churches, mosques, cemeteries, farm margins, and river banks, among other places.

Fenetahun and Eshetu (2017) reported that the preservation of medicinal plants coexists with the preservation of ethnobotanical and ethnopharmacological knowledge. Through interviews and market research, ethnobotanical studies can identify management issues with medicinal plants and provide remedies by encouraging regional traditions and practices that have conservation benefits (Gadgil *et al*., 1993).

2.5.6. Other uses of *Moringa oleifera*

Practically speaking, every component of moringa has been utilized by humans for thousands of years. Because of its nutritional worth, the leaves, flowers, fruits, and roots can be fed to both humans and animals. The leaves are known to address nutritional issues in infants because of their outstanding vitamin and amino acid richness (Fuglie, 2001). In addition, they are employed as biopesticides and fodder, and to produce biogas (Fahey, 2005). The seeds are utilized as fertilizers, food, medicine, and water purification (Foidl *et al*., 2001).

According to Reddy *et al*. (2011), the trunk bark is helpful in the adsorption of heavy metals and the production of ropes and carpets. According to Rashid *et al*. (2008), the oil is utilized as a lubricant in the perfume and cosmetics sector as well as in the manufacturing of biodiesel and human food. The seed husks are used as a raw material to make anion exchangers and activated carbon (Ramachandran *et al*., 1980). The plant can also serve as a windbreak or living fence, and the lignocellulosic biomass of the trunk and branches can be utilized to make cellulosic pulp and ethanol as well as building materials (Fahey, 2005).

In the less developed world, seeds have been used for a very long time to purify water (Wang *et al*., 2016). The flocculent protein from moringa seeds that form flocculate particles in suspension in water was used to demonstrate the mechanism of moringa seeds as water purifying agents (Pramanik *et al*., 2016).

In addition, the seeds are a good source of linoleic, linolenic, and oleic acids, which can lower cholesterol. According to Lalas and Tsaknis (2002), moringa seed oil contains about 76% of these fatty acids, making it a perfect replacement for olive oil.

2.6. Small stock Diseases

2.6.1. Common Livestock Diseases

Animals are susceptible to diseases directly caused by parasites, bacteria and viruses and their presence (Saini *et al*., 2016). Table 9 illustrates some of the common diseases treated with ailments.

Table 9: Livestock diseases treated with common livestock ailments

Livestock Ailments	Animals Treated
Sheep and goat pox	193 000
Ovine pasteurellosis	146 950
Anthrax	48 418
Bovine pasteurellosis	30 250
Blackleg	29 800
Lumpy skin disease (LSD)	17 700

Source: Yirga *et al*. (2012).

2.6.1.1 Mastitis

Mastitis is merely an udder irritation, caused mainly by different bacterial species, but especially *Staphylococcus* or *Streptococcus* (Coffey *et al*., 2004). The udder appears warm, uncomfortable, stiff, and rigid. Penicillin alone may be sufficient, or a broad-spectrum antibiotic may be required. Mastitis often come to be when proper sanitation is not maintained. Numerous mastitis-causing bacteria are prevalent in the environment and may find their way into the milk pail and udder (Ali *et al*., 2011). After every milking, machines need to be thoroughly cleaned, sanitized, and stored.

Mastitis risks are reduced and milk bacteria levels are decreased by using clean equipment (Harris *et al*., 1996).

2.6.1.2 Caseous Lymphadenitis (cheesy gland)

Abscesses form from lymph nodes in caseous lymphadenitis, a frequent chronic disease of adult goats that is most common around the head, neck, and shoulder (Coffey *et al*., 2004). Due to internal abscesses interfering with important organs, this illness may finally result in the affected animal becoming emaciated and dying (Ashfaq *et al*., 2020). Penicillin should be administered four times daily, and the wound should then be flushed with an antiseptic solution until it heals. Only a deliberate program of growing progeny in separate facilities and disposing of the sick animals will be able to eradicate caseous lymphadenitis from a herd. It is believed that using an autogenous bacterium made in a laboratory can help lower the prevalence of the illness (Harris *et al*., 1996).

2.6.1.3 Contagious Ecthyma (Sore Mouth)

Sore mouth is a contagious viral disease that is resistant to treatment; it causes scabs on the lips and gums (Coffey *et al*., 2004). The virus is present in the scabby material and may persist in the soil for a long time therefore causing the risk of transmission. Upon recovering from the initial infection, immunity is built. A vaccine campaign is effective in preventing the illness. The goal of treatment is to stop a subsequent bacterial infection. One can apply zinc oxide or another comparable ointment to the region after using hydrogen peroxide and gauze to gently remove the scabby debris. Plastic gloves should be worn because it can spread to people (Harris *et al*., 1996).

2.6.1.4 Overeating Disease (Enterotoxaemia)

A sudden change in feed or overeating by extremely hungry animals can result in enterotoxaemia when the bacterium grows quickly and releases poison into the intestines. This disease can be prevented by regular feeding and vaccination with *Clostridium perfringens* toxoids of types C and D (Ashfaq *et al*., 2020). While it frequently manifests as abrupt death in kids, depression, intoxication, and poor coordination in adult animals are possible symptoms.

2.6.1.5 Foot Rot

Foot rot is a bacterial disease affecting small ruminants, especially sheep kept in damp, muddy environments with limited ventilation. The hoofs of the animal get infected, which results in swelling in the hoof and eventually decay as well as pain in the foot. The consequences can be lameness, weight loss and even death. Two bacteria synergistically cause the disease; *Dichelobacter nodosus* and Fusobacterium *necrophorum*. It is characterized by lameness, severe discomfort, and a cheesy, grey discharge are all symptoms. For the treatment, one needs to trim the rotten area out carefully, then apply an appropriate ointment; 10 to 30% copper sulphate, or any treatment your veterinarian has recommended to the affected region (Coffey *et al*., 2004). The easiest way to prevent foot rot is to keep your goats in a location that is mostly dry (Strydom n.d.).

2.6.2. Effects of diseases on farm economics

Farmers battle plant poisoning caused by wild onions, commonly known as “onyanga” in the local Oshiwambo language and *Dipcadi glaucum* in scientific terms (Marius *et al*., 2021).

According to Gathiori *et al*. (2006), infectious illnesses and parasites are obstacles to communal goat production in many parts of Southern Africa. These are contributing factors that limit the growth of the herd along with goat theft, which results in financial losses to farmers (Marius *et al*., 2021).

According to Ashfaq *et al*. (2015), one of the main reasons for livestock low milk yield is livestock illnesses. Farmers cannot afford to lose their cattle due to diseases related to the subsistence nature of their livestock farming and the expensive cost of livestock. Diseases in cattle lead to mortality and reduced productivity, which constitutes a danger to the general well-being of poor farmers (Hasnain and Usmani, 2006).

Ashfaq *et al*. (2015) reported foot and mouth disease as the most harmful disease, as it affects all groups of farmers when there is an outbreak. Foot and mouth disease is responsible for almost 70% of all calculated economic losses. The second-worst group of diseases is tick infestation, which is responsible for around 16% of all economic losses. Less than 10% and 5% of all economic losses are attributable to mastitis and haemoglobinuria, respectively (Motiang and Webb, 2016). The percentage of tick-related losses rises and is consistent with the higher morbidity (Ashfaq *et al*., 2014). The table 10 below illustrates the percentage economic losses caused by mastitis, FMD and tick infestation on different farm categories.

Table 10: Percentage of economic losses due to diseases

Disease	Farm Category			
	Small Farmers	Medium farmers	Large Farmers	Overall
Mastitis	14.09	8.34	9.59	9.01
FMD	68.34	78.31	64.40	70.25
Tick infestation	5.61	10.32	22.05	16.35

Source: Ashfaq *et al*. (2014).

2.7. Gastrointestinal Parasites

2.7.1. Main goats Gastrointestinal Parasites

Mpofu *et al*. (2022) listed *Strongyloides papillosus, Eimeria species,* and strongyles, particularly those from the order Strongylida's *Haemonchus contortus* and *Trichostrongylus species*, that afflict goats most frequently in Africa (Table 11). The digestive system contains reproductively capable adults and fertilized females lay a sizable number of eggs (70–150 µm) that are excreted in the faeces and hatch in one to two days (Mortensen *et al*., 2003). *Moniezia* spp. is the only common cestode infestation in small ruminants, particularly goats. The consumption of oribatid mites that have been infested with *Moniezia* spp. cysticercoids are what leads to the occurrence of monieziosis spp. in the tropics (El-Desoky *et al*., 2017). Table 11 below lists the common gastrointestinal parasite species that affects goats in tropical and sub tropic Africa.

Table 11: Most common gastrointestinal parasites affecting goats in tropical and sub-tropical Africa.

Species	Features	Prepatent Period	Optimal temperature (°C)	Predilection site
Haemonchus contortus	Red pseudo coelomic fluid and white coiled ovaries give the barber pole appearance.	2-4 weeks	20-25	Abomasum
Strongyloides spp.	A slender worm measuring 3.5–6 mm long	9-14 days	>10,20	Small and large intestine
Moniezia spp.	The scolex and neck are tiny, but the strobila is a lengthy chain.	30-52 days	28	Small intestine

Source: Mpofu *et al*. (2022)

2.7.2. Effects of Gastrointestinal Parasite

Pathological characteristics of intestinal nematode infestations can differ (Anderson *et al*., 1965). However, the majority of nematodes can produce anaemia and diarrhoea when present in large enough numbers (Blood *et al*., 1979). Other species, like *Haemonchus contortus*, are blood-sucking. Clinical symptoms vary depending on a variety of factors, including the animal's nutritional status, the severity of the infestation, and the type of helminths present (Blackie, 2014).

The host's death is the most obvious consequence of helminth infestations in small ruminants in tropical Africa (Wanyangu *et al*., 1994). Weight loss of 0.6–1.2 kg/year/animal is possible while mortality rates can reach 40% (IEMVT, 1980). The primary economic costs attributed to helminth infestations are thought to be subclinical and chronic illnesses caused by decreased feed intake and impaired feed utilization efficiency (Holmes, 1993).

The most popular method of treating nematode infestations in small ruminants is the use of anthelmintics (Strydom, n.d.). Anthelmintic resistance, however, has been documented in several countries, which poses a challenge to the sustainability of small ruminant production (Domke *et al*., 2011). A more sustainable method of increasing small ruminant production would involve enhancing management and husbandry procedures along with strategic deworming at times when pasture conditions are most favourable for larval development (Blackie, 2014).

2.7.3. Season-related prevalence of gastrointestinal parasites

Seasonal variations in the frequency or severity of certain GIPs have been observed (Kreuzer *et al*., 2005). The dry winter season and the wet hot months/winter season have a higher prevalence of GIP and a higher infestation rate (Mpofu *et al*., 2022). The development, sporulation/hatching, survival, and transfer of the pre-parasitic stages of GIP require high humidity and temperature (Sanchez *et al*., 2005). Most GIPs, including strongyles, are forced to go into hypobiosis during winter due to the harsh climatic conditions. Reduced grazing hours also reduce the likelihood of a host and parasite encounter, which lowers winter prevalence (Mpofu *et al*., 2022).

Although there have been reports of a higher GIP prevalence, Zeng *et al*. (2018) reported parasite populations drastically decrease during winter with the lowest proportion happening just around the peak of the dry season. Mpofu *et al*. (2022) found that host animals carry infestation within themselves from one advantageous season to the next which may explain why GIPs persist in animals even during the dry season when environmental conditions hinder the development and survival of their pre-parasitic stages.

2.7.4. Internal Parasites Treatment and Managing dewormer resistance

Every three to six months, farmers are expected to deworm all their animals. In humid climates, many manufacturers recommend farmers deworm their animals even more frequently, up to once every four weeks (Junker *et al*., 2015). The ability of worms in a population to resist pharmacological treatments that are typically successful against the same species and stage of infestation at the same dose rate is known as drug resistance. According to Kaplan (2004), dewormers are no longer effective due to resistance brought about by overuse of the drugs.

The best way to maintain low parasite populations for a while is likely suppressive deworming (Hepworth *et al*., 2006). This approach will, however, also eventually result in resistance to the used anthelminthic(s) considerably more quickly than if alternative control methods are used. The alternate use of various medicines is one thing to consider in this situation. Hale (2006) and Turner and Getz (2010) reported that rapid drug switching is not a good idea since it could result in unwanted drug resistance. Scarfe (1993) noted that long before parasites in the United States developed resistance to dewormers, there was awareness of the unsustainable procedures that were being used. Some farms still have effective dewormers, while others don't have any (Kaplan, 2004).

Korsor (2018) reviewed various dewormers that can be used on sheep and goats. However, some dewormers are not permitted for use in sheep and goats, therefore there is a need to consult a veterinarian to guarantee suitable "off-label" use. The several classes of dewormers each have a unique method of destroying worms (Mpofu *et al.*, 2022). The type of dewormer used and how frequently it was administered on a certain farm determine the degree of resistance (Hale, 2006). Table 12 below shows drug classes along with their common names and their effectiveness.

Table 12: Types of dewormers and their levels of effectiveness

Drug Class	Common Names	Effectiveness
Benzimidazoles	Albendazole (Valbazen®) Fenbendazole (Safeguard®)	High prevalence of resistance
Ivermectin/Mibemycins	Ivermectin (Ivomec®) Moxidectin (Cydectin®)	Ivermectin— least effective of all available drugs Moxidectin— resistance becoming common when used frequently
Imidazothiazoles/Tetrahydropyrimidine	Levamisole (Tramisol) Pyrantel (Strongid®) Morantel (Rumatel®)	Low to moderate prevalence of resistance

Source: Hale (2006)

2.7.5. Conventional and alternative Internal parasite treatment

Traditional uses of ethnobotanical anthelmintic can be found throughout the world (Coffey, 2014). Generally speaking, "traditional" refers to the entirety of all alternative medical procedures, excluding so-called "Western" medicine. About 80% of people worldwide rely on traditional medicine for their main healthcare, according to the World Health Organization (2002). In recent years, there has been an increase in scientific and economic interest in the medicinal plant species that inhabit natural environments. Between 50,000 and 80,000 blooming plants are utilized as medicines worldwide (Barstow and Dhyani, 2020).

In numerous traditional tribes around the world, particularly in Africa, plants have been essential in treating a wide range of human and animal illnesses (Fajimi and Taiwo, 2005). The indigenous knowledge of different local communities in various countries around the world about various medicinal plants is passed down orally from one generation to the next through professional healers, knowledgeable elders, and/or regular people (Omoruyi *et al.*, 2012). These local communities use their perceptions and experience to classify plants and plant parts to be used when treating different ailments.

There are numerous plants whose importance as anthelmintic has been documented in the literature. The most widely used therapeutic plants with an anthelmintic action include *Allium sativum*, *Nigella sativa*, *Artemisia* spp., *Balanites aegyptiaca*, *Acacia* spp., cucurbits (pumpkin seeds), *Commiphora molmol* (Myrrh), *Calendula micranthaofficinalis*, *Peganum harmala*, and turmeric (curcumin) (Shalaby *et al.*, 2012). Sheep have been used in the great majority of investigations examining

Condensed Tannin's (CT) effects on gastrointestinal tract nematode infestations, whether in experimental or grazing settings (Waghorn *et al*., 2006).

Studies have also demonstrated that condensed tannins have an impact on goat gastrointestinal parasite infestations (Fetene and Amante, 2019). Animals receive and absorb more digestible protein from tannin-producing plants (El-Desoky *et al*., 2017). This is accomplished when tannins form non-biodegradable complexes with protein in the rumen; which break down at low pH in the abomasum and release more protein for metabolism in the small intestine of ruminants (Fetene and Amante, 2019). This enhances the host's resilience and resistance to nematode parasite infestation indirectly. These botanicals may hold promise for the control of parasites that have previously demonstrated resistance to synthetic medicines (Paolini *et al*., 2003).

Biological control (BC) may be defined as the use of one living organism to achieve control over the targeted organism like a parasite and thus reducing the population of a pathogen below a threshold level where it cannot cause clinical problems and/or economic losses in the animals (Fetene and Amante, 2019). The philosophy behind biological control is that by using one of the natural enemies of nematodes, it will be possible to reduce the infestation level on pasture to a level at which the grazing animals will not suffer both clinical and subclinical effects due to parasitic infestations (Rahmann and Seip, 2006).

Only nematophagous fungi, earthworms, and dung beetles have a realistic chance of succeeding as biological control agents among all possible antagonistic organisms, though there are several species whose potential for such use is unknown (Grønvold *et al*., 1996).

2.8. References

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CHAPTER THREE: THE CHEMICAL COMPOSITION OF *MORINGA OLEIFERA* LEAF MEAL AND THAT OF COMMERCIAL DAIRY GOAT PELLETS.

3.1. Introduction

The production of goats is not solely determined by their genetics, but it also depends on natural veld conditions as they browse mostly on shrubs and tree leaves (Skapetas and Bampidis, 2016). Supplementing goat basic feed with more nutritive substances such as fodder trees helps to increase their production (Soliva *et al*., 2005). Korsor *et al*. (2018) stated that a good fodder species should contain high levels of protein and minerals like phosphorus (P). A good fodder tree should also be adapted to the farmer's local conditions and maintain its nutritive value (Mendieta-Araica *et al.,* 2011). Dong *et al.* (2019) reported that moringa trees have been considered as an animal feed source replacement for costly and unavailable feed sources due to their high content of proteins, vitamins, and minerals.

Moringa trees are naturally adapted to semi-arid conditions like those found in Namibia (Korsor *et al*., 2019). Soliva *et al.* (2005) confirmed the ability of *Moringa oleifera* biomass production to be over 100 tons/dm/ha/year under favourable conditions. This provides sufficient biomass to use as feed. The high nutrient composition of moringa is one of the reasons that animals can be supplemented during pregnancy for proper foetus development and during lactation for early growth and development of the new-borns (Baiden, 2007).

Moringa oleifera leaves have a high potential as protein supplement for ruminants and the nutritional value is similar to that of the widely used soybean meal and rapeseed meal (Soliva *et al*., 2005; Leitanthem *et al*., 2022). The leaves show high nutritional importance and an ability to be used when there is scarce feed (Valdez-Solana *et al*., 2015). The chemical profile of this plant has led to research into its inclusion as an animal feed source. Researchers such as Asaolu *et al*. (2012) reported a positive average gain in West African dwarf goats supplemented with moringa. This finding agrees with a study in 2003 by Murro and colleagues, where the moringa diet of growing sheep showed a 20% improvement in growth rate although it had a poor feed conversion ratio (Murro *et al*., 2003).

Ruiz-Hernandez *et al.* (2022) concluded that moringa leaves contain fat, carbohydrates, fibre, protein, 18 amino acids and a profile of micro minerals. The different nutritional compounds can be fragmented to contribute to energy, total mineral content, gastrointestinal function, elimination of carcinogens, control cholesterol uptake and proper physiological function (Mumtaz and Fatima, 2017). Chemical analysis conducted by Jongrungruangchok *et al. (*2010) on 11 samples grown in different areas showed a mean DM (89%), ash (7.07%), fat (2.26%), Protein (23.29%) and Crude fibre (19.91%). Another study by Isitua *et al*. (2015) had a DM of 93.88 %, crude protein content (24.31 %), ash content (11.50 %), crude fibre (10.28), total carbohydrate (55.97 %), fat content (9.22 %) and caloric value (404.10 kcal/100g). Leitanthem *et al*. (2022) reported that moringa leaves is rich in crude protein content (29.40%), calcium (2.65%) phosphorus (0.304 g/100 g) and vitamin C (188–279 mg/100 g). The authors also found that 47% of the moringa leaves protein is rumen bypass protein with a good amino acid profile and good feeding effect as a protein substitute in animal feed. Even though Bryan (2011) reported practical issues including labour requirements in the planting of moringa trees and related conservation methods, there has been an increase in the use of moringa as feedstuff. The objective of this study was to determine the chemical composition of moringa leaf meal and the commercial dairy goat pellets used in the study.

3.2. Materials and Methods

Matured moringa tree leaves were harvested and shade-dried; the leaves were milled to create the moringa leaf meal. The chemical analysis for the leaf composition was conducted for dry matter, organic matter, ash and ether extract in the Department of Animal Production, Agribusiness and Economics Nutritional Laboratory according to methods described in AOAC (1990), while the methods of the ANKOM fibre machine were used to test for the neutral detergent fibre and acid detergent fibre. Crude protein, calcium, and phosphorus minerals were analysed at the ministry of agriculture, water and land reform laboratories. The moringa leaf meal and the commercial pellets used in the study were analysed for nutritional chemical composition.

3.2.1. Chemical composition analysis

Leaf meal and pellet samples were milled through a sieve of 2mm diameter. The sample material was placed in air-tight sample bags. The chemical composition of the samples was determined using various analytic methods. The ANKOM fibre machine was used to determine the Acid detergent fibre and Neutral detergent fibre of the samples (Adesogan, 2005). The ether extract was determined using AOAC (1991) methods of analysing feed.

3.2.2. Organic matter

The organic matter was determined by burning out all the combustible matter. Samples were placed in the furnace overnight at the temperature of 500-550^{0}C. Differences in weights were used to calculate organic matter as shown in the formula below:

Organic matter = Dry matter Weight-Ash weight

3.2.3. Ash

Minerals are the inorganic part of the plants and they were measured based on the ash composition of the leaf meal. The total dry matter placed in a crucible was weighed and placed in a furnace set at 500 ^{0}C - 550 ^{0}C overnight

Ash = (Dry matter weight-Ash weight)/Dry matter weight

3.2.4. Crude protein

The Dumas Combustion Principle on CHN 628 from Leco was used. Dumas nitrogen determination requires well-homogenized samples, heated in a high-temperature furnace where the combustion takes place rapidly at over 950 °C in the presence of pure oxygen. This produces mostly water, carbon dioxide and nitrogen as several oxides. The gas mixture (most water is removed) was passed through a reduction chamber containing copper heated to around 650 °C. This converted nitrogen oxides into elemental nitrogen and collected the excess oxygen. Different traps removed the residual water and carbon dioxide. Total nitrogen content was measured by a thermal conductivity detector.

3.2.5. Ether extracts

The method used to determine the oil and fat composition of the plant; ether was heated in a flask until it boiled. The fat is extracted by the ether, which drops into the flask after it is cooled by water. The ether is evaporated from the flask, leaving the fat. The difference in initial and final weights of the extraction thimble weight was used to calculate the percentage of ether soluble matter in the sample.

3.2.6. Neutral Detergent Fibre and Acid Detergent Fibre

NDF, ADF, ADL % (as-received basis) = 100 x (W3 – (W1 x C1))/W2

Where: W1 = Bag tare weight W2 = Sample weight W3 = Dried weight of filter bag with fibre after the extraction process C1 = Blank bag correction (running average of final oven-dried weight divided by original blank bag weight) was determined using the ANKOM machine.

3.2.7. Microelements

Phosphorus was analysed using a UV/Vis spectrophotometer while calcium was determined using the inductively coupled plasma-optical emission spectroscopy on an iCAP 6000 series from Thermo Scientific.

3.3. Results and Discussion

Table 13 shows the chemical composition of the moringa leaf meal used as the treatment in this study. The results are presented as an aid in the nutritional composition of the leaf meal supplemented to the animals. The moringa leaf meal treatment was fed in addition to the commercial custom-made dairy goat pellets and their chemical composition is also shown in the table. The moringa leaf meal results show the following results; DM (93.33%), Ash (11.54%), CP (23.76 g/100g), Fat (6.75%), CF (7.82), Ca (2.08%) and P (0.238%). These results are in a range with the findings of Sánchez-Machado *et al*. (2010) who reported protein, ash, and fat content of 22.42%, 14.60%, and 4.96%, respectively. These similarities could be attributed to the possible same maturity stages at which the leaves were harvested, furthermore the soil nutrients availability to the plant affects the plant chemical composition.

Table 13: Chemical composition of moringa leaf meal and dairy goat pellets.

Composition	Moringa leaf meal	Dairy Goat Pellets
Moisture %	6.67	11.76
DM %	93.33	88.10
Ash %	11.54	6.96
Starch total %		27.88
Crude Protein (g/100g)	23.76	16.96
FAT %	6.75	4.60
Fibre %	7.82	11.00
ADF %	9.66	
NDF %	13.15	26.95
N %	1.19	
Mg %	0.38	0.21
Mn (mg/Kg)	56.83	
Cu (mg/Kg)	6.21	
Fe (mg/Kg)	261.38	
Zn (mg/Kg)	20.57	
Ca %	2.08	0.80
P %	0.238	0.45
Na %	0.09	0.53
K %	1.58	0.98
Phenolics (mg/g)	35.76	
Condensed Tannins (mg/g)	27.45	

K= % Potassium; Na= % Sodium; Mg= % Magnesium; P=%Phosphorus; Ca= %Calcium; Mn = Manganese (mg/Kg); Cu=Copper (mg/Kg); Fe = Iron (mg/Kg); Zn = Zinc (mg /Kg);

Although high-quality forages are sufficient, goats occasionally require additional feeding, particularly in winter. Coffey *et al*. (2004) reported that goats require a balanced diet that includes roughage or grain, protein, vitamins, minerals, and fresh water. Depending on the goat breed and its physiological stage, different amounts of protein and energy are required. A general rule of thumb applies to all goats: trace-mineralized salt at all times, hay and grain in the winter, browse and pasture in summer (Guide, 2004).

The moringa leaf meal composition results in this study are significantly higher in Protein than those found by Novianti *et al*. (2021) who reported Protein content of 15.97 %, however the results are lower than the fibre of 13.78%; P 0.58% and Ca 1.43% was lower in his study compared to this study. The results difference could be attributed to the different study areas and different ecological zones in which the plants were grown. Although our results were low in comparison to those of Novianti *et al*. (2021) the findings are in range with those of Mbailao *et al.* (2014), Korsor *et al. (*2018) and Dong *et al.* (2019). Isitua *et al*. (2015) reported the animal crude protein requirements to be 16% this amount is 11% lower than the CP in this study.

In conclusion the difference in chemical compositions in the studies could be related to the use of leaf meals harvested from different regions and different harvest stages, other authors may have made use of twigs, stems and whole plant materials that could contribute to both energy and crude protein.

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CHAPTER FOUR: EVALUATION OF *MORINGA OLEIFERA* LEAF MEAL DIETARY SUPPLEMENTION ON SAANEN DAIRY GOAT'S MILK YIELD AND QUALITY.

4.0. Abstract

Goats are popularly kept for meat and milk. Goat milk has precedence over other species of milk but it comes second to cattle milk due to popular use. Dairy goats alternatively substitute dairy cattle in small homesteads. Studies are ongoing for alternative and cheap methods to improve milk production in goats. This study aimed to assess the effects of 0g, 10g and 30g/day *Moringa oleifera* leaf meal inclusion in the Saanen dairy goats' diet on their milk yield and milk quality. The study used a 3x3 Crossover Latin square Design to determine these effects. The animals were kept in field conditions. The evaluation of the goat milk yield was done by hand milking the goats twice daily at 12-hour intervals, whereas milk quality was conducted using a Lactoscan SP. The Statistical Package for Social Science (SPSS®) version 27 (IBM, 2020) software was used for data analysis. Milk yield and quality data were analysed using the General linear model. The comparison of means was done using the Duncan's new multiple range test at $P<0.05$ significance. The milk yields significantly differed in the first experimental period (30 days) and reduced in the second and third periods (30 to 90 trial days). The goats supplemented with 10g and 30g of moringa leaf meal did not significantly produce more milk compared to the control group of 0g/day. Likewise, the treatment had no effect on milk fat, solids non-fat, density, protein, lactose, added water, temperature, freezing point, salts, total solids or pH of the goat milk. In conclusion, the study findings showed no positive response in the milk yield or milk quality for the treatment levels of 10g and 30g/day. The results from this study show that moringa leaf meal could not be used in Saanen dairy goats in the enhancement of milk yield or quality. This study would not recommend the use of 10g or 30g/day *Moringa oleifera* leaf meal supplementation to dairy goats as a milk production booster.

Keywords: Leaf meal, milk yield, milk quality, moringa, Saanen goats.

4.1. Introduction

After the goat's domestication by humans in the early age they were kept mainly for meat, milk and fibre. Meat was one of the final products from the goats, animals had thus been mated to genetically improve the amount of milk produced per head (Rubino *et al*., 1997). In most countries' farmers do not produce goat milk with the intent to market, but rather for household consumption (Rubino *et al*., 1997). There has been considerable growth in the milk industry since 1997 with Monteiro *et al.* (2017) reporting that dairy goats yielded 15.2 million tonnes of milk, contributing about 2% of the total milk produced by livestock species worldwide. Goat milk has been consumed as fresh milk and processed into various products both conventionally and at an industrial level to make other products such as powder and sour milk, cheese, yoghurt and cream (Dubeuf *et al.*, 2018). Celi and White (2012) looked at the challenges faced by dairy goat farmers. They found that there is a fluctuation in the seasonal milk yields due to changes in pasture as the dairy goat industry in Australia was predominantly pasture-based. Bryan (2011) found that changes in seasons affect the milk yield with the ability to drop the milk yield by 40% between summer and winter seasons. The enhancement of individual goat's milk production has been studied using various products including *Acacia sieberiana* and *Dichrostachys cinerea* (Hamdoun *et al*., 2021), and *Moringa oleifera* by various researchers (Mendieta-Araica *et al.*, 2011; Korsor *et al*., 2018; Zhang *et al.*, 2018 and Novianti *et al.*, 2021). In a study by Kholif *et al*. (2015), milk yield was increased by 12% in goats fed with moringa leaf meal. The natural milk yields have also been studied in the past between different dairy goat breeds by Norris *et al*. (2011) in South Africa to see their milk yield according to their genotypes. The study findings showed that the Saanen (1.45kg/day) was the highest milk producer followed by the British Alpine

(0.75kg/day), with the Toggenburg (0.56kg/day) being the lowest producer of the three. Another study by Waineina *et al*. (2021) used the Toggenburg, Anglo-Nubian, German Alpines, Saanen and Boer goat breeds in Kenya. Their findings for each doe's daily milk production were Toggenburg (1.70L), Alpine (1.83L) and Saanen (2.52L). Ishag *et al.* (2012) found that the Saanen goat's overall milk yield mean was 340.78±11.35 kg/lactation. In developing countries, goat milk yield has continued to rise owing to a trend towards self-sufficiency of rural populations, where goat milk is the nutrition basis of millions of people (Monteiro *et al*., 2017).

4.2. Materials and Methods

4.2.1. Animal management and experimental design

The study was conducted at the Neudamm Campus. It used nine (9) homogenous Saanen does in their early lactation stage in a 3x3 Crossover Latin-square Design replicated three times, that is, three treatments, three periods and three goats per treatment. In the first period, the does were randomly allocated three treatments (0g/day, 10g/day and 30g/day) of moringa leaf meal, with three goats (replicates) per treatment. In the second and third periods, the goats were rotated in the treatments by means of a randomised standard Latin-square design so that at the end of the feeding trial, all the goats received all three treatments in different time phases. Each period had 30 days, with 7 days of adaptation between treatments to wear off the effects of the previous treatment before data collection started.

The leaves of *Moringa oleifera* trees grown at Neudamm Farm were harvested and shade-dried following the method used by Korsor *et al.* (2017). *Moringa oleifera* leaf meal was fed at three inclusion rations (treatments) of 0g/day, 10g/day and 30g/day with a recommended daily 3% DM intake of the goat's body weight (Ibrahim and

Tajuddin, 2021). The goats grazed in the fields and were supplemented every morning for a total period of three months. Each period had 7 days of adaptation and 30 days of data collection.

4.2.2. Parameters Measurements

The study had a 7-day adaptation period between rounds with a total of 30 days of data collection. The goats were hand-milked twice a day at an interval of 12 hours between milking sessions and the individual goat milk was weighed per session. The total milk quantity produced by an individual does daily was recorded by summing up the 1^{st} session's milk weights and the 2^{nd} session's milk weights. The milk samples were collected every 10^{th} day for the duration of the study within each period so that three milk samples were collected from each goat in each period. The samples were equally homogenized by adding 50% of the morning milking session to 50% of the evening session to make a homogeneous sample.

4.2.3. Laboratory analysis

The milk chemical composition analysis was done at the University of Namibia, Animal Nutrition Laboratory. The Lactoscan SP was used to assess the fat, solids-non-fat (SNF), temperature, density, protein, lactose, added water and total solids. Due to budget limitations and access to specialized tests, somatic cell count and milk minerals were no determined.

4.2.4. Statistical Analysis

Data was gathered and consolidated on Microsoft Excel 2021 and completed by charts and tables. The Statistical Package for Social Sciences (SPSS®) version 27 (IBM, 2020) software and Microsoft Office Excel® program were used for all data analysis. The data on milk quantity and quality were analysed using the General linear model

(1). The comparison of means was done using the Duncan's New Multiple Range test. Statistical significance was set at $P < 0.05$. The partial eta and Cohen f (Cohen, 2013) effect sizes were employed to quantify the sizes of the effects.

The mathematical model for the general linear model for the Latin Square used in this study is as follows:

$Y_{ijk} = \mu + \beta_i + \gamma_j + r_k + \varepsilon_{ijk}$ (1)

Y_{ijk} = the ith goat observation in the jth period under the kth treatment

μ = overall mean of response variable

β_i = the effects of the ith treatment

γ_j = the effect of the jth goat

r_k = the effect of the kth period

ε_{ijk} = random error.

Before using the model, the model diagnostic checks were done to test the assumptions of normality, independence and constant variance. The normality assumption was tested by assessing the histogram of residuals and by using the Shapiro Wilk's test on residuals. The test for homogeneity of variance was checked graphically using the scatter plots of residuals versus fits/predicted values and statistically using the Levene's test. The test for the independence assumption was tested using the plot of residuals versus observation order. The coefficient of determination (R-squared) and the regression F-test were used to assess the overall model goodness of fit. Where model assumptions had not been met, appropriate data transformation were performed and the data was re-analysed on the transformed data.

4.3. Results

4.3.1 Milk Yield

Table 14 presents the results for the goat milk yields during periods 1,2 and 3 of the study. The results of the period show a significant difference at P< 0.05 in the milk yield at p<0.05 in the first period of the treatment administration having the highest average milk yield of 3.178Kg/day/goat. The second and third periods did not significantly differ at P< 0.05 with the lower goat's average daily milk yield in the second period of 2.848kg and third period of 2.831kg. The table shows the analysed animal weights in the periods, there was no significant difference at P< 0.05 between the weights of the animals during the different periods of the trial as shown in table 14 below.

Table 14: Average milk yield and animal weights per period

Periods	Milk yield	Animal weights
Period 1	3.178[a]	44.844
Period 2	2.848[b]	46.667
Period 3	2.831[b]	47.378
SEM	0.059	0.917
P-Value	0.001	0.168

[(abcd)] means with different superscripts differed significantly at P<0.05

Table 15 shows the results of the milk yield per moringa leaf meal treatment level over the three periods of the study and the overall study milk yield per moringa leaf meal treatment level. The figures in the table demonstrate that there is no significant difference at P< 0.05 between the treatment levels in each period considered and throughout the study in terms of milk yield of the groups supplemented with 0, 10 and 30g/day moringa leaf meal. The table also illustrates the animal weights during the supplementation with moringa leaf meal and there is no significant difference at P< 0.05 between the weights of the animals supplemented with moringa leaf meal throughout the study.

Table 15: Average milk yield and animal weights per moringa leaf meal inclusion level

Treatments	Milk yield at 30 days (kg/day)	Milk yield at 60 days (kg/day)	Milk yield at 90 days (kg/day)	Milk yield	Animal weights
0g Moringa Leaf Meal	2.690	3.485	2.534	2.903	46.911
10g Moringa Leaf Meal	3.884	2.604	2.468	2.985	47.044
30g Moringa Leaf Meal	2.960	2.453	3.490	2.968	44.933
SEM	0.391	0.299	0.412	0.059	0.917
P-Value	0.157	0.099	0.225	0.592	0.225

Table 16 illustrates the individual goat results for the average milk yield of the goats used in the study. The results show a significant difference at $p<0.05$. The highest average milk yield per goat was 4.668kg/day followed by 3.376kg/day and 3.067kg/day respectively. Four of the nine goats averaged a range of 2.814-2.546kg/day with the lowest milk yields recorded at 2.443 and 2.101kg/day. The average goat weights throughout the study were also significantly different at $P< 0.05$ with the highest average weight at 50.267kg and 50.067kg and the lowest weight at 42.133 kg.

Table 16: Average individual animal Milk yield and animal weights

Goats	Milk yield	Animal weights
1	2.101^{f}	44.067^{bc}
2	2.443^{e}	44.600^{bc}
3	4.668^{a}	50.267^{a}
4	2.815^{cd}	44.667^{bc}
5	2.828^{cd}	42.133^{c}
6	3.376^{b}	46.133^{abc}
7	2.546^{de}	45.933^{abc}
8	2.724^{de}	48.800^{ab}
9	3.067^{c}	50.067^{a}
SEM	0.102	1.588
P-Value	0.000	0.028

$^{(abcd)}$ means with different superscripts differed significantly at $P<0.05$

4.3.2 Milk Quality

Milk quality results per period of the study are represented in Table 17 below. Fat content was significantly different at $P< 0.05$ for the first period of the study (3.738%) against the second (3.139%) and third (3.168%) periods; the solids non-fat content was significant at $P< 0.05$ in the first (7.866%) and second (7.759%) periods against the third period (7.512%) at $p<0.05$. The lactose content was significant at $P< 0.05$ in the first (4.324%) and second (4.282%) periods against the third period (4.173%). There was a significant difference at $P< 0.05$ between the temperature and salt content of the goat's milk during periods 1 and 2 in comparison to period 3 as shown in the table below. The added water amount was significantly higher at $P< 0.05$ during the 3rd period of the study along with the freezing point results. The total solids and pH were significantly high at $P< 0.05$ during the 1st period with a reduction during periods 2 and 3.

Table 17: Average milk quality per period

Periods	Fat	Solids non-fat	Density	Protein	Lactose	Added water	Temperature	Freezing Point	Salts	Total solids	pH
Period 1	3.738^a	7.866^a	29.767	2.877	4.324^a	5.232^b	25.488^a	-.498^b	.627^a	11.602^a	6.922^a
Period 2	3.139^b	7.759^a	26.715	2.840	4.282^a	6.356^b	25.220^a	-.487^b	.621^a	10.912^b	6.848^b
Period 3	3.168^b	7.512^b	25.966	3.211	4.173^b	8.517^a	22.943^b	-.473^a	.607^b	10.833^b	6.824^b
SEM	0.104	0.046	1.881	0.260	0.025	0.488	0.317	0.004	0.003	0.126	0.024
P-Value	0.002	0.001	0.346	0.553	0.002	0.001	0.000	0.005	0.001	0.001	0.032

$^{(abcd)}$ means with different superscripts differed significantly at $P<0.05$

Table 18 below illustrates the milk quality per moringa leaf meal treatment. There was no significant difference at $P < 0.05$ amongst the milk quality components of fat, solids non-fat, density, protein, lactose, added water, temperature, freezing point, salts, total solids and pH attributed by the moringa leaf meal supplemented as illustrated in the table below.

Table 18: Average milk quality per moringa leaf meal inclusion level

Treatments	Fat	Solids non-fat	Density	Protein	Lactose	Added water	Temperature	Freezing Point	Salts	Total solids	pH
0g Moringa Leaf Meal	3.300	7.665	29.767	2.805	4.231	7.442	24.640	-.482	.612	10.989	6.841
10g Moringa Leaf Meal	3.426	7.679	26.715	2.838	4.265	6.249	24.406	-.488	.620	11.179	6.893
30g Moringa Leaf Meal	3.319	7.792	25.966	3.285	4.284	6.414	24.605	-.488	.623	11.179	6.861
SEM	0.104	0.046	1.881	0.260	0.025	0.488	0.317	0.004	0.003	0.126	0.024
P-Value	0.660	0.085	0.358	0.373	0.334	0.209	0.854	0.515	0.111	0.484	0.340

4.4. Discussion

4.4.1. Milk Yield

Goats' lactation periods have been reported to average about 231 days in which dairy goats yield an average of 500kg (Gökdal *et al*., 2017). A study by Wanjekeche *et al*. (2016), revealed that Saanen breeds produce higher milk yield than the Alpine and Toggenburg breeds. In the study by Shuvarikov *et al*. (2021), the Saanen breed recorded the highest yield of 630 kg in a lactation cycle of 305 days. This study's findings on milk yields were higher than a study by Ibrahim and Jalil (2022) who evaluated age effects on the Saanen milk yield and milk composition and reported 0.944kg/day as their production pick despite other studies that agree with the average daily yield of 2.5kg reported in this study (Norris *et al*., 2011; Ferro *et al*., 2017; Ibrahim and Tajuddin, 2021; Msalya *et al*., 2021 and Waineina *et al*., 2021). This study was conducted with second gestation does, in their early lactation phase. This resulted in a significant difference in the three study periods with the 1st period having the highest yield and a drop in the average milk yield in the second and third periods. This corresponds to the findings of Marcinkoniene and Ciprovica (2019) who stated that milk yield increases in the first lactation up until the third just before it starts to decline at the final lactation stage. This study results also showed that the goat's daily milk yield ranged between 2.1kg/day and 4.7kg/day despite their homogeneity in the lactation phases, parities and environmental conditions. This variation in the milk yields could be attributed to other various factors reported by Mestawet *et al*. (2012), such as the diet, goat breed, parity of the goat, feeding habit, season environment conditions and stage of lactation.

The research results were not significantly different for the milk yield nor the milk composition due to the moringa leaf meal inclusions. Our findings disagree with multiple researchers who have stated that *Moringa oleifera* increased animal milk yield and improved their milk composition. Kholif *et al*. (2015), reported that replacing sesame meal with moringa improved milk yield in goats. Korsor (2018) stated that moringa leaf meal increased both the yield and composition of the Boer goat milk. According to Zhang *et al*. (2018), there was an increase in the milk of cows supplemented with moringa leaf meal, while Novianti *et al*. (2021) reported that moringa led to an increase of 1.061kg/day production in goats. The difference could be due to the level of moringa inclusions and the research animal management as the study animals were in rangeland conditions. This research findings on the milk yield agree with those of Mendieta-Araica (2011), Dong *et al*. (2019) and Kekana *et al*. (2019) who all agree that moringa supplementation did not significantly improve milk production in lactating dairy cows.

This research results on the goat weight agree with those of Tendonkeng *et al*. (2012) and Yusuf *et al*. (2018) who reported moringa as a protein supplement that maintained and improved the goat's weight. This could be attributed to the rich nutritional content of moringa leaf meal.

4.4.2. Milk Quality

Comparisons had been made based on the milk composition of different species but mainly the goat, cow and human milk (Shuvarikov *et al*., 2021). The milk composition of goats has proved to be of superior quality to that of cows and humans (Park, 2012). Like the milk yield, the milk composition is affected by several environmental, genetic, physiological and managerial factors (Park *et al*., 2007). Gökdal *et al*. (2017) reported that the lactation stage significantly affects the milk composition. Lund and Ahmad (2021) affirmed that goat milk contains, total solid, protein, fat, lactose, minerals, free lipids and phospholipids. While Park and Haenlein (2007) reported that goat milk contains vitamins, carnitine, glycerol ethers, orotic acid, enzymes, fat globule size, and casein polymorphisms that are unique to goat milk and significant to humans. Our study results include fat, solids non-fat, density, protein, lactose, added water temperature, freezing point, salts, total solids and pH of the milk. These results were significant in the study periods; the first study period had the highest values and the second and third periods were in the same ranges except for the added water content. In this study total solids (11.6%), protein (3.21%), fat (3.74%) and lactose (4.1) content were found to be in line with the results obtained by Park (2006) and Rafiq *et al*. (2016), with the following values; total solid (12.2% and 12-13.5%), protein (3.5% and 3.5%), fat (3.8% and 3.8-4.5%), lactose (4.1% and 4.1%), respectively. The research findings for all the periods show the milk had a pH average of 6.8 which is slightly higher than the findings of Igwegbe *et al*. (2015) and Sumarmono (2022) who stated pH levels between 6.4 and 6.6. The difference in pH could be attributed to the time of analysis and the sample handling. However, the pH readings agreed with those found in the study done by Tendonkeng *et al*. (2012) and Pal *et al*. (2017).

Contrary to our study, *Moringa oleifera* has been used to improve milk composition in other studies (Korsor, 2018; Zhang *et al*., 2018 and Novianti *et al*., 2021). The differences in results could be due to different inclusion levels used and other factors such as intensive and extensive grazing. Moringa has been reported to increase milk fat and total serum protein while reducing somatic cell count and oxidative stress (Kekana *et al*., 2019). Fresh moringa supplement gives a grassy flavour to milk according to Mendieta-Araica (2011).

4.5. Conclusion and recommendation

The need to improve animal productivity remains high and diet improvement is one of the approaches that can be used to achieve this goal. Moringa leaf meal proved to have a good palatability for goats and this was evident by the fact that the goats consumed all the supplement without minimal wastage. This study showed that *Moringa oleifera* leaf meal at inclusion levels of 10g and 30 g/day had no effect on the milk yield or milk quality of Saanen dairy goats. The milk yield and milk quality were not improved by the supplementation of moringa leaf meal despite the claimed lactogenic effects of moringa. The study recommends the increase in the inclusion levels and the use of a larger sample. The animal weights in this study were consistent throughout and this is a good research area to consider in the future use of moringa leaf meal.

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CHAPTER FIVE: ASSESSMENT OF *MORINGA OLEIFERA* LEAF MEAL EFFECTS ON GASTROINTESTINAL PARASITES OF SAANEN DAIRY GOATS.

5.0. Abstract

The study aimed to optimize dairy goat milk production and herd health by utilizing *Moringa oleifera* leaf meal as an anthelmintic supplement. A total of 9 lactating Saanen does were used in a completely randomized design (CRD) allocated into three groups of three does per treatment using *Moringa oleifera* leaf meal (0g/day, 10g/day and 30g/day). The supplement was fed once every morning and the goats grazed in the veld during the day. Fecal samples were collected every 10^{th} day for 30 days after seven days of adaptation. The samples were collected directly from the goat's rectum to determine the parasitic egg loads. A quantitative Faecal Flotation, the McMaster Egg Counting Technique and a conversion factor of 1:50 was used to determine the number of eggs per gram of fecal sample. The Statistical Package for Social Science (SPSS®) version 27 (2020) software was used for data analysis. The findings showed the presence of parasite eggs belonging to three genera, mainly *Strongyloides, Moniezia* and *Coccidia*. The study treatment levels of 10g and 30g of moringa leaf meal/day were effective in the reduction of *Strongyloides* egg load. The 30g/day moringa leaf meal inclusion level was ineffective on *Monieza* species egg load compared to the 10g/day moringa leaf meal. The coccidia egg load was the most reduced by the 10g/day level. The study findings showed a positive response of parasites to moringa leaf meal by the reduction of parasitic egg load with 10g and 30g/day treatments. In conclusion, the 10g/day and 30g/day treatments were effective, with the highest reduction of the egg load of members belonging to *Coccidia* and *Strongyloides* genera for the 10g/day group.

Keywords: Egg load, leaf meal, moringa, parasite egg count, Saanen goats.

5.1. Introduction

The sensitivity of goats to gastrointestinal parasites has been highlighted by several researchers (Hepworth *et al*., 2006; Coffey, 2014 and Korsor, 2018) who agree on the negative effects of parasites on goats' performance such as poor growth, decreased fertility, abortion, low feed conversion and in some cases death. Hendrix and Sirois (2007) noted that some of the common helminths found in ruminants are nematodes (roundworms), trematodes (flukes) and protozoa (unicellular organisms). Whilst at times the negative impacts of the parasites are not visible or immediate, farmers aim to minimize these negative effects by deworming, dosing or vaccinating (Korsor, 2018). Hepworth *et al*. (2006) stated that the problems faced by many farmers are the unavailability of anthelmintic drugs, their high cost, and the development of resistance against conventional drugs. An alternative method of treatment would be the use of ethno-veterinary medicinal plants. Korsor (2018) reported that *Moringa oleifera* was one of the plants that can be used for the treatment of gastrointestinal parasites in animals. *Moringa oleifera* is considered to be effective in the treatment of many diseases (Caceres *et al*., 1991). Zeng *et al*. (2018) stated that different parts of the moringa plant, especially the leaves, have nutritional, prophylactic and therapeutic properties. Korsor (2018) further agreed with the above authors about the medicinal properties of *moringa* making it a potential source for improving the health status of small ruminants and other livestock.

Most of these parasites have direct life cycles whereby eggs are passed into the environment with host faeces. The eggs embryonate over some time depending on climatic conditions such as moisture, temperature and oxygen (Hendrix and Sirois, 2007). The parasite's behaviour also coincides with the end of the main breeding season of the host and ensures new susceptible individuals are available for infestation (Turner and Getz, 2010).

Love and Hutchinson (2003) highlighted that many infestations may not prove fatal and may be resolved spontaneously due to the development of strong host immune responses. Infested animals, nonetheless, continue to contaminate the environment with eggs placing the next generation of animals at risk (Jansen and Burg, 2004). Infestations in ruminants are generally controlled by anthelmintic treatment using a variety of drugs. Anthelmintics are drugs that either kill egg-laying parasites or larvae before they mature. The major problem with using anthelmintics is the development of resistance by gastrointestinal parasites. According to Regassa *et al*. (2006), one method of anthelmintic treatment can appear to be effectively controlling parasites in a herd, but its efficacy can be significantly lowered when resistance develops. Resistance to anthelmintics can develop as a result of the overuse of one dewormer over the years and improper dosing with available anthelmintics.

Anthelmintics should be used only to treat animals when necessary and should be thought of as a limited resource to be used sparingly. The objective of this study was to determine the effects of *Moringa oleifera* leaf meal on gastrointestinal parasites (GIPs) as an alternative to the use of commercial dewormers.

5.2. Materials and Methods

5.2.1. Animal management and experimental design

The study was conducted at the Neudamm Campus. A total of nine (9) lactating Saanen does were used in a completely randomized design (CRD) allocated into three groups of three does per treatment of *Moringa oleifera* leaf meal. The leaves of *Moringa oleifera* trees grown at Neudamm farm were harvested and shade dried, until the commencement of feeding trials. *Moringa oleifera* leaf meal was supplemented at three inclusion levels of 0g/day, 10g/day and 30g/day to the three groups of does with a recommended daily intake of 3% DM of the goat's body weight. The supplement was fed once every morning and the goats grazed in the veld during the day. Fecal samples were collected after seven days of adaptation. Faecal samples were collected as described by Cringoli *et al*. (2004) once every 10 days over 30 days directly from the goat's rectum.

5.2.2. Laboratory analysis

Coprological analysis for the presence and composition of gastrointestinal parasite eggs was conducted in the parasitology laboratory of the School of Veterinary Medicine at the Neudamm campus. Faecal centrifugal floatation method using a sodium chloride solution was used as described by Matsuo and Kamiya (2005). Quantitative Faecal Egg Counting (FEC) using the McMaster chamber was used to determine the egg count per gram of fecal sample using a conversion factor of 1:50. Parasite eggs were identified and quantified to measure the parasitic egg load in the faecal samples per gram (EPG) using the method suggested by Rinaldi *et al*. (2014).

5.2.3. Statistical Analysis

Data were gathered and input into Microsoft Excel 2016; and presented in charts and tables. Descriptive statistics and visualisation were done in R version 3.6.2 (R Core Team, 2020). The Statistical Package for Social Sciences (SPSS®) version 27 (IBM, 2020) software and Microsoft Office Excel® program were used for all data analysis. The data on the parasitic egg counts were analysed using the generalised linear mixed effect model (Poisson regression model). The comparison of means was done using the Duncan's new multiple-range test. Statistical significance was set at a $P \leq 0.05$.

The partial eta and Cohen f (Cohen, 2013) effect sizes were employed to quantify the sizes of the effects.

5.3. Results

The results of the study are presented in Table 19. The study observed the presence of parasite eggs belonging to three genera, mainly *Strongyloides*, *Moniezia* and *Coccidia*. The Strongyloides parasite egg load results showed a significant difference (P<0.05) in the individual treatment levels with 0g/day (86.11 eggs per gram) moringa group having the most parasite egg load while moringa had significantly lowered the amounts of egg load in the 10g/day (66.67 e.p.g) and 30g/day (69.44 e.p.g) treatment. The 10g/day and 30g/day treatments were not significantly different. The table demonstrates the results for Moniezia egg load which were significantly different at P< 0.05; the treatment level of 30g/day (36.11 e.p.g) moringa leaf meal had the highest egg load compared to those of 0g and 10g/day. Meanwhile, the Moniezia egg loads for 0g/day and 10g/day treatment levels were not significantly different at P< 0.05. The egg count for coccidia eggs was significantly different at P< 0.05 throughout the three moringa leaf meal treatment levels; the highest egg count was observed at 0g/day (55.6 e.p.g) followed by 30g/day (22.22 e.p.g) and 10g/day had the lowest coccidia egg count at 13.89 e.p.g. In this study the total egg count per treatment was significantly different at P< 0.05; the most effective treatment level for the study was 10g/day moringa leaf meal as it had the lowest overall egg count of 94,44 e.p.g, meanwhile, the 30g/day treatment level of (127.78 e.p.g) showed a significant overall lower egg count than 0g/day (152.78 e.p.g). During the study duration, the animal weights showed no significant difference at P< 0.05 between the three animal groups used as shown in Table 19.

Table 19: Average parasite egg loads and animal weights

Treatments	Parasite eggs, genera			Total count	Animal weights
	Strongyloides	*Moniezia*	*Coccidia*		
0g moringa leaf meal	86.11[a]	11.11[b]	55.56[a]	152.78[a]	46.911
10g moringa leaf meal	66.67[b]	13.89[b]	13.89[c]	94.44[c]	47.044
30g moringa leaf meal	69.44[b]	36.11[a]	22.22[b]	127.78[b]	44.933
SEM	2.722	1.242	1.242	3.239	0.917
P-Value	0.000	0.000	0.225	0.000	0.225

[(abcd)]Means with different superscripts in a column are significantly different ($P<0.05$)

5.4. Discussion

Mpofu *et al*. (2022) listed *Strongyloides papillosus, Eimeria species*, *Moniezia* spp., and strongyles, particularly those from the order Strongylida's *Haemonchus contortus* and *Trichostrongylus species,* that afflict goats most frequently in Africa. The animals get infested with parasites through grazing; the consumption of oribatid mites that have been infested with cysticercoids is what leads to the occurrence of internal parasites in the tropics (El-Desoky *et al*., 2017). The digestive system contains adults capable of reproduction, and fertilized females lay a sizable number of eggs (70–150 μm) that are excreted in the faeces and hatch (Mortensen *et al*., 2003). The egg count in the faecal sample can be used to determine the infestation levels in animal digestive tracts.

The study results agree with those of Kumba *et al*. (2003) who found similar parasite genera of eggs in a study conducted throughout all seasons in Eastern Namibia. The study of a few parasite genera presence and infestation level are in line with the study of Zeng *et al*. (2018) who stated that season plays a role in the prevalence of parasites. This could be explained by the harsh climatic conditions of winter that force parasites to go into hypobiosis during winter; the reduced grazing hours also reduce the likelihood of a host and parasite encounter, which lowers winter prevalence (Mpofu *et al*., 2022).

The use of moringa has proven to work against gastrointestinal parasites in studies with a higher inclusion rate under a controlled environment and had a higher reduction of parasitic eggs (Berkovich *et al*., 2013 and Soltan *et al*., 2017). These results are observed to contradict our study as 30g inclusion levels of moringa leaf meal had lower effects than the 10g/day. This could be attributed to several variables. Although other studies used greater inclusion levels of >150g per day the egg loads in this study were equally reduced using 10g/day inclusion. The moringa tree gains the additional recognition of being an anthelmintic for ruminants as a result of its enrichment in phenolics (Soltan *et al*., 2017).

This study's results are in line with the findings of Southwell *et al*. (2008) who stated that *Moniezia* species are not common within goats; in this study, there was a low infestation of *Moniezia* species. A study by Korsor *et al*. (2017) further supported this study's findings on the *Moniezia* species that showed a lower infestation level in Boar goats compared to that in the dairy goats used in this study. Despite the low infestation, the *Moniezia* species were significantly susceptible to *Moringa oleifera* leaf meal; this study's findings however show *Moniezia expansa* was the least affected of the three genera observed in this study. The difference in study results could be attributed to other factors such as animal access to grazing fields, that were not restricted in this study, but they were controlled in their study. The levels of coccidia oocysts agreed with those in studies conducted by Junker *et al*. (2015) and Korsor *et al*. (2017) who reported high levels of infestation and the highest levels of reduction following moringa supplementation. This could be due to the susceptibility of the parasites to moringa chemical compositions. Studies have also demonstrated that condensed tannins have an impact on goat gastrointestinal parasite infestations (Fetene and

Amante, 2019). Moringa may hold promise for the control of parasites that have previously demonstrated resistance to synthetic medicines (Paolini *et al*., 2003).

5.5. Conclusion and recommendation

This study showed that *Moringa oleifera* has an anthelminthic effect on lactating dairy Saanen goats. Given the inability of farmers to prevent the infestation of animals by parasites, there is a need to implement good management practices that reduce the risks of parasite infestation in a herd of animals. The use of natural anthelmintic products such as the *Moringa oleifera* leaf meal that was used in this study can be a good alternative for resource-limited farmers. Despite a low infestation rate and a limited number of parasite genera in animals used in this study, the objective of the study was reached as testified by the overall reduction in the parasitic egg load; 10g/day treatment caused the highest reduction of parasites. It is therefore legitimate to conclude that *Moringa oleifera* leaf meal has an effect on the GIPs in Saanen Dairy goats kept in rangeland. This study recommends the use of 10g/day of *Moringa oleifera* leaf meal supplementation for dairy goats for ecologic management of the goats.

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CHAPTER SIX: GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The need to improve animal productivity remains a priority for many farmers to improve their diet and maintain good health at the lowest cost. The overall objective of the study was to determine the effects that *Moringa oleifera* leaf meal has on Saanen dairy goats when supplemented as a nutritional and medicinal source while the animals are grazed on rangeland. The goats showed a good palatability towards moringa leaf meal. The objectives of the study were attained; these showed that the moringa leaf meal at inclusion levels of 10g and 30 g/day does not affect the milk yield or quality. The study showed that moringa leaf meal at 10g and 30g/day has an anthelmintic effect against gastrointestinal parasites. The extensive rearing conditions in this study could contribute to the inability of the goats to achieve their maximum potential in both milk and quality production. The limitations encountered in this study include the number of animals available for replication and the inability to evaluate the milk somatic cell count. Natural anthelmintics such as *Moringa oleifera* leaf meal that was used in this study can be resorted to as a method for GIP treatment. The study animal weights throughout the study were consistent, this led to the conclusion that there is a need for further research to consider the use of moringa leaf meal as a replacement feed.

6.2. Recommendations

The objectives of the study were to evaluate the effects of *Moringa oleifera* leaf meal on Saanen diary goats' milk yield and milk quality. The study also aimed to assess the effect of moringa supplements on gastrointestinal parasite load in these animals. Based on the study results the following recommendations can be formulated:

1. Increment of inclusion levels of moringa leaf meal in the diet and the use of a larger group of dairy goats is suggested to improve the validity of data obtained in terms of milk quantity and quality.
2. Additional Saanen goat milk parameters could be analysed in future studies to evaluate the full potential of moringa leaf meal supplementation.
3. This study recommends the use of 10g/day moringa leaf meal to be supplemented to Saanen dairy goats for the control of gastrointestinal parasites.
4. Further studies could focus on identifying the bioactive compounds present in moringa that contribute to its anthelmintic effects.
5. Due to the scarcity of dairy goats in Namibia, studies can be conducted to evaluate different dairy breeds' adaptability to the different Namibian environmental conditions.

APPENDICES

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: NEC0011 **Date:** 19/09/2022

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project: Evaluation of Moringa oleifera effects on milk yield, milk quality and the helminthic load of Saanen dairy goats on rangeland conditions at Neudamm Farm

Principal researchers: Mr. Immanuel Shea

Staff Number/ Student number: 201705294

Remarks: the research proposal respects all the parameters to obtain the ethical clearance

Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:

i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,

ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

Prof. Umberto Molini (Chairperson Neudamm Decentralized Ethics Committee)

Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)

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RESEARCH PERMISSION LETTER

Date: 17/03/2023

Student Name: Immanuel Shea

Student Number: 201705294

Programme: Master of Science in Agriculture

Approved Research Title: Evaluation of Moringa oleifera effects on milk yield, milk quality and the helminthic load of Saanen dairy goats on rangeland conditions at Neudamm Farm

TO WHOM IT MAY CONCERN:

I hereby confirm that the above-mentioned student is registered at the University of Namibia for the programme indicated. The proposed study met all the requirements as stipulated in the University guidelines and has been approved by the relevant committees.

The proposal adheres to ethical principles as per attached Ethical Clearance Certificate. Permission is hereby granted to carry out the research as described in the approved proposal.

Best Regards

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