EVALUATION OF GROWTH PERFORMANCE OF WEANER DAIRY GOATS FED BASAL RHODES GRASS (*Choris gayana*) HAY SUPPLEMENTED WITH CHICORY (*Cichorium intybus*) AND YEAST (*Saccharomyces cerevisiae)*

JOSPHAT BETT KIPKORIR

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Master of Science Degree in Animal Nutrition of Egerton University

EGERTON UNIVERSITY

OCTOBER, 2024

DECLARATION AND RECOMMENDATION

Declaration

This is to declare that the work contained herein is my original work and that it has not been submitted to Egerton University or any other institution of higher learning for examination.

Signature: Date: 11/09/2024

Kipkorir Josphat Bett

KM113/13072/21

Recommendation

This thesis has been submitted with our approval as University supervisors.

Signature. Date: 11/09/2024

Dr. Perminus K. Migwi, PhD

Department of Animal Sciences,

Egerton University, Njoro.

Signature: Date: 11/09/2024

Prof. James O. Ondiek, PhD

Department of Animal Sciences,

Egerton University, Njoro.

DEDICATION

This thesis is dedicated to my parents, the late Stephen Kibet and my dear mother Caroline Chepkoech for their tireless commitment towards my education and my lovely wife Naomi and my children Blessing and Mark for their motivation throughout the study period.

ACKNOWLEDGMENTS

First, I wish to express my sincere gratitude to the Almighty God for His unending kindness and protection, which have kept me going during this time of vigorous academic study. I wish to express my sincere gratitude to the committed staff at Egerton University and the Department of Animal Sciences for their unwavering support during my studies. I would also like to thank The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), who generously funded my research study through the Master Card Foundation in partnership with Transforming African Agricultural Universities to meaningfully contribute to Africa's Growth and Development Program (TAGDev). My profound gratitude goes to my distinguished supervisors, Dr. Perminus K. Migwi and Prof. James O. Ondiek of Egerton University's Department of Animal Science, for their support. Their mentoring has been extremely important in steering my studies and helping me finish this thesis successfully. I sincerely thank the technologists in the Animal Nutrition laboratory of the Department of Animal Science for their assistance with chemical analyses. I appreciate my wife, Naomi Ngeno, and my children, Mark Peter, and Blessing Chepchumba, for their constant prayers and emotional support. I have found much strength in your encouragement during this academic journey.

ABSTRACT

Rhodes grass (*Choris gayana*) hay, in particular, is widely used by most dairy goat farmers in Kenya, even though it is known to be deficient in protein. However, little is known about the growth performance of dairy goats when fed basal Rhodes grass hay supplemented with Chicory (*Cichorium intybus*) and yeast (*Saccharomyces cerevisiae*). Therefore, the objective of the present study was to evaluate the performance of growing dairy goats fed on Rhodes grass hay supplemented with Chicory and yeast. The specific objectives were to determine the chemical composition of the experimental diets, voluntary feed intake, weight gain, and synergistic effects of supplemental diets. Eight experimental diets were allocated in a completely randomized design (CRD) with a (4x2) factorial arrangement and replicated three times. The basal diet was Rhodes grass hay and chicory supplementation at four levels (0, 10, 20, and 30%) as the main effects and with (+) or without yeast (-) yeast addition as interaction levels. The proximate analysis was done to determine the chemical composition of the ingredients. The *in-vitro* gas production method was done, and organic matter digestibility (IVOMD) was calculated. For voluntary feed intake and weight gain, the feeds were formulated into eight diets and offered to 24 weaned female dairy goats (14±0.5 Kg) using a CRD in a (4x2) factorial design. The diets were Rhodes grass hay and chicory supplementation at (T1:0, T2:10, T3:20, and T4:30%) as the main effects and yeast, with (+) or without yeast (-) as interaction levels. Data was collected for eight weeks following a 14-day- adaptation period. Feed offered and refused was measured daily and recorded while body weights were taken at the end of every week. To determine the synergistic effect of yeast and chicory-inulin and estimate GHGs on the animal gut, the rumen fluid was tested for pH, NH_3-N, and VFAs at the end of the feeding experiment. Data were analyzed by a general linear model of the analysis of variance (ANOVA) using the statistical analysis system SAS, 2002 version 9.4. Results indicated that 30% of supplementation improved significantly ($p<0.05$) CP (196.0 gKg^{-1} DM) and Ash (109.2 gKg^{-1} DM) in the diets. It also significantly lowered the NDF, CF, and ADF. Results showed that 30% of supplementation positively and significantly influenced ($p<0.05$) voluntary feed intake (591.70 g/day) and ADG (.154.64.8 g/day). The findings suggest a synergistic impact of chicory and yeast on feed intake and nutrient digestibility, contributing to improved growth performance in growing goats. The study recommends the incorporation of chicory at a 30% inclusion level and yeast supplements at 10 g/day/goat in growing goat diets for optimal feed utilization and robust growth.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

Ad libitum	unrestricted access to feed
ADF	Acid Detergent Fibre
ADG	Average Daily Gain
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BW	Body Weight
CP	Crude Protein
CRD	Completely Randomized Design
DM	Dry Matter
EE	Ether Extract
GLM	General Linear Model
IVDMD	*in-vitro* Dry Matter Digestibility
IVOMD	*in-vitro* organic matter Digestibility
In-vitro	in glass (Done in an artificial environment in the laboratory)
In-vivo	in a living organism (A test done within a living organism)
LSD	Least Significant Difference
LWG	Live Weight Gain
ME	Metabolizable Energy
NDF	Neutral Detergent Fibre
SAS	Statistical Analysis System

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Nearly 60% of Kenyan population reside in rural areas, making agriculture the primary economic and social support system. About 40% of Kenya's population is estimated to be poor, with the most significant proportion residing in rural areas, especially in arid and semi-arid areas (Musyoki, 2017). The agricultural sector's development strategy aims to guarantee that all Kenyans access adequate food and nutrition while increasing the economy's productivity and providing more jobs, especially in the countryside. Although much has been achieved to this end, the issues of food security, poverty reduction, and transitioning agriculture from subsistence to farming as a commercially viable business undertaking are still a mirage (Mulwa & Kabubo-Mariara, 2022). The impact of climate change has further exacerbated this condition, and its adverse effects are being felt everywhere by most farmers, especially those who rely on rain-fed agriculture (Musyoki, 2017). Some of the significant challenges constraining the agricultural sector include pests and diseases that affect both crops and livestock, the high cost of essential farm inputs, and the increasing sub-division of agricultural land to smaller parcels that are largely unprofitable. Therefore, sustainable farming must utilize available and viable resources such as affordable protein sources like Lucerne, calliandra, and Chicory.

Globally, the significant limit on output, especially for smallholders, is a direct result of the increasing demand placed on limited arable land by a growing human population. Land in Kenya and the rest of Eastern Africa are under increasing pressure to increase food production to feed the ever-growing population. Due to extensive subdivision of land, land parcels per household have generally significantly decreased in recent years, with many smallholder farmers surviving at subsistence production levels with no surplus for the market. Furthermore, most of the production by smallholder farmers, most of whom practice a mixed crop-livestock farming system, could be more profitable. Most smallholder farmers have resorted to intensification in livestock to maximize the available arable land, with most opting for small ruminants, especially dairy goats.

Since dairy goat production requires fewer resources, they have become very popular with most smallholder farmers (Rahimi *et al*., 2022). Furthermore, many smallholder and part-time farmers can benefit from engaging in dairy goat production as a viable agricultural business and earn some income for their livelihood. Dairy goat farmers have found success in a variety of commercial niches, including goat milk pasteurization and a successful on-farm operation, as well as the production and retail sale of processed dairy products such as artisanal cheeses, yogurt, soap, and lotion (Rahimi *et al*., 2022). There is also the possibility of selling milk to processors, who are typically located in the same region.

In many parts of developing countries, goat milk is a cherished food item that ensures food and nutritional security to many members of the family, especially infants and the sick. Many people also highly seek goat milk because of its reputation for therapeutic qualities and distinctive flavor. Goat milk has been credited with a wide range of health benefits, although the scientific evidence for most of these claims is scant. The fat or lipid content in goat milk is a crucial but sometimes ignored factor. Typical goat milk fat contains much more butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), and linoleic (C18:2) fatty acids than average cow milk fat, but less stearic (C18:0) and oleic acid (C18:1) (Haenlein, 2004).

Furthermore, compared to cow's milk, goat milk is considered to be higher in medium-chain fatty acids (C6-C10). While the protein structures of goat and cow milk are comparable, there are notable distinctions (Miller & Lu, 2019). Also, people allergic to the lacto albumin-s protein in cow's milk find it safer to consume goat milk without developing those allergic reactions. These variations account for the fact that some persons with cow-milk allergies can drink goat milk for extended periods, and the smaller fat globules in goat milk remain suspended, giving the impression of "natural homogenization (Haenlein, 2004)." The benefit of goats' milk is, therefore, even to consumers. Since goats are such good browsers, they are able to obtain the nutrients they need from a wide variety of plants, including those with aromatic or flavor components that can be transferred to the goat's milk or cheese and used to create one-of-a-kind specialty products (Rahimi *et al*., 2022).

Despite all these nutritional and livelihood benefits of dairy goats, their productivity is constrained by many factors ranging from nutritional deficiencies, poor quality breeds, a lack of quality breeding and replacement stock, and generally poor standards of management, all contributing to the overall poor output. This is because all these aspects of goat management are considered to be frequently below ideal levels, and this is despite the dairy goat industry having immense potential if it is fully exploited. Among all the factors hindering the growth of dairy goat production nationally, the most important is the shortage of good quality feed. Lack of a year-round supply of good quality feed has both direct and indirect effects on the production performance of dairy goats as it affects milk production, reproduction, and even the animal's health (Gitau, 2013). Undernourishment is from the perspective of basal feeds and supplements, so any dairy goat nutrition intervention must address the two issues simultaneously. However, owing to changes in farming systems from free range to zero grazing, there is a need to have a suitable formulation that will ensure that the confined dairy goats can meet their daily nutritional requirements.

Rhodes grass (*Chloris gayana*) hay is widely used as a basal forage for most ruminant livestock kept by farmers in Kenya, including dairy goats. However, depending on age, it must provide sufficient nutrients for optimum growth and production (Miller & Lu, 2019), with crude protein content ranging from 7.5 to 8.5%. Because of its ease of propagation, Rhodes grass is generally easy to cultivate and maintain. Therefore, it is widely grown and utilized by most farmers either as grazed pasture or preserved as hay. Furthermore, because of its high herbage biomass production, the Kenyan varieties, especially the Boma Rhodes, are plentiful and suitable for grazing and hay production. Despite having a low nutritious value, especially protein, when old, livestock readily devours them (Osuga *et al*., 2012). However, their yields and nutritional status tend to drop with varying yearly weather conditions, making it impossible to meet the year-round dietary needs of animals (Osuga *et al*., 2012). Therefore, as a basal forage, it must be supplemented with protein sources such as herbaceous legumes, multipurpose trees, oil seed cake, and Chicory (*Cichorium intybus*), among others, to improve its utilization.

Chicory (*Cichorium intybus*) has long been utilized as cattle feed in numerous parts of the world (Mahmoud, 2021). Due to its many beneficial medicinal, culinary, and nutritional properties, Chicory is rapidly gaining popularity, especially in Kenya. It is grown by farmers in most dairy farming areas. Also, chicory fodder has the same effect on animals as legumes and even more so than grass-based pastures. When added to basal pasture grasses during feeding, Chicory enhances milk production, as Mahmoud (2021) reported. According to Minneé (2017), the crude protein content of most chicory types is over 19% on a DM basis, which is 1.6-2.4 times greater than the value of most traditional grains like wheat, rice, corn, and barley; this indicates that Chicory is the best alternative source of protein. The Chicory is rich in phytochemicals like inulin (Lepczyński *et al*., 2021). Inulin is frucstosan, a polymer of fructose, an alternative storage carbohydrate to starch, mainly in temperate pastures and some plants such as artichoke, Chicory, and some vegetables. Previous studies have shown that fresh Chicory roots contain 68% inulin (DM basis), a storage polysaccharide just like starch and, therefore, potentially rich in energy, besides protein, among other benefits to the nutrition and health of the animal.

Because of these qualities, Chicory is an alternative option for an affordable, all-natural, and long-lasting feed supplement or alternative for the livestock. This makes protein in animal's diets available and affordable. The inulin found in Chicory is a source of soluble dietary fibre, a prototypical prebiotic particularly advantageous in animal nutrition, and a functional food additive (Lepczyński *et al*., 2021). Available literature shows that prebiotics improve health by encouraging the growth of beneficial bacteria in the gut, like lactobacilli and bifidobacteria (Lepczyński *et al*., 2021). Inulin is a prebiotic that has been linked to a variety of health benefits, including immune system stimulation, reduced levels of harmful bacteria in the intestine, relief from constipation, a lower risk of osteoporosis due to improved absorption of crucial minerals like calcium, and a reduced risk of atherosclerosis due to decreased synthesis of triglycerides and fatty acids in the liver and reduced serum levels (Lepczyński *et al*., 2021). In Kenya, Chicory is planted in fertile and well-drained soils with pH ranges between 6.5 and 7.2. Chicory is suited to cool climate zones. Chicory has nutritional and medicinal properties, so breeding among goats is boosted to a greater extent. Healthy goats generally perform well in terms of reproduction. A minimum of 7% crude protein is required in a diet of dairy goats for improved performance.

Yeast (*Saccharomyces cerevisiae*) is a probiotic material widely used as a feed supplement for livestock worldwide (Shurson, 2018). In many cases, using yeast in animal feeding programs has enhanced rumen fermentation, health, milk yield, and acclimatization to heat stress. Yeast is a low-cost material compared to other feed supplements/additives to boost animal productivity without additional cost (Shurson, 2018). Domestic animal diets have been modified to include yeast in animal feed. Animals kept as pets also benefit from this because their health and productivity typically improve. The yeast *Saccharomyces cerevisiae* is widely used in animal feed (Shurson, 2018). Brewer's dried yeast, primary dried yeast, and torula dried yeast are also frequently used in animal feed. The nutritional value of fermented human foods, such as beer and bread, is greatly enhanced by the use of yeasts, and this may also apply to animal feed. Yeast is added to animal feed to alter rumen fermentation, boost nutrient digestion, decrease the likelihood of rumen acidosis, and boost animal productivity (Kashongwe, 2013). It is specifically used in this study to affect the dairy goats' rumen fermentation parameters synergistically. Due to its high energy, protein, and amino acid content, yeast is an excellent supplement for animal feeds (Vohra *et al*., 2016). Additionally, yeast tends to benefit more in animals feeding on poor-quality roughages such as standing hay/dry grass, cereal straw, and stover that form the main basal diet for bulk feeders like cattle and buffaloes, unlike goats, which are generally concentrated selectors.

Many studies have documented the benefits of various probiotics, such as yeast, and prebiotics, such as inulin or Fructosan (Ayichew *et al*., 2017; Kechagia *et al*., 2013; Markowiak

&Śliżewska, 2018). Besides the apparent nutritional benefit and health through decreasing the need for medication such as antibiotics, it is noted that feed additives, like probiotics and prebiotics, are considered very safe with no known adverse side effects on the body and the environment. Further research is needed to fill the gaps in our understanding of how probiotics like yeast affect animal health and performance. Attempts should be directed toward understanding how these products enhance these animals' production and reproductive capacity through low-tech solutions that primary producers, especially smallholder farmers, can quickly adapt. The country is well endowed with a wide range of feed resources that include pasture browses and agro-industrial by-products that, if used correctly, can significantly contribute to improved livestock productivity through better nutrition and health. Besides, some of the locally available forages do contain extracts that contain secondary compounds that could benefit the nutrition, performance, product quality, and health of sheep and goats. Moreover, yeast (*Saccharomyces cerevisiae*) and other beneficial probiotics can fill in for antibiotics and, therefore, reduce antibiotic use (Malik *et al*., 2019).

Most small-scale dairy goat producers respond to this difficulty by raising and feeding goats a diet of different forages, often requiring reliable scientific data on the effects on the goats' productivity (Miller & Lu, 2019). However, more research data needs to be on goat management and production primarily on energy and protein nutrition. It is generally appreciated that while there is a need for energy from the basal diet that comes from the basal forage, such as Rhodes grass hay, that energy can only be efficiently utilized if there is an adequate and balanced protein/nitrogen supply both at the rumen and tissue metabolism level (Migwi *et al.*, 2013). Therefore, there is a strong case for conducting a study on energy and protein utilization in dairy goats to improve their productivity for better livelihood, focusing on smallholder dairy goat farmers, specifically, with the emphasis on establishing the optimum performance of dairy goats, Chicory, a supplement of Rhodes grass hay, mixed yeast (*Saccharomyces cerevisiae*) in this study. Brewer's yeast is made from *Saccharomyces cerevisiae* and is beer-making's by-product. The objective of the present study is to evaluate the performance of a growing dairy goat fed on Boma Rhodes grass hay supplemented with Chicory mixed with brewer's yeast (*Saccharomyces cerevisiae*).

1.2 Statement of the problem

Dairy goats in Kenya are often fed a basal diet that is generally deficient in essential nutrients, especially protein. Boma Rhodes grass is low and variable in protein and is mostly used as a primary basal forage. Therefore, there is a need to supplement basal forages with protein sources such as plant-based Chicory, which is fairly cheap compared to protein sources such as cotton seed cake and sunflower. Much needs to be known about Chicory's energy and protein potential. Probiotics such as yeast and prebiotics such as inulin found in Chicory have great potential to improve the animal's performance and minimize greenhouse gases emissions. Nonetheless, the potential of these products in addressing nutritional and health effects in dairy goats still needs to be explored in Kenya. There is a need to explore the potential of supplementing basal forages with protein sources – mixed with probiotics. The study focuses on the performance potential of feeding dairy goats on Rhodes grass hay combined with Chicory and/or yeast.

1.3 Objectives

1.3.1 General objective

To contribute to food security and poverty alleviation through the improvement of growth performance of weaner dairy goats fed on Rhodes grass hay supplemented with different levels of Chicory with or without yeast

1.3.2 Specific objectives

i. To determine the chemical composition and *in-vitro* organic matter digestibility of Rhodes grass hay when supplemented with different levels of Chicory with yeast or without

ii. To determine the effect of supplementing different levels of Chicory with or yeast to growing dairy goats fed on Rhodes grass basal diet on voluntary feed intake and weight gain

iii. To determine the synergistic effect of yeast and Chicory on rumen fermentation parameters and estimation of greenhouse gases

1.4 Hypotheses

i. There is no significant difference the chemical composition and *in-vitro* organic matter digestibility of Rhodes grass hay when supplemented with different levels of Chicory with yeast or without

i. There is no significant difference in supplementing different levels of Chicory with or without yeast to growing dairy goats fed on Rhodes grass basal diet on voluntary feed intake and weight gain.

ii. There is no significant difference in the synergistic effect of yeast and Chicory on rumen fermentation parameters and estimation of greenhouse gases.

1.5 Justification of the study

Many people in rural areas in Kenya depend on dairy goats for their nutrition, food security, and livelihood, especially household income. Despite the enormous potential that the dairy goat industry has, its productivity is constrained by many factors, leading to low output. Although Rhodes grass is commonly cultivated in Kenya, it is generally deficient in protein and, therefore, not efficiently utilized by ruminants such as dairy goats. It, therefore, requires supplementation with deficient nutrients such as protein nitrogen. Chicory has the potential to play this role, but it's nutritional and health role in goat nutrition has not been determined. However, a growing goat may not get enough of its needs on a diet consisting solely of Rhodes grass hay (Murney *et al*., 2019). Like many other livestock, goats suffer from nutrient deficiencies, especially in energy and protein, as they mature. There must be an additional supply of protein in addition to the grass hay. Herbaceous plants like Chicory are excellent sources of protein and other nutrients. Incorporating fodder crops into diets already containing low-quality roughages has boosted dry matter (DM) consumption and animal productivity. Probiotics such as yeast have also been found to positively affect animal health and productivity (Markowiak & Śliżewska, 2018).

To a large extent, adverse climatic conditions triggered by global climate change are the current order of the day on the global stage. This makes livestock farming a challenge; there is a need to focus on smart agriculture. The traditional feeding techniques, such as open-field browsing, could be more balanced, resulting in a low nutrient intake since extreme weather patterns limit the free growth of nutritive animal feeds in the fields. In this regard, supplementing dairy goats' basal diets (Rhodes grass hay) with protein sources Chicory with or without yeast is reasonably balanced. Results from this study will be used to advise farmers on the optimal supplementation levels for feeding dairy goats, to enhance the animal productivity and reduce greenhouse gases emissions. Additionally, it provides guidelines for minimizing greenhouse gases emissions, which is a global concern currently.

CHAPTER TWO
LITERATURE REVIEW

2.1 An outlook of Kenya's dairy goats industry

The Kenyan dairy goat industry started prospering after the white settlement in Kenya – when exotic dairy goat breeds were introduced into the Sub-Saharan country. The exotic breeds introduced included Alpine, Toggenburg, Saanen, and Anglo-Nubian. According to FAO (2010), local and exotic goats have been crossed to batten the local goats. Commercially-purposed dairy farming, under intensive farming programs, has witnessed prosperity and contributed to improved human nutrition, batten economy, and income (Reddy, 2018). Improved dairy goats in Kenya are the most reared breeds by most individuals. This implies that the dairy goat industry in the country is gaining popularity, especially in Kenya's dairy-farming-suitable highlands. The cross-breed of local and Toggenburg goats is gaining fame in East Africa. According to Bernardine (2011), Toggenburg dairy goats, together with their resulting cross-breeds, are the primary income earners in the country through the sale of new breeds. Furthermore, Bernardine's (2011) establishments – which are further backed by the articulation of Mburu *et al*. (2014) – report improved goats have an enhanced level of milk production compared to their local counterparts.

Because of their resilience and adaptability, goats play a significant role in the livestock industry, particularly for small and urban farms. Goats are essential to the rural economy and people's health since they provide significant milk and milk products. Ca, Mg, and P levels in goat milk are higher than in cow and human milk. Farms can benefit from goats in manure, meat, and cash. With its low production costs and simple maintenance, dairy goat farming is becoming an attractive business opportunity for Kenya's smallholder farmers. Dairy goat farming has the potential to provide a sustainable income for a large number of farmers, which could help them achieve Sustainable Development Goals 1 and 2.

2.2 Position of dairy goats in the Kenyan economy

Apart from other reasons dairy goats are reared in Kenya – which may include manure and breeding stock production – farmers keep dairy goats with the significant intention of producing milk. Goats and camels have a total milk production accounting for twelve percent, with the rest being produced by cows. As compared to cows, goats have the potential to give birth more times within a short duration, hence giving more returns to the farmer (Bizna, 2018). In this consideration, therefore, goats are a robust economic pillar for many farmers in terms of both income and food supply. Eating meat and milk as food and selling goat products, such as milk and breeds, earn the farmer food security and monetary income, respectively. As such, dairy farming – concerning goats – is a food security booster and poverty alleviator.

According to Bernardine *et al*. (2011) establishments, a double return – both in terms of milk production and sales – is witnessed by dairy goat farmers (whose dairy goats are improved) than individual rearing local goats. As land sizes continue to decrease over time (Birch, 2018), switching to a more intensive production has been established as a suitable and sustainable approach in the dairy goat industry. Mburu *et al*. (2014) discovered that the potential of dairy goats in Kenya is high. Both improved and pure breeds of dairy goats are currently in high demand; according to Reddy (2018), the high demand needs to be met through advancements in goats' developmental activities. According to FarmersTrend (2016), enhanced breeds of dairy goats foster food security and alleviate poverty among farmers.

2.3 Nutritive value of goat's milk in human health

As discovered by vast recent literature, goat milk is suggested to have a high value of nutritional and health benefits to humans. Axe (2018) discovered goats' milk to treat gastrointestinal tract complications and allergies contributed by cow's milk. Based on Axe's (2018) findings, goat's milk is the best option for feeding malnourished individuals. Edward (2018) also found goat's milk superior to cow's milk in health and nutritive benefits. Many human complications can be treated with goat's milk – whose medicinal quality is directly contributed by high levels of medium-chain fatty acids (MCFA) and short-chain fatty acids (SCFA). MCFA that comprise C6:0, C8:0, and C10:0 (Caproic, caprylic, and capric acid, respectively) – As confirmed by Getaneh *et al*. (2016) – treat a wide range of complications associated with malabsorption syndrome of individuals with ailments such as gallstones, cystic fibrosis, and steatorrhea among others. According to the discoveries by Getaneh *et al*. (2016), MCFA also decreases cholesterol levels in the blood serum and restrains the deposition of cholesterol in soft tissues. MCFAs have antiviral, antibacterial, and anticoccidial effects that affect the host and the probiotics. As such, MCFA and probiotics act synergistically. In their findings, Axe (2018) recommended that people with health issues related to anemia, malabsorption, and osteoporosis should constantly be fed goats' milk; goat's milk is hemoglobin revitalized.

2.4 Feeding of dairy goats

Goats are comparable to other livestock; appropriate feeding techniques are always required to guarantee the best performance. Mdukatshani (2015) affirms that quality production performance and appropriate growth are witnessed when proper care is provided to the goats. Goats are remarkably different from other ruminants as they majorly feed through browsing and selectively feed on leaves, soft shoots, and flowers (Mdukatshani, 2015). Based on the articulation of Tanmay (2014), goats can feed on rations made at home and local grasses. It is observed that the supply of good forages to dairy enhances both growth performance and milk production at a cheaper cost than commercial feeds (Agbabiaka ,2019).

In this case, the proper growth of animals and dairy goats must be provided with sufficient dietary demands throughout the year. Forage that has been cultivated and various crop leftovers, as well as household wastes like potato and banana peels, are frequently used to feed dairy goats. Despite the paucity of nutritional information on the used diets, dairy goat farmers frequently use more than one type of forage at a time, leading to mixed rations. A solid goat management program's primary goal is to have a doe weigh 45 Kg at first kidding, which equates to a growth rate of roughly 120 g per day for exotic breeds and 20 to 35 kg for indigenous goats (Thobile *et al*., 2021). According to Ngunjiri (2020), the average daily growth in body weight is 139 g, with a maximum daily gain of 272 g. Conversely, a lower pre-weaning growth rate of 92 g/day and a post-weaning growth rate of 76 g/day, as well as a growth rate range of 50–100 g/day for kids aged between one and three months, have all been observed for exotic and native goats, respectively (Ngunjiri,2020). Because commercial feeds are so expensive, supplementation for developing goats is not a procedure that is often used.

The slower growth rate in these improved dairy goats causes later puberty and sexual maturation, which delays the age of first kidding. Since early breeding has been done, females can have kids as young as a year old because goats attain sexual maturity as early as 4-6 months. According to Safaa *et al*. (2015), the age at first kidding of Saanen goats is approximately 458 days. As a result, creating a year-round forage program that allows for ample nutrition all year is vital to ensure that goats grow well. The high cost of dairy production inputs like commercial feeds and other support services, as well as their accessibility, are significant challenges in smallholder dairy production (Muia *et al*., 2011). However, even though pastures and fodders are claimed to be the most affordable form of animal feeds accessible in terms of quality and quantity and are thus advised for feeding ruminants (Bakhashwain, 2010), inadequate nutrition is still one of the main challenges in goat feeding (Muia *et al*., 2011). The shortages can be reduced by supplementing roughage diets with commercial feeds that provide the lacking elements. However, the high cost of using such commercial feeds as a supplement to goat diets has significant limitations (Muia *et al*., 2011). This can be met by supplementing primary diets with available nutritive farm-based supplemental ingredients.

2.4.1 Protein and energy

Growing animals require energy for growth purposes. The primary source of energy for goats is carbohydrates. Goats require maintenance energy to maintain temperature and enhance normal body functions and activities. To gain weight, goats also require energy. High energy is required to boost many body functions, enhancing growth instead of low energy. Protein is required in animals' bodies to grow and repair tissues during critical metabolic activities. Protein is highly required to produce components such as blood and muscles. Fifteen to eighteen percent of crude protein in diets is recommended for growing goats to enhance their growth fully (Reddy, 2017). Ki *et al*. (2009) discovered that digestibility and feed intake are boosted by high energy and crude protein in growing goats' diet than low energy and crude protein.

Table 2. 1: Nutrient requirements for growing goats:

	Recommended (%)	**Rhodes Grass (basal diet in %)**
Crude Protein	15-18	10-11
Crude Fibre (%DM)	12	35.5
Acid Detergent Fibre (%DM)	23	75.7

Source: NCR. (2007).

2.4.2 Minerals and vitamins

Gasparotto (2015) is keen in their articulation, mentioning the vitality of minerals and vitamins on goats' health. When added to the diet in low quantities, they are highly nutritional. Spencer (2019) listed sodium (Na), calcium (Ca), and Chlorine (Cl), among others, as the most crucial minerals in goats' diet. On the other hand, vitamins take an active role in animals' metabolic processes. They include vitamins A, D, E, and K, which are fat-soluble, and vitamins B and C, which are water-soluble. Water-soluble vitamins can be synthesized directly in an animal's body. Fat-soluble vitamins need to be added to the diet due to the inability of goats to synthesize them directly. In order for the productive performance of dairy goats to be enhanced appropriately, according to NRC (2007), 84 IU and 400 IU of vitamin E and A, respectively, are required for goats weighing 10 to 20.5 kilograms, while 144 IU and 700 IU of vitamins E and A are required for those weighing 20.5 kilograms.

2.4.3 Fats and water

Fats are nutritive ingredients in animals' diets that provide energy. Generally, fats are not necessarily required in the diet unless for exceptional cases like lactating individuals. However, Salah *et al*. (2014) clarified that the inclusion level of fat in an animal's diet should be less than seven percent. Water is another requirement in goats' diet since it aids in digestion, absorption of nutrients, and excretion of wastes. Gasparotto (2015) mentioned that water directly impacts the animal's feed intake and ability to fight ailments. Therefore, the animal's physiological status can be significantly impacted without water.

2.4.4 Source of protein for goats

Ruminants feed on a wide variety of feeds, which comprise local grass and some legumes. Legumes are animal feed rich in protein and classified as protein-rich forages. Some common protein-rich forages are Mulberry (*Mulberry spp*), sweet potato vines, and Desmodium (*Desmodiumspp*). As opposed to local grass, legumes have high crude protein content. Leguminous forages are advantageous to ruminants; they enhance the functionality of the rumen, enhance the intake of protein, and improve the energy and overall performance of the animal. Leguminous forages can be supplemented with typical basal diets to enhance the quality of the animal's diet. However, some non-leguminous forage that includes Chicory can also supplement grass-based diets; Chicory is protein-rich forage.

2.4.5 Chicory

The Chicory plant (*Cichorium intybus*) is a biennial herb that grows best on somewhat fertile, well-drained soils (Murney *et al*., 2019). With its deep root system that allows it to survive during extended dry periods, this plant, with proper care, can produce a large quantity of forage biomass with high crude protein. Besides, it also has prebiotic inulin, which promotes the development of beneficial bacteria in the digestive tract that can deliver both nutritional and health benefits to the animal. There are several kinds of Chicory with various economic uses, and there needs to be more clarity over the botanical classification of such variants. Brussels chicory, Treviso red chicory, and Endive are only a few of the commercial variants of the intybus species of vegetable that have attained widespread recognition for their exceptional economic value. Since Chicory can stay green longer than other forage species, it also contains less dry matter and fewer structural carbohydrates (Nwafor *et al*., 2017). These qualities are why farmers have come to value chicory significantly.

According to research by Di Grigoli *et al*. (2012), Chicory forage significantly impacts dairy performance in grazing sheep and can supply long-lasting, high-quality herbs. According to research by Laws and Genever (2013), lambs raised on chicory forage grow at rates up to 70% faster than those raised on a conventional grass sward, and their performance is comparable to that of lambs raised on leguminous fodder. Herbal supplements given to livestock have been shown to improve rumen fermentation, digestibility, and the composition of milk's fatty acids (Nwafor *et al*., 2017). Additionally, fermentation results in the production of volatile fatty acids (VFAs). These VFAs are a valuable source of substrate carbon for cellular synthesis. Acetate and Butyrate (Acetogenic VFAs) are, therefore, important sources of energy (ATP), heat, and substrate carbon for various biosynthetic functions such as the synthesis of non-essential amino acids, among others. Propionate is important as a source of energy (ATP) and a major substrate for glucose synthesis via gluconeogenesis, besides being useful in the synthesis of other organic products. Feed efficiency in ruminants can be increased through plant extracts or medicinal herbs. Therefore, this is an area of growing interest.

2.4.6 Beneficial effects of inulin from Chicory

Inulin is a fructose polymer found primarily in plants in temperate climates and various vegetables, artichokes, and Chicory. Inulin, like starch, is a storage polysaccharide. Previous research has revealed that fresh chicory roots contain 68% of them (on a dry matter basis), making them a potentially significant energy source and protein source. According to Samanta *et al*. (2013), inulin can maintain intestinal health by increasing the activity and population of Bifidobacterium and Lactobacillus in the colon. This effect is referred to as the prebiotic effect. Short-chain fatty acids (acetic acid, butyric acid, and propionic acid) were created by fermentation of inulin and FOS in the back of the colon, decreasing the pH and encouraging good bacteria growth. In addition to serving as a source of energy for the host, short-chain fatty acids also have a variety of other impacts, such as controlling the migration, differentiation, and proliferation of intestinal epithelial cells, which in turn affects the metabolism of lipids and glucose.

Additionally, it is essential for preserving the gut environment's stability and influencing the colon's mucosal barrier (Rebolé *et al*., 2010). The process by which inulin DP regulates gut microbial flora is highly influenced (Zhu *et al*., 2017). Given that both FOS and inulin must be hydrolyzed into monosaccharides before being utilized by intestinal microbes and that fructose with low polymerization experiences relatively rapid microbial fermentation, it is likely the reason why FOS results were superior to inulin in the regulation of intestinal microorganisms in mice. Long-chain fructose has a higher resistance to fermentation and spends more time in the digestive system. Through competitive exclusion, inulin-type fructans stop harmful bacteria from colonizing (Samanta *et al*., 2013). Additionally, it has been suggested that feeding inulin and FOS to broilers may improve the shape of the intestinal mucosa, such as raising villus height, which may promote the absorption of nutrients (Rebolé *et al*., 2010).

2.4.7 The use of yeast in ruminant nutrition

Yeast and other probiotics are widely utilized in animal feeding due to their favourable influence on health and encouragement of growth (Markowiak & Śliżewska, 2018). Gastrointestinal microbial composition, therapeutic effects, metabolic effects, and immunomodulation are just a few of the health and performance areas that probiotics can improve. Yeast provides beneficial effects on ruminants, including promoting the growth of cellulolytic bacteria such as Bacillus, Erwinia, and Pseudomonas (better ruminal breakdown of dry matter), decreasing acidosis incidence by maintaining a steady ruminal pH, and enhancing feed efficiency (starch and cellulose). Since this increases the availability of nutrients in milk, it helps lambs grow faster. It also increases nitrogen fixation as bacterial protein and critical amino acids by boosting microbial production. Yeasts have been helpful in ruminants, particularly those that consume low-quality roughages that are heavy in fibre, including cereal crop wastes like straw and stover. The yeast cultures are mixed in with the forages right before feeding time. Since anaerobic fungi play a crucial role in the breakdown of fibrous feed material, their proliferation in the rumen improves the digestion of dietary fibre. In addition, it has been hypothesized that yeast colonies in the rumen could generate low-molecular-weight chemicals that promote the expansion of cellulolytic bacteria. This may synergistically affect the host organism by increasing cellulolytic activity in the rumen, which is especially helpful for animals that get their nutrition from refractory fibrous roughages such as cereal straw and stover.

2.4.8 Supplementation of goats' basal diet with Chicory

For supplementation purposes to be practical for the animal, the supply of basal diet needs to be adequate. The supplementary diet is expected to provide the rumen microbes with the nutrients deficient in the basal diet, hence enhancing the digestibility of the basal diet. Chicory (*Cichorium intybus*) is an herbaceous plant of the *Asteraceae* family. The plant is established to do well in moderate to good drainage soils – whose PH levels are 5.5 and above.

Luginbuhl (2006) states that the goats' forage is drought resistant. The forage is an herb, not a legume or a grass.

Inulin – an oligosaccharide derived from the chicory plant, can be supplemented into goats' diets as a fibre. As a basal diet supplement, inulin contributes many physiological benefits to goats (Birmani *et al*., 2019). Based on a recent research study, inulin keeps the microflora in the intestines in balance, enhances immunity, improves weight gain, and also helps to ensure the conditions of the intestines are maintained at optimal standards (Petkova *et al*., 2015). Yeast is found to be responsible for stimulating the growth of ciliate protozoa (Tripathi & Karim, 2011). It is well-established that ciliate protozoa maintain the pH of the rumen (Amin & Mao, 2020). As such, yeast – through enhancing the growth of ciliate protozoa – appropriately maintains the pH levels in the goat's rumen. Dias *et al*. (2018) confirmed the inclusion of yeast in the diet to enhance the digestibility of the basal diet; yeast was discovered to enhance the growth of microbes responsible for digesting fibre.

Supplementation of the basal diet with yeast is confirmed to contribute to stabilized gut health through stabilization of rumen condition and reduced diarrhea (Amin & Mao, 2020). Also, yeast inclusion in the diet improves feed intake (Amin & Mao, 2020). This is achieved through yeast triggering the reproduction of cellulolytic and lactate-utilizing bacteria. Despite the enormous significance of the combination of yeast (probiotic) and inulin (prebiotic), limited studies exist on their effects on growing dairy goats.

2.5 Voluntary feed of goats

According to Matovu (2016), the productive performance of animals is dictated by their feed intake. When not restricted, the animal's total feed amount is its voluntary feed intake. Ruminants have different total feed intake and ruminating times (Pakistan, 2013). According to the researcher, goats – compared to sheep – have higher feed intake. The ruminating time based on Pakistan's (2013) reports differences between the two animals.

2.5.1 Factors associated with animals' feed intake

Matovu (2016) states that three factors influence ruminants' feed intake. The factors are associated with feeding, environment, and the animal. The animal-related factors impacting feed intake comprise sex, age, and physiological status of the animal. Ocak *et al*. (2018) confirmed that the animal's physiological status affects its feed intake. For instance, the individual in a lactating phase demands more food to provide the required energy, hence a higher feed intake than a dry one. According to Ngunjiri (2020), male animals require more physiological energy than females, demanding higher feed intake than females. The researcher also noted that growing animals require more food than adults since they continually grow (Ngunjiri, 2020). The animal's age, sex, and physiological status are animal-related factors impacting their feed intake.

Based on the findings of Ngunjiri's (2020) articulation, the palatability of the feed – which tastes and smells – affects the amount of feed the animal is willing to consume. The animal consumes a tasty feed supplemented with the appropriate amount of minerals and other tasty additives more than contaminated or poor-quality feed. Environmental-related factors such as weather conditions, temperatures, stresses, and parasite infestations impact animals' feed intake (Ngunjiri, 2020). During heavy rains, animals are unwilling to eat, reducing feed intake. According to Ngunjiri (2020), poor health may be associated with parasites and declines in the intake the animals are willing to take. During cold, compared to warm conditions, the animal eats more for the body to generate enough of the demanded warmth.

2.6 Growth factors in goats

Goats are comparably similar to other animals; the progress of their growth and development – ecological elements – are impacted by numerous factors. Marete *et al*. (2011) confirm – among other factors – sex, nutrition, birth season, and birth type (multiple or single) as factors impacting the growth performance of dairy goats. Based on the research discoveries by Alade *et al*. (2008), the growth of goats' kids is faster in single births than in multiple births. The explanation is that single births expose a child to sufficient milk from the mother. In the case of multiple births, kids are observed to compete for the available milk amount, reducing the amount of milk consumed by each kid. In this regard, kids from single birth are exposed to higher average daily weight gain (ADG) than their counterparts from multiple births. The kids from first parity are reported to gain lower weight gain as compared to kids who are from higher parities (Deribe & Taye, 2013). In higher parity, the doe is big-bodied, creating higher chances of bearing heavier kids and enhanced yields for lactation.

Also, according to Deribe and Taye (2013), the rainy season is suitable for kids to grow faster due to a sufficient food supply, unlike the dry seasons. Deribe and Taye (2013) – in their articulation, found that growing goats from higher parity, born during the rainy season and born from single births, portray higher growth performance than those from multiple births, of first parity and born during little-or-no-rain seasons. Safaa *et al*. (2015) showed that male growing goats grow faster than their female counterparts. According to Anya *et al*. (2011), the growing goats perform poorly – when supplied with insufficient nutrition or when diets are not supplemented. When goats are reared on poor-quality feeds or not supplemented, their daily feed intake is below required, and they grow poorly.

2.7 Performance of Saanen and Toggenburg crossbreed

Crossbreeding of the Saanen and the Toggenburg dairy goats has received attention owing to their ability to improve the milking qualities in various climates (Flores-Najera *et al*., 2020). Saanen goats, developed in Switzerland, are, for instance, popular for their high milk production rate, which averages 3-4 liters per day, and their adaptation to intensive farming practices. On the other hand, Toggenburg goats also originating from Switzerland are known for their tolerance and productivity in cool climates. Saanen is receptive to climate change and does well but, has low milk production. At the same time, Toggenburg could produce milk and endure the hot climate but crosses between these two breeds will result in offspring that could perform well in different farming conditions (Günay *et al.,* 2021). Findings further suggest that crossbreds exhibit hybrid vigor which results in improved milk yield, growth, and robustness than the purebred (Flores-Najera *et al.*, 2020).

However, crossbreeding can only be done carefully to ensure the favorable characteristics of each breed are not lost. Experiments concerning crossbred dairy goats indicate that the Saanen-Toggenburg cross yielded a better milk performance than the Toggenburg ones (Nziku, 2022). Further, the crossbreeds have a longer lactation period thus most feasible for smallholder farmers (Gore, 2021). This makes them suitable for regions with poor climates for either of these dogs on their own and makes them very versatile. This has placed the Saanen-Toggenburg crosses in a strategic position and is thus widely used in dairy goat farming in various regions (Pakpahan & Furqon, 2023).

2.8 Constraints to development in Kenya's dairy goats industry

Kenya's dairy goat industry, just as closely compared to any other livestock industry in the country, is never exceptional as far as being constrained by a wide range of performance' stumbling blocks is concerned. Lack of breeding stock, diseases, inaccessible credit, lack of dairy management skills, un-assured markets, poorly organized marketing channels, lack of commercial feeds formulated for dairy goats, acceptance of goat milk, and a lack of goat milk processing plants are just some of the challenges dairy goat production in Kenya faces.

A recent Marete *et al*. (2011) articulation settled on highlighting nutritional insufficiencies, inbreeding systems, health challenges, and traditional methods of production as some of the problems surrounding the industry in the East African country. Elsewhere, Mbinyo *et al*. (2017) mentioned unreliable security, inconsistency in buck rotation, high nutritional costs, and unreliable market sources for goats and their products as other extra constraints in the highly-coveted industry. The decreased productivity, weight loss, diseases, or even mortality result from reduced quality and quantity of livestock feed (Mulwa & Kabubo-Mariara, 2022). This reduces the income of goat producers and has an adverse effect on the nation's ability to provide for the livelihood of the farmers, especially nutrition and food security. This is because dairy goats, primarily browsers, can benefit from their excellent palatability, nutritional content, and overall suitability (Murney *et al*., 2019).

Tropical regions, at times, are fiercely faced by unreliable weather patterns, witnessed by a lack of enough rain. In consideration of this fact, such hash periods expose dairy goats to a starvation crisis – which may deprive them of access to high-quality nutrition programs like quality feeds and supplementation. Regarding this, Mburu *et al*. (2014) instance – of a dairy goat producing a liter of milk instead of a potential of up to five liters – suggests reduced productivity on diminished nutritional accessibility. Dairy goat farmers are not strategically positioned to produce well with their goats by incorporating commercial feeds – this is attributed to soaring costs (Mbinyo *et al*., 2017).

According to Marete *et al*. (2011), instances of poorly developed udders and signs of bisexuality among goats are some physical indications portraying the dairy goat industry as being dominated by inbreeding systems. Mbinyo *et al*. (2017) summarised their research with findings displaying – market instability, ailments, soaring nutritional costs, insufficient feeds, buck rotation issues, and insecurity – as the highest to the lowest constraints surrounding the Kenya dairy goat industry in that order.

2.9 Kenya's dairy goats industry's enhancement opportunities

To avoid the unfavourable effects of the challenges mentioned in the obstacles sub-section above, a wide range of opportunities create an enabling environment for enhanced, reliable, and sustainable dairy goat production. According to Marete *et al*. (2011), the prosperity in the industry diminished by the inbreeding systems can be restored by the development and appropriate use of buck rotation's new software. According to Marete *et al*. (2011), the software will provide well-guided protocols enabling buck rotation to be operationalized into the system. Mbuku *et al.* (2015) recommendation, which Nirajan *et al*. (2019) backed, endorsed cross-breeding to foster productivity and growth rates.

Many efforts need to be concentrated on dairy goats' nutritional plans. Through the concentrated emphasis on animal nutrition, the performance of products was highly fostered.

Mbinyo *et al*. (2017) recommend that farmers be clinical on matter feeding management. According to Mbinyo *et al*. (2017), farmers must be constantly trained to establish and conserve dairy goats' fodder crops, with a focus on protein-rich forages. Nutritional systems of feeding dairy goats that concentrate more on locally available resources are more sustainable than commercial-based feeds. Chicory is herbaceous forage; it can be a viable supplement to the basal diet of Rhodes hay grass. In this respect, the supplementation boosts nutrient intake and hence enhances the performance productivity of dairy goats. Bakhashwain (2010) affirmed that high-quality forage is both digestible and protein-rich. The primary purpose of this study was to establish the performance of growing dairy goats – whose basal diet is Rhodes hay grass – when supplemented with Chicory, with or without yeast.

CHAPTER THREE

THE CHEMICAL COMPOSITION AND *IN-VITRO* ORGANIC MATTER DIGESTIBILITY OF RHODES GRASS HAY SUPPLEMENTED WITH DIFFERENT LEVELS OF CHICORY, WITH OR WITHOUT YEAST (*Saccharomyces cerevisiae*)

Abstract

This study evaluated the *in-vitro* organic matter digestibility of Rhodes grass hay supplemented with different levels of Chicory - with or without yeast (*Saccharomyces cerevisiae*). The feeds were formulated into eight diets in a CRD with a (4x2) factorial arrangement. The diets were Rhodes grass hay and chicory supplementation at (T1:0, T2:10, T3:20, and T4:30%) as the main effects and yeast (+) and without yeast (-) as interaction levels given as (T1-,T1+,T2-,T2+,T3-,T3+,T4- and T4+). The proximate analysis was done to determine the chemical composition of the ingredients in terms of dry matter (DM), crude protein (CP), ether extract (EE), organic matter digestibility (OMD), and ash using the AOAC's recommended methods. The *in-vitro* organic matter digestibility was determined using the gas production method for all experimental diets. The data was analysed using a general linear ANOVA model using SAS software version 9.4. The results show that T4+ (30% chicory+70% Rhodes grass+ yeast) recorded the lowest Neutral detergent fibre (NDF), crude fibre (CF), and acid detergent fibre (ADF) ($p<0.05$), which explains the increased Metabolizable energy (ME) (21.45%) and OMD (3.81 $MJkg^{-1}$ DM)obtained. It also had the highest CP (109.2 gKg-1 DM) and ash (132.9 gKg-1 DM). Results from the *in-vitro* degradability indicate that Rhodes grass hay supplemented with 30% chicory and mixed with yeast had the highest gas production (29.63 ml/200 mg DM) and (31.70 ml/200 mg DM) at 24 and 48 hours, respectively, indicating that the Chicory and yeast combination is suitable for low-quality forages. This study concludes that 30% Chicory mixed with yeast is a potential supplement to Rhodes grass hay to improve the growth of dairy goats.

3.1 Introduction

Agriculture is the primary source of food security and livelihood for almost 17 million Kenyans (Mulwa & Kabubo-Mariara, 2022). However, the rapid increase in human population has led to land subdivision, threatening many people's food security and livelihood in rural areas. The impact of climate change has further exacerbated this condition, and its adverse effects are being felt far and wide by most farmers, especially those who rely on rain-fed agriculture (Musyoki, 2017). Besides the increasing sub-division of agricultural land to smaller parcels that are primarily unprofitable, the other significant challenges constraining the agricultural sector include pests and diseases that affect crops and livestock and the high cost of essential farm inputs. Therefore, there is a need to practice sustainable farming that utilizes available land efficiently and the available and affordable feed resources such as protein sources like Lucerne, calliandra, and Chicory.

Over the past few years, there has been an increasing inclination toward optimizing livestock nutrition to enhance overall health and productivity. Dairy goat farming necessitates meticulous consideration of nutritional composition to achieve maximum growth and milk yield (Rahimi *et al*., 2022). The consumption of forage is of utmost importance in the dietary regimen of ruminant animals, and the nutritional value of forage can substantially influence the overall performance of these animals. Rhodes grass hay, a frequently used fodder, offers vital nutrients but may exhibit a deficiency in specific bioactive components that could potentially augment the overall welfare of dairy goats (Miller & Lu, 2019). Rhodes grass (*Chloris gayana*) has been widely employed to enhance pasture conditions due to the convenient availability and straightforward establishment and management of its seeds. In Kenya, a significant proportion of herbage biomass is generated by various plant varieties, making it suitable for both grazing and hay production (Osuga *et al*., 2012). Livestock readily ingests them even in their mature state, even though their nutritious value significantly diminishes with age. Previous attempts have been undertaken to facilitate the cultivation of Rhodes grass and other native grass species, namely *Cenchrus ciliaris*, *Eragrostis superba*, *Enteropogon macrostachyus*, and *Chloris roxburghiana*.

These grasses are believed to possess the ability to thrive in the challenging climatic conditions of the Arid and Semi-Arid Lands (ASALs) located in the southern and central-northern regions of the Kenyan rangelands. Nevertheless, these crops' productivity and nutritional value sometimes diminish under varying climatic circumstances throughout the year, rendering them insufficient to meet livestock's dietary needs over the entire year.

According to Murphy (2010), tropical grasses typically exhibit low levels of digestibility, crude protein content, and total digestible nutrients while generally having a high fiber content. The primary factor contributing to the deterioration in the quality of tropical grass is its classification as a C4 photosynthetic pathway plant, which exhibits a growth pattern that is more prevalent in hotter climates (Lamidi & Ologbose, 2014). The increasing presence of structural carbohydrates in C4 grasses, as a result of their adaptation to high-temperature and high-light intensity conditions, has led to a reduction in soluble carbohydrates (namely starch). According to Temu *et al*. (2014) and Pedreira *et al*. (2017), this reduction in soluble carbohydrates has been found to negatively influence the nutritional quality of these grasses for herbivores. The provision of sustenance for cattle in tropical regions presents a significant obstacle due to the varying availability of feed, both in terms of quality and quantity, during different seasons (Lamidi & Ologbose, 2014).

Chicory has historically been employed as a source of livestock feed in several regions across the globe (Mahmoud, 2021). Chicory is experiencing a surge in popularity, particularly in Kenya, due to its several advantageous attributes in medicine, cuisine, and nutrition. Consequently, farmers in various regions of dairy farming areas have begun cultivating this plant. Moreover, it is worth noting that chicory fodder exhibits effects on animals comparable to legumes, and its impact surpasses that of grass-based pastures.

According to Mahmoud (2021), including Chicory in the diet of basal pasture grasses has been observed to boost milk production. Minneé (2017) asserts that the crude protein content of several chicory species exceeds 19% on a dry matter (DM) basis. This number surpasses the protein level found in conventional grains such as wheat, rice, corn, and barley by a factor of 1.6-2.4. This finding suggests that Chicory represents a superior alternative protein source. Chicory possesses a substantial content of phytochemicals, such as inulin, as reported by Lepczyński *et al*. (2021). Inulin is a fructosan, which is a polymer composed of fructose units. It is an alternate storage carbohydrate to starch, primarily found in temperate pastures and some plant species such as artichoke, Chicory, and certain vegetables. Prior research has indicated that fresh chicory roots had a 68% inulin content on a dry matter basis. Inulin, a polymer to starch, serves as a storage polysaccharide and hence holds potential as a valuable energy source, in addition to its protein content and various other nutritional and physiological advantages for animals.

Due to these inherent characteristics, Chicory is a viable choice for livestock owners seeking a cost-effective, environmentally friendly, durable feed supplement or substitute. This facilitates the accessibility and affordability of protein in animal diets. Chicory contains inulin, which serves as a soluble dietary fiber. Inulin is recognized as a prototype prebiotic, offering numerous benefits in animal nutrition. Additionally, it is utilized as a functional food ingredient (Lepczyński *et al*., 2021). The literature indicates that the consumption of prebiotics positively impacts health by promoting the proliferation of advantageous gut bacteria, such as lactobacilli and bifidobacteria (Lepczyński *et al*., 2021). Inulin, a prebiotic, has been associated with numerous health advantages, such as immune system activation, diminished presence of detrimental intestinal bacteria, alleviation of constipation, decreased likelihood of osteoporosis through enhanced absorption of vital minerals like calcium, and a lowered risk of atherosclerosis due to reduced hepatic synthesis of triglycerides and fatty acids, as well as decreased serum levels (Lepczyński *et al*., 2021).

Chicory cultivation in Kenya primarily occurs in regions characterized by fertile and well-drained soils, with a pH level ranging from 6.5 to 7.2. Chicory demonstrates a preference for regions characterized by cooler climates. The presence of nutritional and therapeutic characteristics in Chicory suggests that breeding among goats is significantly enhanced. The health of goats directly impacts their overall well-being. Including a dietary protein content of 7% per goat is justifiable. The combination of Rhodes grass hay and Chicory exhibits the potential to boost the nutritional composition of the dietary intake, thereby leading to improved growth performance among dairy goats.

Furthermore, yeast supplementation has been recognized as a beneficial nutritional approach in ruminant diets alongside using Chicory. Including yeast, namely *Saccharomyces cerevisiae*, has positively affected fiber digestion, microbial protein production, and nutrient absorption (Shurson, 2018). The possibility of using Chicory and yeast supplementation in the diet of dairy goats is to provide a balanced and nutritionally enriched feeding regime, resulting in improved growth rates and, therefore, enhanced milk output. Further research is needed to fill the gaps in our understanding of how probiotics like yeast affect animal performance and health. Therefore, there is a strong case for conducting a study on energy and protein utilization in dairy goats to improve their productivity for better food security and livelihood. It focuses on smallholder dairy goat farmers, specifically emphasizing establishing the optimum performance of dairy goats. This study evaluated the *in-vitro* organic matter digestibility of Rhodes grass hay supplemented with different levels of Chicory- with or without yeast (*Saccharomyces cerevisiae*).

3.2 Materials and methods

3.2.1 Feed sample preparation

The basal diet was Rhodes grass (*Chloris gayana*) hay, with Chicory leaves and yeast serving as supplements. The hay was obtained from within the Njoro area. Chicory was grown at the Egerton University farm and harvested after three months. Before the experiment's commencement, the Chicory leaves and grass were dried and then shredded to pass through a 1 mm screen for chemical analysis and a 4 mm sieve for feeding purposes (AOAC, 2005). The feeds were then formulated into eight diets and kept at the lab for further analysis.

3.2.2 Chemical analysis

Dry matter (DM), organic matter (OM), and crude protein (CP) contents were determined according to the standard methods (AOAC, 2005). Neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were determined according to the methods of Van Soest *et al*. (1991). The total extractable tannins (TET) were estimated indirectly after being absorbed into insoluble polyvinyl polypyrrolidone (PVP). The concentration of TET was calculated by subtracting the TEPH remaining after PVP treatment from the TEPH.

3.2.3 Rumen fluid sampling and *in-vitro* digestibility

The *in-vitro* gas production was determined for all experimental diets with strict adherence to the guidelines outlined by Getachew *et al.* (2002). Rumen liquor from randomly selected eight goats from each treatment – two goats from each group, approximately 300 ml – was extracted using a suction pump before morning feeding and two days before the end of the feeding trial. The liquor was filtered in a two-layered cheesecloth to allow strained fluid to be obtained. The fluid was stored in a thermos flask after being flushed with carbon (IV) oxide. Three samples of diets, every 0.2 g, were weighed into 100 ml plungers-fitted calibrated glass syringes. The syringes were then filled with 30 ml of rumen fluid and buffer solution – in 10 ml and 20 ml proportions, respectively. Three 30 ml blank samples of only buffer and inoculum were then prepared. All the samples were incubated at the same time. From 0 to 96 hr, the incubation process was conducted in a water bath at 39^{o}C (controlled thermostatically). The recordings of the gas production were done at 0 to 96 hr, at an interval of 3 hours. The average volume of the gas produced from the blanks was subtracted from the diet-based sample's volume of produced gas. The data of the net volumes of the gas was then transferred into

Ørskov and McDonald's (1979) equation. *In-vitro* organic matter digestibility (OMD) was then determined from the equation below: -

The exponential equation was: -

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

Y = gas produced at the time t

a+b = potential gas produced (ml),

c = the gas production rate constant, and t is the incubation time.

A graph was drawn to display the incubation trend for the properties of the basal diet (Rhodes grass hay) and supplemental diets. Metabolizable energy (ME) and organic matter digestibility (OMD) were determined using the gas generated.

3.2.4 Statistical analysis

Data collected on proximate fibre, tannins, and minerals was subjected to the analysis of variance (ANOVA) in a completely randomized design (CRD) using the General linear model procedure of Statistical Analysis System (SAS, 2002) version 9.0. The model was as follows:

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

Where:

Y_{ij} = dependent variable

μ = overall mean

T_i = effect of the treatment

ε_{ij} = random error term

3.3 Results

3.3.1. Chemical composition of Rhodes grass hay and Chicory

The proximate chemical composition of Rhodes grass hay (basal diet) used is given in **Table 3.1**.

Table 3. 1: Chemical composition of Rhodes grass hay and Chicory (gKg^{-1} DM)

Parameter	Chicory	Rhodes Grass Hay
DM	947.4	955.8
CP	220.6	99.0
Ash	132.9	88.8
EE	19.5	25.7
CF	118.6	324.0
NDF	291.0	732.0
ADF	247.3	473.0
ADL	102.9	34.9
TET	12.3	47.3

DM=Dry matter, CP=Crude protein, EE=Ether extracts, NDF=Neutral detergent fibre, ADF=Acid detergent fibre, ADL=Acid detergent lignin, CF=Crude Fiber, TET=Total extractable tannins.

Rhodes grass hay had the highest DM content compared to Chicory. The CP content in the basal diet was lowest at 99 gKg^{-1} DM, while Chicory had the highest with 220.6 gKg^{-1} DM. Rhodes grass had the lowest ash content at 88.8 gKg^{-1} DM, while Chicory recorded 132.9 gKg^{-1} DM. There was a similar trend in OMD and ADL, with Chicory having the highest values. Rhodes grass hay recorded the highest NDF, CF, and ADF. Conversely, Chicory had the lowest total extractable tannins at 12.3 gKg^{-1} DM, while Rhodes grass hay had the highest at 47.3 gKg^{-1} DM.

3.3.2 Chemical composition of basal diet and supplemental diets

The proximate chemical composition of dietary treatments used is given in **Table 3.2.**

Table 3. 2: Chemical composition of the experimental diets (gKg^{-1} DM)

Parameter	**Dietary composition**								**p-value**
	T1		T2		T3		T4		
	(-)	**(+)**	**(-)**	**(+)**	**(-)**	**(+)**	**(-)**	**(+)**	
DM	955.8±0.00^{ab}	956.6±0.00^{ab}	957.1±0.00^{a}	952.1±0.00^{a}	953.5±0.00^{bc}	954.8±0.04^{ab}	951.3±0.16^{c}	954.3±0.01^{abc}	0.0001
CP	99.0±0.09^{e}	111.3±0.28^{d}	126.5±0.24^{c}	125.8±0.26^{c}	184.6±0.08^{b}	187.8±0.07^{ab}	188.3±0.13^{ab}	196.0±0.06^{a}	<.0001
ASH	88.8±0.02^{d}	90.9±0.23^{d}	97.2±0.16^{c}	102.7±0.03^{b}	104.5±0.04^{ab}	106.2±0.01^{ab}	108.1±0.07^{a}	109.2±0.01^{a}	<.0001
EE	25.7±0.10^{a}	26.0±0.00^{a}	24.7±0.01^{a}	21.0±0.03^{b}	20.3±0.01^{bc}	19.5±0.00^{bc}	19.3±0.00^{bc}	18.7±0.04^{c}	<.0001
CF	324.0±0.90^{a}	329.0±0.29^{a}	300.8±0.12^{b}	304.5±0.08^{b}	290.1±0.11^{bc}	283.5±0.14^{c}	260.1±0.06^{d}	261.1±0.08^{d}	<.0001
NDF	732.0±0.23^{b}	719.1±0.43^{a}	629.8±0.37^{c}	616.2±0.01^{d}	614.0±0.04^{d}	614.5±0.17^{d}	565.9±0.35^{e}	539.9±0.03^{f}	<.0001
ADF	473.0±3.11^{a}	358.3±0.75^{b}	406.6±0.33^{ab}	433.4±2.98^{ab}	368.3±0.25^{b}	367.2±0.19^{b}	366.6±0.15^{b}	380.3±0.22^{b}	0.0008
ADL	34.9±0.17^{c}	57.6±0.34^{b}	74.9±0.18^{a}	58.9±0.28^{b}	88.9±0.17^{a}	35.8±0.23^{c}	36.9±0.17^{c}	33.9±0.69^{c}	<.0001
TET	47.3±0.01^{a}	37.8±0.00^{b}	37.5±0.00^{c}	37.3±0.00^{d}	37.1±0.00^{e}	29.8±0.00^{f}	16.1±0.00^{g}	11.3±0.00^{h}	<.0001

[***a, b,c,d,e,f,g,h***] *means in the same row with different superscripts are significantly different at p<0.05)* DM=Dry matter, CP=Crude protein, EE=Ether extracts, NDF=Neutral detergent fibre, ADF=Acid detergent fibre, ADL=Acid detergent lignin, CF=Crude Fiber, TET=Total extractable tannins; with yeast (+), without yeast (-); T1-(Rhodes grass), T1+(Rhodes grass + yeast), T2-(10% chicory), T2+(10%Chicory+Yeast), T3-(20%Chicory), T3+(20%Chicory+Yeast), T4-(30%Chicory), T4+(30%Chicory+Yeast).

The combination of the ratio T4- (30% chicory and 70% Rhodes grass hay and no yeast) had the lowest dry matter (951.3 gKg^{-1} DM), while T1+ (Rhodes grass with yeast) had the highest at 956.6 gKg^{-1} DM (Table 3.2). The CP for the basal diet T1- was the lowest (99 gKg^{-1} DM), while there was an increasing trend in the supplemental diets, with T2, T3, and T4+ being the highest at 196 gKg^{-1} DM. Supplemental diets had the highest ash compared to basal diets, with the highest being T4+ with 109.2 gKg^{-1} DM and the lowest being T1- with 88.8 gKg^{-1} DM. The basal diet had the highest NDF, ADL, and TET at 732 gKg^{-1} DM, 57.6 gKg^{-1} DM, and 37.8 gKg^{-1} DM, respectively. Additionally, there was a decreasing trend in the CF, the basal diet with yeast having the highest at 329 gKg^{-1} DM and T4- having the lowest at 260.1 gKg^{-1} DM. OMD increased with the addition of yeast, and thus, the basal diet had the lowest with 214.9 gKg^{-1} DM, while T2+ had the highest with 312.8 gKg^{-1} DM.

3.3.3 The *in-vitro* gas production

Gas production and fermentation parameters are presented in **Table 3.3** and **Figure 3.1**. When supplemented with different levels of Chicory-mixed with yeast, Rhodes grass hay degraded at 24 and 48 hr. The gas is usually produced by the fermentation and degradation of organic matter by microbes in the feed. From the results, at 24 and 48 hr, Chicory had the highest cumulative gas at 40.24 ml/200 g and 46.07, respectively. On the other hand, Rhodes grass (T1-) had 17.74 ml/200 g and 30.48 ml/200 g, respectively. The addition of yeast had a significant effect ($p<0.05$) in increasing gas production across all the treatments.

Table 3. 3: *In-vitro* gas production (ml/200 mg DM) at 24 and 48 hr and fermentation characteristics of Rhodes grass hay when supplemented with different levels of Chicory-mixed with yeast

	Reading hour		**Degradation constants**					**Estimated Parameters**		
Samples	24	48	A	B	c	A+B	RSD	SCFA	OMD	ME
Chicory	40.24^{a}	46.07^{a}	0^{a}	6.02^{a}	15.8^{a}	6.02^{a}	3.71^{ab}	0.17^{b}	25.46^{c}	4.11^{a}
T1-	17.74^{g}	30.48^{g}	0.4^{a}	5.15^{ab}	2.03^{a}	5.55^{ab}	4.96 ^{ab}	0.23^{ab}	21.66^{d}	3.21^{d}
T1+	19.39^{f}	21.91^{h}	0.45^{a}	2.6^{c}	4.72^{a}	3.05^{d}	3.49 ^{ab}	0.23^{ab}	21.49^{d}	3.24^{d}
T2-	2010^{e}	32.52^{d}	0^{a}	4.33^{abc}	10.64^{a}	4.33^{c}	4.85 ^{ab}	0.23^{ab}	30.7^{b}	3.36^{d}
T2+	20.75^{e}	37.28^{b}	0^{a}	4.98^{ab}	12.3^{a}	4.98^{abc}	5.59^{a}	0.18^{b}	34.78^{a}	3.57^{c}
T3-	23.41^{d}	32.20^{de}	0.52^{a}	4.22^{abc}	14.18^{a}	4.74^{bc}	3.27^{b}	0.2^{b}	27.68^{bc}	3.75^{b}
T3+	29.36^{b}	31.50^{f}	0.52^{a}	3.73^{bc}	12.00^{a}	4.26^{c}	4.32 ^{ab}	0.21^{ab}	31.01^{b}	3.79^{b}
T4-	25.39^{c}	35.69^{c}	0.05^{a}	4.95^{ab}	11.19^{a}	5.00^{abc}	3.83 ^{ab}	0.21^{b}	29.26^{b}	3.7^{bc}
T4+	29.63^{b}	31.70^{ef}	0.45^{a}	4.31^{abc}	6.60^{a}	4.76^{bc}	4.06 ^{ab}	0.3^{a}	21.45^{d}	3.81^{b}
SEM	0.37	1.05	0.08	0.21	1.3	0.17	0.19	0.01	0.92	0.06
P-Value	<0.0001	<0.0001	0.5258	0.0003	0.1884	<0.0001	0.0236	0.0033	<0.0001	<0.0001

$^{a, b, c, d,e,f}$*means that the same Column with different superscripts is significantly different at p<0.05).* OMD: Organic Matter Digestibility (calculated from Menke and Steingass, 1988 formula, RSD: Residual Standard Deviation; A is the initial gas produced; B is the actual gas produced during DM degradation; A+B is the total gas produced during fermentation; c is the rate of gas production per hour; OMD (%) = 18.53 + 0.9239*(gas production at 48 Hrs) + 0.0540* CP (Menke & Steingass, 1988), SCFA (m mol/200mg DM)=0.0222 GP-0.00425, Where GP is 24h net gas production (ML/200 mg DM), Menke and Steingass, 1989formula, and ME (MJ/kg DM) = 2.2 + 0.1357 × gas produced (ml/200 mg DM) + 0.0057 × CP (g/kg DM) + 0.0002859 × EE2 (g/kg DM), Menke and Steingass (1989), for roughages

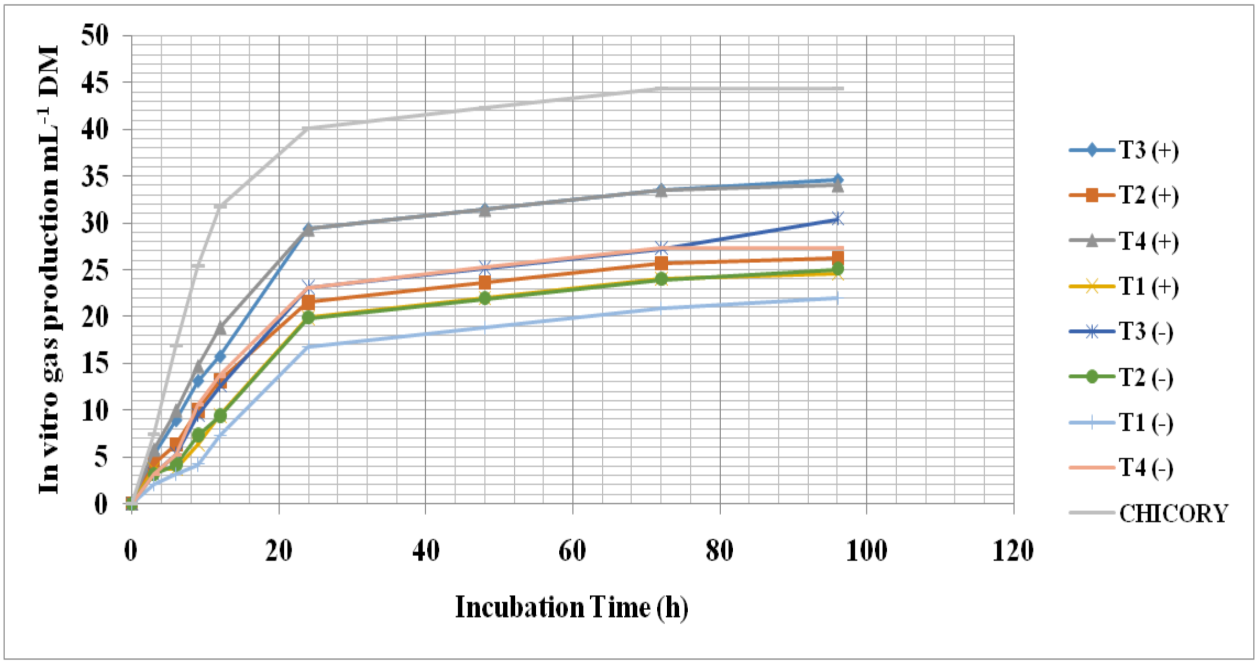

Figure 3. 1: Patterns of *in-vitro* cumulative gas production on Chicory, Rhodes grass hay when supplemented with different levels of Chicory-mixed with yeast

3.4 Discussion

3.4.1 Chemical composition

Chicory is among the alternative protein sources for livestock due to its nutritive value, which is far better than other protein sources such as Lucerne and Calliandra. The results from this study showed that Chicory had the highest CP at 220.6 gKg^{-1} DM, which is consistent with values reported by Laws and Genever (2016). Additionally, it can be seen that combining it in different levels with Rhodes grass raises the CP of these ingredients, which demonstrates its usefulness as a protein source for dairy goats. In this study, Rhodes grass recorded a CP content of 99 gKg^{-1} DM, slightly higher than 80 gKg^{-1} DM reported by Ngunjiri (2020). The difference is a result of the harvesting stage and geographical location. In ruminants, the dietary intake of crude fibre stimulates increased chewing, rumination, and saliva production, all of which contribute to maintaining a stable and favourable rumen pH and continuing regular rumen activity.

According to the findings, it was observed that Rhodes grass hay had the highest neutral detergent fibre (NDF) content, measuring 732 gKg^{-1} dry matter (DM), in comparison to legume forages. On the other hand, Chicory had the lowest NDF content, with a recorded value of 291 gKg^{-1} DM. Ngunjiri (2020) a lower NDF of 690.8 gKg^{-1} DM. This phenomenon may be attributed to the developmental stage of the forage, as the cell wall content tends to increase with maturity, thus leading to higher NDF levels that depress digestibility. In the present study, the NDF values for Chicory were determined to be 291 gKg^{-1} DM, marginally lower than the previously reported value of 353.0 gKg^{-1} DM (Niderkorn *et al*., 2019). The observed high lignin content in Rhodes grass hay agrees with other studies indicating that grasses generally had higher lignin content than legumes (Ngunjiri, 2020). The experimental diets exhibited significant variation in terms of their chemical composition. The supplemented diets generally had a significantly ($p<0.05$) higher CP content than the control diet.

The CP content ranged from 99 gKg^{-1} DM for Rhodes grass (T1-) to 220.6 gKg^{-1} DM for T4+ (30% Chicory + yeast). The NDF and ADF levels were lowered by supplementation due to yeast fermentation's activity. The results also showed a lower NDF and ADF in Chicory. These results agree with the findings by Niderkorn *et al*. (2019). TET was significantly reduced ($p<0.05$) across T1- to T4+. This could be attributed to the fermentation effect of yeast and increasing the level of CP in the diets. These findings are in agreement with those of Vlassa *et al*. (2022), who reported that utilization of yeasts (*Saccharomyces cerevisiae*) or *Saccharomyces boulardii*) effected a process of fermentation that decreased the level of ant-nutritive components and increased the protein content. Additionally, there was a significant ($p<0.05$) increase in the ash content from T1- the lowest at 88.8 gKg^{-1} DM and T4+, the highest at 109.2 gKg^{-1} DM. This may be attributed to the high ash content in Chicory and the effect of yeast fermentation. The results corroborate with findings from Poursakhi *et al*. (2020), who reported that ash in Chicory ranges from 100 to 130 gKg^{-1} DM.

3.4.2 *In-vitro* gas production

The *in-vitro* fermentation characteristics of the Rhodes grass hay, when supplemented with different levels of Chicory-mixed with yeast DM, varied widely among the diets. The lowest gas production recorded was from the basal diets Rhodes (T1-), a mixture of Rhodes grass and yeast (T1+), which had (17.74 ml/200 g, 30.48 ml/200 g) and (19.39 ml/200 g and 21.91 ml/200 g) respectively. There was a significant difference in gas production between the basal diets and the levels of supplementation.

The potential values (a + b) and the rate (c) varied between 17.74 and 46.07 ml and 3.05 and 6.02 /hr, respectively. The relationship between the rate of gas production (c) and the rate of feed movement through the rumen is primarily responsible for explaining this phenomenon. On the other hand, the potential gas production (a + b) is linked to the potential degradability of the feed, as stated by Vandermeulen *et al*. (2018). This suggests that the elevated values observed for potential gas production in the Chicory treatments (T4+) and (T4-) could potentially be attributed to improved nutrient accessibility for rumen bacteria (Nwafor *et al*.,2017). The determined organic matter digestibility (OMD) exhibited a range of values from 21.45% to 34.78%. T2+ exhibited the highest percentage (34.78%), whereas Rhodes (T1) demonstrated the lowest percentage (21.66%). The results are higher than those reported by Niderkorn *et al*. (2019). The difference could be a result of geographical location and stage of harvesting. Additionally, the variation might have been caused by the fermentation effect of yeast. These findings demonstrate that adding Chicory and yeast to a diet will increase the amount of non-degradable rumen protein relative to rumen degradable protein, which will enhance the proper utilization of the nutrients and may translate to better animal performance.

3.5. Conclusion

The results from chemical analysis indicate that Rhodes grass hay supplemented with 30% Chicory and yeast has the highest crude protein content and superior ash profile. Also, from the *in-vitro* degradability, Rhodes grass hay supplemented with 30% chicory mixed with yeast has the highest gas degradability, indicating that the Chicory and yeast combination is suitable for low-quality forages. Additionally, NDF and ADF levels were lowered by supplementation due to yeast fermentation's activity. It is concluded from this study that Rhodes grass hay supplemented with 30% Chicory and mixed with yeast has excellent potential as a feed for dairy goats.

CHAPTER FOUR

THE EFFECT OF SUPPLEMENTING DIFFERENT LEVELS OF CHICORY AND YEAST TO GROWING DAIRY GOATS FED ON RHODES GRASS BASAL DIET ON THEIR VOLUNTARY FEED INTAKE AND WEIGHT GAIN

Abstract

This study explored the impact of supplementing Chicory and yeast in varying proportions to the diets of weaned dairy goats primarily fed a Rhodes grass basal diet. The study was conducted at Egerton University's Tatton Agricultural Park (TAP), Njoro. The feeds were formulated into eight diets and offered to 24 Saanen×Toggenburg crossbred weaned female dairy goats weighing 14±0.5 Kg in a CRD with a (4x2) factorial arrangement. The diets were Rhodes grass hay and chicory supplementation at (T1:0, T2:10, T3:20, and T4:30%) as the main effects and yeast, with (+) and without yeast (-) as interaction levels. The findings suggest that including yeast and Chicory has a significant effect ($p<0.05$) on ADG and voluntary feed intake. Average daily gain (ADG) was notably higher in supplemented goats, with the highest observed in diets containing 30% Chicory and yeast (154.64 g/day). Non-supplemented diet Rhodes grass (T1-) recorded a negative ADG at -7.14g/day. Yeast addition to the basal diet (T1+) boosted the ADG to 28.21 g/day. However, there were variations in treatment T2+ (71.55 g/day) and T3+ (75.48g/day), which were not significantly different. The addition of yeast at this level might not have influenced the weight gain. The study recommends the incorporation of Chicory at a 30% inclusion level and yeast supplements at 10 g/day/goat in growing goat diets for optimal feed utilization and robust growth, offering a promising avenue for sustainable and efficient goat farming practices.

4.1 Introduction

Effective management of dairy goat nutrition is essential in the ever-changing realm of livestock production as it ensures the well-being of the animals and the development of high-quality dairy products (Silva *et al*., 2022). In addition to having a higher concentration of medium-chain fatty acids, goat milk is safer for individuals with lacto-albumin allergies. Despite these advantages, production of dairy goats is constrained by many challenges ranging from inadequate management, nutritional deficiencies, inferior genotypes, and a scarcity of quality replacement stock and breeding opportunities. In particular, the scarcity of high-quality fodder is a significant impediment to the expansion of the dairy goat industry.

Rhodes grass (*Chloris gayana*) is regarded as an important ruminant basal feed because of its appealing taste and rich nutritional content (Van Soest, 1994). Rhodes grass, a commonly utilized primary feed in Kenya but is inadequate for optimal growth and development, and production due to its low protein content. In order to enhance its utilization by ruminants, it should be supplemented with protein sources such as herbaceous legumes, multipurpose trees, oil seed cakes, and Chicory. In recent years, Chicory has become a widely recognized substitute for legumes, and also increasingly popular because of its therapeutic, gastronomic, and nutritional attributes. The crude protein content of this forage is in excess of 19%, and therefore being 1.6-2.4 times greater than that found in conventional cereal grains such as wheat, rice, corn, and barley (Vandeputte *et al*., 2017). Chicory also contains a high amount of phytochemicals, such as inulin, which is a type of soluble dietary fibre. Inulin acts as a prebiotic, enhancing animal nutrition by promoting good health. Inulin is associated with immune system activation, decreased levels of pathogenic microorganisms, alleviation of constipation, decreased susceptibility to osteoporosis, and reduced likelihood of developing atherosclerosis (Vandeputte *et al*., 2017). Chicory is cultivated in Kenya, specifically on fertile and well-drained soils ideal for cool temperature zones.

The nutritional and therapeutic characteristics of this forage also enhances the reproductive capacity of goats. Yeast (*Saccharomyces cerevisiae*) is a probiotic substance which is extensively utilized in animal feeds to improve rumen fermentation, promote health, increase milk production, and aid in adapting to heat stress (Henderson *et al*., 2015). The yeast is cost-effective and can enhance animal productivity without incurring significant extra expenses. Yeast is also advantageous for dairy goat nutrition as it enhances their rumen fermentation parameters and improves their nutritional value (Chaucheyras-Durand & Durand, 2010). Yeast and Chicory

(*Cichorium intybus*) are two potential options that contain distinct bioactive compounds capable of influencing the delicate equilibrium between the ruminant digestive system and metabolic processes. Further research is needed to understand how probiotics like yeast and prebiotics like chicory-inulin affect animal health and performance. Therefore, the objective of this study was to determine the effect of supplementing different levels of Chicory with (+) and without (-) yeast to growing dairy goats fed on Rhodes grass basal diet on voluntary feed intake and weight gain.

4.2 Materials and methods

4.2.1 Study site

The study was conducted at Egerton University's Tatton Agricultural Park (TAP), Njoro. The farm is situated in Kenya in Njoro Sub-County, Nakuru County in the Rift Valley of East Africa, on the eastern slopes of the Mau Escarpment. Its latitude and longitude are 0º 23'S, longitude 35º57'E, respectively and an altitude of 2,200 to 2,280 meters above sea level. The region experiences a bimodal rainfall pattern with long rains coming in March to May, and short rains in September to November.

4.2.2 Experimental animals

The experimental animals for this study consisted of twenty-four (24) crossbreed (Saanen and Toggenburg) weaned dairy goats with initial weights of 14±0.5 Kg and ages between 3-4 months. Each goat's initial weight was determined by averaging it over three days.

4.2.3 Experimental diets

The basal diet comprised of Rhodes grass (*Chloris gayana*) hay, with chicory leaves and yeast serving as supplements. The hay was obtained from Njoro area. A tractor-driven forage shredder was used to shred the well-cured Rhodes grass hay into 2 cm size and then stored in gunny sacks. Chicory was grown at the Egerton University farm and harvested, then dried. It was then cut into 2 cm size using an electric power fodder chopper and kept in gunny bags. Two weeks before the start of the trial, the feeds were transported to the experimental site. The feeds were kept in a clean, dry store at room temperature with plenty of ventilation throughout the experiment. Each feed sample was hammer-milled to pass through a 1-2 mm screen before being placed in sampling bottles for later chemical analyses. The experimental diets consisted of (T1) as the control comprising of Rhodes grass hay and basal plus chicory included at three levels T2 (10%), T3 (20%) and T4 (30%), and with all the four dietary treatments being with yeast (+) at a rate of 10g/goat. Day and without (-) yeast **(Table 3.2).** The higher DMI figure recorded for goats was used to compute dry matter intake, which was 5% of the live weight of each goat. The supplement diets were fed at 10, 20, and 30% of the expected daily DM intake, whereas the base diet was provided *ad libitum*. The amount fed was modified at the start of each week to account for changes in body weight. It was fed to them before their *ad libitum* to the base diet to guarantee that the goats eat the entire supplement.

Table 4. 1: Dietary treatments consisting of basal hay different levels of Chicory and with (+) and without (-) yeast

	Basal Rhodes grass hay	**Chicory**	**Yeast**	
T1 (Control)	100%	0	-	+
T2	90%	10%	-	+
T3	80%	20%	-	+
T4	70%	30%	-	+

4.2.4 Experimental design

The experimental design was a completely randomized design (CRD) in a (4x2) factorial arrangement replicated thrice with eight dietary treatments. The dietary treatments were as shown in Table 3.2 with four levels of Chicory at 0, 10, 20 and 30% with and without yeast. The animals were confined in individual, slatted-floor, well-ventilated pens. Every fortnight the experimental animals were drenched with 10% Albendazole (anti-helminthic) to prevent internal parasites, while the acaricide was used to control external parasites. Data collection was done for eight weeks after a 14-day adaptation period. The eight dietary treatments were allocated to the animals in a randomized manner. The animals were fed the experimental diets twice daily, in the morning at 08:00 hr and in the afternoon at 14:00 hr. In the morning diet, supplements were prioritized in feeding, followed by the basal diet. In the afternoon diet (14:00 hr), the basal diet was offered to the experimental animals with respect to the 08 00 hr basal diet intake. Each animal’s basal and supplement diet intake was recorded daily. The refusals from the previous day's feed were collected, weighed, and recorded. At the end of every week, the weights of the experimental animals were taken before morning diets, and all weights were recorded.

4.2.5 Feed intake and weight gain

Voluntary feed intake was determined by summing up the animal's voluntary intake with respect to the basal and supplemental diets, less refusal, all in DM.

Total dry matter intake (TDMI) = DMI of the basal diet (g) + DMI of the supplemental diets (g).

To establish the weight gain, the initial weight of each goat before the commencement of the feeding process was deducted from the weekly recordings of weights during the feeding experiment.

Weekly weight gain (WG) = Weekly weight recorded (WWR) – Initial weight recorded (IWR).

4.2.6 Statistical analysis

The values of the measured parameters (DMI, ADG, crude fibre, minerals, IVOMD, ME) were determined by analysis of variance (ANOVA) using the general linear model (GLM) procedure of statistical analysis system (SAS, 2002). Significant differences in means were separated using the least significance difference (LSD) at ($p < 0.05$).

Statistical model: -

Yijk =µ + Ai +Bj + (BR) ij + eijk

where: -

Yijk = (Intake, and Weight gain)

µ = overall population mean

Ai = effect of level of factor A (Main effects): Chicory levels, {i= 1, 2, 3 & 4}

Bj = effect of level of factor B, (Yeast levels) j = {1, 2}

(BR) ij = effect of interaction between Factor A and B.

eijk = random error associated with Yijk

4.3 Results

4.3.1 Voluntary feed intake and average daily gain

The experimental diets' values for dry matter intake (DMI), weight gain, and average daily gain are shown in **Table 4.2.** The dry matter intake (DMI) of the basal diet exhibited a significant increase ($p<0.05$) as a result of supplementation and yeast addition. Diet T4+ had the highest intake of 591.70 g/day, whereas T1- (Rhodes grass) showed the lowest DMI at 359.21/day. The increased DMI with supplementation from 10-30% was due to the improved level of CP as a result of supplementation as well as the fermentation effect of yeast.

In terms of weight change, there were significant ($p<0.05$) differences in average daily gain (ADG) across the treatments (Figure 4.3). Supplemented goats showed higher ADG compared to non-supplemented. Basal diets that were supplemented with the highest level of supplementation (30%) showed a higher ADG. These were Rhodes grass +30% chicory + yeast (T4+), Rhodes grass +30% chicory, without yeast (T4-), and Rhodes grass +20% chicory + yeast, which had ADG of 154.64.8 g/d, 125.12.0 g/d and 110.83 g/d respectively. Non-supplemented diet Rhodes grass (T1-) recorded a negative ADG at -7.14 g/day. Yeast addition to the basal diet (T1+) boosted the ADG to 28.21 g/day. However, there were variations in treatment T2+ and T3+, which were not significantly different. The addition of yeast at this level might not have influenced the weight gain.

Table 4. 2: Dry intake (DMI) and ADG of goats fed Rhodes grass hay, supplemented with different levels of Chicory and yeast

	Dietary Treatments								
	T1		T2		T3		T4		
Parameter	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	p-Value
DMI (g/day)	359.21^{f}	424.40^{e}	451.20^{de}	476.51^{dc}	488.57^{dc}	503.82^{bc}	533.39^{b}	591.70^{a}	<.0001
INWT (Kg)	14.23^{a}	14.07^{a}	13.87^{a}	13.73^{a}	14.33^{a}	14.13^{a}	14.17^{a}	14.13^{a}	0.2262
FWT (Kg)	14.03^{f}	14.86^{ef}	15.44^{de}	15.74^{de}	16.44^{dc}	17.24^{bc}	17.67^{ab}	18.46^{a}	<.0001
WTG (Kg)	-0.20^{e}	0.60^{de}	0.63^{cd}	1.48^{cd}	1.77^{c}	3.10^{b}	3.63^{ab}	4.17^{a}	<.0001
ADG (g/day)	-7.14^{e}	28.21^{d}	56.07^{dc}	71.55^{c}	75.48^{c}	110.83^{b}	125.12^{b}	154.64^{a}	<.0001

[a, b, c, d, e,f] *means in the same row with different superscripts are significantly different at p<0.05)*,Chicory (C), Diet with yeast (+), diet without yeast (-); T1=(Rhodes grass), T1+(0%+ yeast), T2-(10%C), T2+(10%C+Yeast), T3-(20%C), T3+(20%C+Yeast), T4-(30%C), T4+(30%C+Yeast), DMI= Dry matter intake, INWT=initial weight, FWT=final weight, WTG=weight gain, ADG=average daily gain.

4.4 Discussion

4.4.1 Voluntary feed intake

The present study showed that there was a significant increase in DM intake when weaned dairy goats were fed with Chicory and yeast. Goats whose primary diet consisted of only basal diet of Rhodes grass hay without yeast (T1-) recorded the lowest feed intake, 359.21 g/day, while T4+ goats recorded the maximum intake, 591.7 g/day. These results corroborate with the findings by Murney *et al*. (2019) that also reported a significant increase in DMI when housed goats were supplemented with yeast and Chicory. According to their findings, adding yeast to the diet stimulates rumen microorganisms, leading to enhanced fibre digestion and as a result greater feed DM intake. Elghandour *et al*. (2022) demonstrated that goat kids not given yeast supplementation exhibited a reduced average daily gain compared to those given 2.5 and 5 g/day of yeast. In addition, Salem *et al*. (2023) noted that incorporating a yeast culture with monensin (a common prebiotic and probiotic combination) into the diet of lambs resulted in enhanced body weight gain.

The incorporation of probiotics into animal diets appeared to enhance the growth of lambs, resulting in increased live weight gain and improved feed conversion ratio (Soliman *et al*., 2016). The increased intake may have been due to the additional provision of rumen-degradable nitrogen supplied by the addition of Chicory. This enhances the activity of the bacteria in the rumen, thus enhancing the digestibility of organic matter and, consequently promoting higher feed dry matter intake (Soliman *et al*., 2016). The increased feed intake by the goats may be attributed to the palatability of Chicory in diets containing it, as opposed to diets lacking Chicory like in T1- in this study. This is in agreement with the findings by Perović *et al*. (2021) that also noted that Chicory has a diverse range of nutrients, such as fibre, vitamins, and minerals. Chicory's high nutritional content is likely to fulfil the nutritional needs of growing goats. Chicory's other nutritional beneficial components, like inulin, may positively impact on rumen microbial activity and gut health, which could enhance digestion and nutritive value of the diet Perović *et al*. (2021). Chicory contains both soluble and insoluble fibres, which are within the required levels of ruminants (291 g Kg^{-1} DM). Sufficient dietary fibre promotes rumination and increased saliva flow and is crucial for preserving the well-being of the rumen and for optimal digestion in ruminant animals.

The high NDF content (732 gKg^{-1}DM) of Rhodes grass hay is a factor that led to decreased feed intake in the non-supplemented goats compared to the supplemented animals whose diets had low NDF levels. This is because the level of NDF in an animal ration typically affects their feed consumption as it brings about a faster rumen fill. It also implies that the supplemental diets had a higher feeding value than Rhodes grass hay as the higher proportion of cell contents is a good index of the nutritional value of a feed. Additionally, Niderkorn *et al*. (2019) found that the digestibility of Chicory has a significant role in determining its effect on feed consumption. Enhanced nutrient absorption and increased animal performance can result from high digestibility and intake of a feed. Nwafor *et al*. (2017) opine that because of its relatively high digestibility, Chicory can enhance the efficient utilization of nutrients by developing goats, hence positively impacting their growth and development.

The combination of Chicory and yeast may synergistically impact the amount of feed consumed by goats. From this study, non-supplemented goats recorded the lowest intake (359.21 g/day) while supplemented ones, particularly in the diet with yeast addition (T2+, T3+, and T4+), improved intake at 476.51 g/day, 503.82 g/day and 591.70 respectively. These results are also in agreement with those of Saleem *et al*. (2017) that reported that probiotic supplementation has a beneficial impact on feed intake after weaning. This effect may be attributed to an increase in the quantity and proportion of cellulolytic bacteria in the rumen, as well as an improvement in ruminal pH. These improvements are likely to result in better fibre digestion and therefore enhanced feed intake.

Similarly, Ogbuewu and Mbajiorgu (2022) found that the DM intake of Saanen goats increased when they were given 0.2 g/head. Day of *Saccharomyces cerevisiae* (CNCMI-1077) over 12 weeks. The enhanced digestive process may result in a higher feed consumption since goats can more nutrients from the combined chicory and yeast diet. The use of Chicory and yeast may also enhance nutrient absorption in goats. The process of yeast fermentation can increase the accessibility of nutrients in the rumen. At the same time, the nutritional composition of Chicory has the potential to contribute to a well-balanced diet. The improvement in DM intake has also been reported before (Khalid *et al*., 2011). In contrast, there has also been report of yeast culture not having any beneficial impact on the dry matter intake and live weight gain in finishing lambs (Kawas *et al*., 2007).

4.4.2 Average daily gain

The Average daily gains (ADG) of non-supplemented animals (-7.14 g/day) were consistent with findings by Kenana (2022), who noted that goats fed with basal Rhodes grass alone recorded weight gain of -20 g/day. The ADG of supplemented goats was greater than that of non-supplemented goats. The basal diets that received the highest supplementation of Chicory (30%) exhibited a greater average daily gain (ADG). Diet T4+ (Rhodes grass + 30% chicory + yeast) and T4- (Rhodes grass + 30% chicory no yeast) had ADGs of 154.64 g/day and 125.12 g/day, respectively. The enhanced growth relative to non-supplemented diets may have been caused by higher protein (CP) and energy levels from supplementation, which may have contributed to the higher ADG observed in supplemented diets.

The basal diet without yeast T1- had a negative ADG (-7.14g/day) compared to one with yeast T1+, which recorded positive results (28.21 g/day). These results are consistent with the findings of Sawsan *et al*. (2012) that reported that the fibre-degrading properties of specific yeast isolates may increase the digestibility of fibre in Rhodes grass when yeast supplementation is used. This may result in enhanced utilization of nutrients by the goats. Furthermore, Conte *et al*. (2018) reported that growth performance was improved as noted from the higher final body weight and average daily gain. Moreover, according to Alugongo *et al*. (2017), yeast has been linked to enhanced immune activity in livestock. This may enhance the health and well-being and development of a growing goat as a whole.

The current study found that enhanced nutrient intake can increase weight gain efficiency in growing goats as indicated by high DMI (591.70 g/day) resulting in high ADG (154.64 g/day). These results are also in agreement with those reported by Pradhan *et al*. (2018), that reported that supplementing sure goat kids with active dried yeast (*S. cerevisiae* CNCM I-1077) at a rate of 2% of dry matter intake resulted in enhancement of growth, feed conversion efficiency, and a reduction in feeding cost. The potential contribution of Chicory to gut health, combined with the excellent influence of yeast on digestion, may improve overall growth performance, as shown by the results in this study. The synergistic impact of Chicory and yeast on feed intake, nutrient digestibility, and gut health can enhance growth and overall performance in growing goats, is also supported by findings by Shurson (2018). Moreover, Attia *et al*. (2017) opine that yeast and Chicory may exert synergistic effects on the health of the digestive tract. Chicory's prebiotic characteristics and the yeast's probiotic impacts can synergistically establish a harmonious and salubrious microbial environment within the goat's gastrointestinal tract. This can lead to better nutrient utilization and stimulate development in growing goats. The potential efficacy of Chicory's ant-parasitic properties may result in a diminished parasite burden within the gastrointestinal tract of goats, thereby providing additional support for their growth and general well-being.

4.5 Conclusion

The optimal concentration of Chicory for promoting the growth of dairy goats is 30% when supplemented with 10 g/goat/day of yeast. To achieve feed efficiency and strong development, farmers may add Chicory and yeast to the diets of growing goats to improve productivity. Further investigation is needed to explore the possible long-term effects and economic feasibility of adding Chicory and yeast to the diet of lactating dairy goats.

CHAPTER FIVE

EVALUATION OF THE SYNERGISTIC EFFECT OF YEAST AND CHICORY-INULIN ON RUMEN FERMENTATION PARAMETERS AND ESTIMATION OF GREENHOUSE GASES

Abstract

Probiotics and prebiotics are feed additives that have been extensively utilized in animal nutrition for a considerable duration. However, only some studies have investigated their synergistic effects on rumen fermentation parameters and their role in minimizing methane emission. Therefore, this study examined the impact of combining chicory-inulin with yeast (*Saccharomyces cerevisiae*) on rumen fermentation parameters and methane emissions in weaned dairy goats. The feeds were formulated into eight diets and offered to 24 Saanen×Toggenburg crossbred weaned female dairy goats weighing 14±0.5 Kg in a Completely Randomized Design with a (4x2) factorial arrangement. The diets were Rhodes grass hay and chicory supplementation at four levels: 0, 10, 20, 20, and 30% as the main effects and with (+) and without yeast (-) yeast as interaction levels. Portable pH and temperature meters (HANNA HI-8424 Portable pH/ORP Meter, Woonsocket, USA) were used to quickly measure the fluid's pH and temperature respectively in the rumen. Ammonia nitrogen (NH_3-N) was analyzed with a Kjeltech Auto 1030 Analyser, and volatile fatty acids (VFAs) using a high-performance liquid chromatography method. The findings indicated that the inclusion of yeast and Chicory had a significant effect ($p<0.05$) on rumen pH, ammonia nitrogen concentrations, production of volatile fatty acids, and no significance in estimated methane emission ($p=0.4582$). The highest pH was recorded in T1- with 7.27. It was followed closely by T1+ with 6.73. T1+ recorded the highest methane (39.67 mmol/L), while T4- had the lowest (32.42 mmol/L). This study concludes that Chicory-inulin has prebiotic properties by maintaining pH levels and affecting amounts of ammonia nitrogen. The lack of a significant interaction effect between yeast and Chicory in methane emission implies that their combined influence may not significantly affect methane emissions in the current study's experimental settings.

5.1 Introduction

The necessity to continually seek out and increase the pool of feeds and additives to increase ruminant production is crucial to meet the ever-escalating demand for animal products. However, increasing ruminant livestock production is faced with many constraints, among them, inadequate supply of feed resources that are necessary to supply adequate nutrients to the animals. This calls for the diversification of the available feed resources so as to meet the nutrient requirements of the animals and preserve the equilibrium between production and environmental sustainability.

Chicory has long been utilized as cattle feed in numerous parts of the world (Mahmoud, 2021). Due to its many beneficial medicinal, culinary, and nutritional properties, Chicory is rapidly gaining popularity, especially in Kenya. It is grown by farmers in most dairy farming areas. Also, chicory fodder has the same effect on animals as legumes and even more so than grass-based pastures. When added to basal pasture grasses during feeding, Chicory enhances milk production, as Mahmoud (2021) reported. According to Minneé (2017), the crude protein content of most chicory types is over 19% on a DM basis, which is 1.6-2.4 times greater than the value of most traditional grains like wheat, rice, corn, and barley; this indicates that Chicory is the best alternative source of protein. Lepczyński *et al.* (2021) found that chicory is abundant in inulin and other phytochemicals. Primarily found in temperate pastures and some plants like artichoke, chicory, and certain vegetables, inulin is frucstosan, a fructose polymer and an alternate storage carbohydrate to starch. Fresh chicory roots have many nutritional and physiological benefits, including a high concentration of inulin (68% DM base), a storage polysaccharide similar to starch, and potential richness in energy and protein.

According to Roodposhti and Dabiri (2012), probiotics are live, helpful microbes that support rumen functions and keep the gut microbiome well-balanced. For instance, the probiotic yeast *Saccharomyces cerevisiae* has a beneficial effect on the microorganisms in the rumen, specifically by raising the overall population of bacteria, anaerobic fungi, and protozoa and by enhancing the functionality of the rumen itself (Ding *et al*., 2014). Since *S. cerevisiae* is relatively inexpensive compared to other feed supplements and additives, it can increase animal output at no extra expense (Shurson, 2018). Yeast has been added to animal feed to improve the diets of domestic animals. *Saccharomyces cerevisiae* supplies growth-promoting substances, such as organic acids, B-complex vitamins, and amino acids, which support the growth of microorganisms in the rumen and, therefore, indirectly maintain a stable pH.

In contrast to probiotics, prebiotics function differently as a source of nourishment for specific microorganisms, resulting in advantageous outcomes for the host animal (Ding *et al*., 2014). Prebiotics exhibit resistance to gastric acidity, absorption, and hydrolysis by enzymes secreted in the gastrointestinal tract (Samal & Behura, 2015). The by-products of prebiotic fermentation by the microorganisms in the gut have the advantage of reducing the pH, thus inhibiting the growth of harmful bacteria in the gut (Gibson *et al*., 2010). Various prebiotics are utilized in cattle production, including fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), mannan oligosaccharides (MOS), β-glucans, inulin, and lactulose (Patel & Goyal, 2012). Inulin is a complex carbohydrate composed of fructose molecules as the monomers linked together by a β 2, 1 glucosidic bond, with minor quantities of glucose present. Therefore, inulin is classified as a polysaccharide carbohydrate called fructosan (fructans). Chicory (*Cichorium intybus L.*) and Jerusalem artichoke (*Helianthus tuberosus L.*) are the primary sources of inulin (Masanetz *et al*., 2010). Inulin undergoes minimal digestion and absorption in the small intestine and, therefore, ends up in the lower part of the gastrointestinal tract (hindgut), where bacteria rapidly ferment it to volatile fatty acids and gases.

Lactobacillus bacteria, including Bifidobacterium, exert a favorable impact on gut metabolism. The consumption of inulin, therefore, provides nutrients to the cells in the intestines, reduces the acidity in the gut, and promotes the growth of the villi and micro-villi in the intestines, as well as an increase in the number of cells on each villus, which increases the absorptive area for nutrients (Xiao *et al*., 2016). Synbiotics are a combination of live microorganisms and specific substances consumed by the host microorganisms that positively affect the host's health. The concurrent use of a probiotic and a prebiotic can result in a mutually enhancing and advantageous outcome for the animal. The two feed supplements, when combined, can increase the gastrointestinal tract implantation rate and survival of a direct-fed microbial, as well as activate the metabolism of a small number of beneficial bacteria and encourage their growth.

Furthermore, a significant issue encountered in the rearing of ruminants is the release of methane, which is strongly linked to enteric fermentation in the gastrointestinal and is affected by various types of microbes, especially the cellulolytic flora (Zhou *et al*., 2018). Methane is released due to enteric microbial fermentation of feed both in the foregut and hindgut in herbivores, especially ruminant herbivores. Enteric fermentation is estimated to represent a loss of up to 12% of the feed's gross energy, which could have benefitted the host animal. The loss occurs because bacteria use organic acids, such as formic and acetic acids, to produce volatile fatty acids (Malmuthuge & Guan, 2016).

Additionally, methane is one of the major greenhouse gases that contribute to climate change. In recent years, there has been a strong global interest in decreasing methane gas emissions in animal production through the use of feed additives that impact the microbiome composition in the ruminant digestive system (Patel & Goyal, 2012; Uyeno *et al*., 2015). Probiotics and prebiotics are feed additives that have been extensively utilized in animal nutrition for a considerable duration. However, only some studies have investigated their synergistic effects on rumen fermentation parameters and their role in minimizing methane emissions. Therefore, the objective of this study was to determine the synergistic effect of yeast and chicory-inulin on rumen fermentation parameters and methane emission estimation.

5.2 Materials and methods

5.2.1 Study site

The study was conducted at Egerton University's Tatton Agricultural Park (TAP), Njoro. The farm is situated in Kenya, the Njoro Sub County in Nakuru County in the Great Rift Valley of East Africa, on the eastern slopes of the Mau Escarpment. Its coordinates are 0º 23'S latitude and 35º57'E longitude, and an elevation of 2,200 to 2,280 metres above sea level. The region experiences a bimodal rainfall pattern with long rains from March to May, occasionally extending to June, and brief short rains from September to November.

5.2.2 Experimental animals

The feeds were formulated into eight diets replicated three times and offered to 24 Saanen×Toggenburg crossbred weaned female dairy goats weighing 14±0.5 Kg in a CRD with a (4x2) factorial arrangement. Each goat's initial weight was determined by averaging it over three days.

5.2.3 Experimental diets

The basal diet comprised Rhodes grass (*Chloris gayana*) hay, with chicory leaves and yeast serving as supplements. The hay was sourced within the Njoro area and shredded into 2 cm size using a tractor-driven forage shredding machine. The shredded hay was subsequently kept in plastic gunny bags while awaiting the feeding trial. Chicory was grown at the Egerton University Tatton farm and harvested, then dried. It was then chopped into 2 cm size using an electric power forage chopper and kept in plastic gunny bags.

Two weeks before the start of the feeding trial, the feeds were transported to the experimental site in readiness for the feeding trial. The feeds were kept in a clean, dry, and temperature-controlled store with adequate ventilation throughout the experiment. The basal diet (T1), which was also the control, consisted of Rhodes grass hay, while the other experimental diets were as follows: T2, T3, and T4 with different levels of Chicory (10, 20, and 30%) with (+) and without yeast (-) at a rate of 10 g/goat—day as shown in Table 1.1. The higher DM intake level recorded for goats was used to compute dry matter intake, which was 5% of the live weight of each goat. The supplement diets were fed at 10, 20, and 30% of the expected daily DM intake.

In contrast, the basal Rhodes grass hay diet was provided *ad libitum* so that the unavailability of the basal forage did not restrict intake. The amount fed was adjusted at the start of each week to cater for changes in body weight. The supplement was provided to the animals as a priority before offering the basal diet *ad libitum* to guarantee that the goats eat the daily supplement.

Table 1: The Dietary treatments for the study

	Rhodes grass hay	Chicory	Yeast (Without)	With Yeast 10g/goat/day
T1	100%	0	-	+
T2	90%	10%	-	+
T3	80%	20%	-	+
T4	70%	30%	-	+

5.2.4 Experimental design

The study used a completely randomized design (CRD) in a (4x2) factorial arrangement replicated thrice. Eight dietary treatments were used in the study's experiment, which was based on the basal diet and different levels of chicory (10, 20 & 30%) and yeast supplements **(Table 5.1)**. The animals were confined in individual slatted-floor pens that were well ventilated. Fortnightly, each experimental goat was drenched with 10% Albendazole (anti-helminthic) to prevent internal parasites, while external parasites were prevented using acaricides. Data collection was done for eight weeks after a 14-day adaptation period. The eight dietary treatments were allocated to the animals in a randomized manner. The supplements were offered to the animals twice daily, in the morning at 08:00 hr and the early afternoon at 14:00 hr, while the Rhodes grass hay basal diet was made availability to the animals *ad libitum*.

5.2.5 Determination of the rumen fermentation parameters

On the last data-gathering day, rumen fluid samples were collected using a vacuum pump at 0 and 4 hours following feeding. Each time, a stomach tube connected to a vacuum pump was utilized to extract roughly 50 mL of rumen fluid from the lower region of the organ's core. The pH and temperature of the fluid in the rumen were quickly assessed using portable pH and temperature meters (specifically, the HANNA HI-8424 Portable pH/ORP Meter from Woonsocket, USA). The subsequent action involved passing the rumen fluid samples through four layers of cheesecloth in order to remove any particles. Right after filtering, 45 mL of rumen fluid was moved to a plastic container with 5 mL of sulfuric acid solution to eradicate lingering bacteria and stop the fermentation process. The mixture was centrifuged at a speed of 16,000 x g for 15 minutes using a Table Top Centrifuge PLC-02. The resulting supernatant was stored in a cold storage facility at -20oC for future analyses. These analyses involved measuring ammonia nitrogen (NH_3-N) with a Kjeltech Auto 1030 Analyzer and volatile fatty acids (VFAs) using a high-performance liquid chromatography (HPLC) method (Mathew & Kalyanasundaram, 2001). The HPLC setup included Controller Instruments, water model 600E, 484 UV detector, Novapak C18 column (4 mm 150 mm), and a mobile phase of 10 mM H2.

The equation utilized to predict ruminal methane (CH_4) production using proportions of volatile fatty acids (VFA) was based on the work of Moss *et al*. (2000). It is expressed as follows: CH_4 production=0.45 acetate + 0.275 propionate + 0.4 butyrate.

5.2.6 Statistical analysis

The data collected on the various parameters was subjected to the analysis of variance (ANOVA) using the general linear model (GLM) procedure of the statistical analysis system (SAS, 2002). Where significant differences were detected and means were separated using the least significance difference (LSD) at (p< 0.05).

5.3 Results

The results for the synergistic effects of yeast and inulin from Chicory are shown in **Table 5.2**. The highest pH was recorded in T1- (Rhodes grass with no yeast) with 7.27. It was followed closely by T1+ (Rhodes grass +yeast) with 6.73. The other treatments recorded had similar trends and no significant difference. There was a significant difference (p<0.05) in the basal diet with yeast (T1-) compared to T1+. The ammonia nitrogen values significantly (p<0.05) differed across the treatments, and the highest was T1- with 85.36 mg/L, while T4+ recorded the lowest with 56.07 mg/L. This study showed a decreasing trend with an increase in chicory level and yeast addition.

A similar trend was witnessed with acetate production, and T1- had the highest acetate concentration at 58.37 mmol/L, while T4+ had the lowest at 41.46 mmol/L. There was a significant difference (p<0.05) across diets on yeast addition and increased levels of Chicory. However, the synergistic effects of the levels and yeast addition were insignificant (p=0.4219) on acetate concentrations. Similar trends were witnessed in propionate (p=0.1849), butyrate (p=0.0851), and methane (p=0.4582) gas production. Yeast and chicory levels exerted their effects significantly (p<0.05) across the treatments and affected all the rumen parameters. Acetate to propionate ratio was only significant (p<0.05) on chicory levels. T1+ recoded the highest CH_4 (39.67 mmol/L) while T4- had the lowest (32.42 mmol/L).

.

Table 5. 1. The rumen fermentation parameters in the dairy goats fed on basal Rhodes grass hay supplemented with various levels of Chicory with and without yeast

Parameter	**Dietary composition**								**p-value**		
	T1		**T2**		**T3**		**T4**		Diet	**Yeast**	**Diet*Yeast**
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)			
pH	7.27^{a}	6.73^{b}	6.52^{c}	6.50^{c}	6.44^{c}	6.47^{c}	6.58^{bc}	6.50^{c}	<.0001	<.0001	<.0001
NH_3-N (mg/L)	85.36^{a}	82.62^{ab}	78.81^{bc}	77.50^{c}	75.24^{c}	65.83^{d}	62.98^{d}	56.07^{e}	<.0001	<.0001	0.0008
Acet (mmol/L)	58.37^{b}	53.83^{a}	47.67^{dc}	51.16^{bc}	43.66^{de}	46.78^{d}	35.66^{f}	41.46^{e}	<.0001	<.0001	0.4219
Prop (mmol/L)	53.83^{e}	58.37^{d}	51.18^{dc}	54.27^{c}	55.01^{c}	60.58^{b}	63.22^{ab}	65.92^{a}	<.0001	<.0001	0.1849
Buty (mmol/L)	38.60^{e}	44.72^{d}	49.51^{dc}	51.87^{bc}	55.99^{ab}	58.29^{a}	60.78^{a}	61.00^{a}	<.0001	0.0022	0.0851
Acet:Prop	1.32^{a}	1.23^{a}	0.93^{bc}	0.94^{b}	0.79^{bc}	0.77^{dc}	0.56^{e}	0.63^{dc}	<.0001	0.6654	0.1458
CH_4	36.0^{b}	39.67^{a}	35.79^{bc}	37.94^{ab}	36.07^{b}	37.39^{ab}	32.42^{c}	34.75^{bc}	0.0001	0.0003	0.4582

$^{a, b, c, d, e, f}$*means in the same row with different superscripts are significantly different at $p<0.05$)* NH_3-N= Ammonia nitrogen, Acet= Acetate, Prop=Propionate, Buty= Butyrate, Acet:Prop = Acetate : Propionate ratio, CH_4= Methane gas, with yeast (+), without yeast (-); T1-(Rhodes grass), T1+(Rhodes grass + yeast), T2-(10%Chicory), T2+(10%Chicory+Yeast), T3-(20%Chicory), T3+(20%Chicory+Yeast), T4-(30%Chicory), T4+(30%Chicory+Yeast)

5.4 Discussion

The efficient breakdown and absorption of feed by a ruminant animal depend significantly on the rumen microbiome, which profoundly affects its nutritional well-being. The microorganisms in the rumen of ruminants play a crucial role in fermenting more than 70% of the energy substrates that the animal consumes and absorbs (Xu *et al.*, 2021). Grass-fed ruminants typically maintain a pH range of 6 to 7, creating an ideal internal environment for anaerobic microbes to thrive and carry out fermentative processes (Zeitz *et al.*, 2016). This research observed that the pH levels across all dietary treatments remained within the optimal range of 6-7, except for the basal diet, which had a slightly higher pH of 7.27. These results support the findings of Jonova *et al.* (2021), who demonstrated that yeast increases sugar availability by stimulating the growth of lactate-utilizing bacteria (Megasphaera elsdenii) while also competing with the lactate-producing bacteria (Streptococcus bovis) for the available sugar.

This study found that incorporating Chicory had a significant effect in stabilizing pH. These findings are consistent with the research of Liu *et al.* (2012), who observed that Chicory influences fermentation patterns and microbial populations, which may act together with yeast to control rumen pH. Prebiotics such as Chicory have improved rumen fermentation metabolism and gastrointestinal tract health. The addition of Chicory in this study significantly aided in stabilizing pH levels, which may be attributed to the prebiotic qualities of Chicory's inulin. These results align with previous findings that demonstrated an increase in Bifidobacterium count and acetic acid levels, as well as a decrease in intestinal pH, following the addition of prebiotic inulin to pig feed (Tzortzis *et al.*, 2005). Similarly, another study reported a reduction in intestinal acidity in turkeys after being administered a 2% concentration of fructo-oligosaccharides (FOS) for eight weeks.

Based on research by Tripathi and Karim (2011), microbes can utilize ammonia nitrogen more effectively for growth in the presence of yeast. This is attributed to yeast's ability to enhance protein synthesis. Similarly, according to Mangwe (2020), Chicory's secondary metabolites, such as tannins, have the potential to impact rumen protein breakdown, thereby reducing ammonia levels positively. This combination can improve dietary nitrogen utilization and increase feed efficiency. The study revealed that supplementing animals' feed with yeast and increasing chicory levels significantly reduced NH_3-N levels.

Studies have indicated that Chicory can regulate the nitrogen metabolism in the rumen (Wang *et al.*, 2021). Additionally, research conducted by Ganai *et al.* (2015) and Amin and Mao (2021) revealed that yeast can enhance protein utilization and reduce the accumulation of ammonia in the rumen. The combination of yeast and Chicory can have a collaborative effect in enhancing nitrogen utilization in the rumen, leading to a decrease in NH_3-N concentration. The supplementation of Chicory may have increased the availability of microbial protein to the dairy goats in the study by providing more fermentable organic matter (FOM), which is crucial for the growth of rumen microbes.

The variations in acetate, propionate, and butyrate levels across different diets illustrate the impact of yeast and Chicory on the fermentation processes in the rumen. The higher concentration of acetate in T1 suggests that including yeast may enhance the breakdown of fiber and increase acetate production (Guedes *et al.,* 2008). The negative relationship between acetate levels and chicory levels is not unexpected, as the carbohydrate-rich supplement may have provided easily fermentable sugars, resulting in greater propionate production at the expense of acetate. Specifically, Chicory is known for its high fructosan (inulin) content, a storage polysaccharide that, much like starch, is readily fermentable in the rumen (Umucalilar *et al*., 2010). Moreover, a study by Liu *et al.* (2012) revealed that supplementing the diet of finishing beef steers with inulin improved their growth performance. This enhancement was likely due to changes in the fermentation pattern, particularly increased propionate production or the growth of beneficial bacteria in the rumen, which the dietary composition may influence.

The notable fluctuation in the acetate-to-propionate (A: P) ratio suggests that changes in the diet could be influencing alterations in the rumen fermentation pathways. The decrease in the A:P ratio seen with higher Chicory levels and yeast may be due to increased propionate levels at the acetate cost, indicating a potential shift towards more favorable fermentation and enhanced utilization of basic food. The disparities in methane production among the different treatments illustrate the influence of yeast and Chicory on rumen methanogenesis. According to Janssen (2010), yeast can alter microbial populations and suppress methanogenesis, reducing methane emissions. Despite this, the lack of significant interaction between Chicory and yeast suggests that their combined effect may not substantially impact methane synthesis under this study's specific experimental conditions. Though yeast and Chicory had noticeable effects on several rumen parameters, their combined influence appears to be additive rather than interactive. This finding underscores the importance of considering the effects of various ingredients when formulating diets for ruminant animals.

5.5 Conclusion

The results showed that yeast and Chicory levels significantly affected several parameters, including pH, ammonia nitrogen, acetate, propionate, butyrate, acetate to propionate ratio, and methane emissions. Yeast positively influenced pH, microbial protein production, and nitrogen utilization, while Chicory helped to stabilize pH and influenced the fermentation process. The research did not show a significant synergistic impact on methane emissions. However, adding yeast did reduce methane emissions. The combined effects of yeast and Chicory were additive rather than interactive, as anticipated, especially regarding methane emission. These findings underscore the importance of assessing dietary supplements' individual and combined influences on the rumen ecosystem and fermentation mechanisms. The collective impacts of yeast and Chicory on stabilizing pH, enhancing microbial protein synthesis, optimizing nitrogen utilization, and influencing fermentation patterns offer valuable insights for enhancing ruminant nutrition, potentially resulting in improved animal health, productivity, and environmental sustainability.

CHAPTER SIX

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 General discussion

The study's outcomes revealed that Chicory exhibited the highest crude protein (CP) content at 220.6 gKg^{-1} DM, aligning with the findings of Laws and Genever (2016). The combination of Chicory with Rhodes grass showcased an additive effect on crude protein levels, indicating its potential as a valuable protein source for dairy goats. Rhodes grass, with a CP content of 99 gKg^{-1} DM, demonstrated a slight increase compared to Ngunjiri (2020) reported value of 80 gKg^{-1} DM, attributed to variations in harvesting stages and geographical locations.

In the fibre analysis, Rhodes grass hay displayed the highest neutral detergent fibre (NDF) content at 732 gKg^{-1} DM, while Chicory exhibited the lowest NDF content at 291 gKg^{-1} DM. The variation in NDF levels is consistent with Ngunjiri (2020) findings, indicating that forage maturity increases cell wall content, consequently elevating NDF levels and reducing digestibility. Tanniniferous extractable tannins (TET) significantly decreased across T- to T4+, potentially due to yeast fermentation and increased CP levels, supporting the observations of Vlassa *et al.* (2022).

The *in-vitro* fermentation characteristics of Rhodes grass hay, supplemented with Chicory and yeast DM, demonstrated significant differences in gas production. Basal diets and Chicory with yeast combinations exhibited distinct gas production levels, implying increased undegradable rumen protein and improved nutrient utilization. The significant increase in dry matter intake (DMI) among goats fed with Chicory and yeast aligns with Murney *et al.* (2019) findings, attributing it to enhanced fibre digestion stimulated by yeast, corroborated by Elghandour *et al*. (2022).

The study revealed significant positive effects of yeast and Chicory supplementation on the growth performance and overall well-being of weaned dairy goats. The basal diet without yeast (T1-) exhibited a negative average daily gain (ADG) of -7.14g/day, while the addition of yeast (T1+) showed positive results with an ADG of 28.21 g/day. These findings align with Sawsan *et al.* (2012), who reported that specific yeast isolates with fibre-degrading properties could enhance fibre digestibility in forages like Rhodes grass, improving nutrient utilization by goats. Conte *et al*. (2018) further supported these results, demonstrating improved growth performance, higher final body weight, and increased average daily gain in response to yeast supplementation.

The study emphasized the role of enhanced nutrient intake in increasing weight gain efficiency in growing goats, evidenced by a high dry matter intake (DMI) of 591.70 g/day and a resulting high ADG of 154.64 g/day. Pradhan *et al*. (2018) corroborated these findings by reporting that supplementing goat kids with active dried yeast (*S. cerevisiae* CNCM I-1077) at a rate of 2% of dry matter intake led to enhanced growth, improved feed conversion efficiency, and reduced feeding costs. The study highlighted the potential contribution of Chicory to gut health, coupled with the positive influence of yeast on digestion, as factors contributing to overall growth performance. Attia *et al*. (2017) and Shurson (2018) supported these observations, suggesting synergistic effects of Chicory and yeast on feed intake, nutrient digestibility, and gut health. The prebiotic characteristics of Chicory and the probiotic impacts of yeast were proposed to establish a harmonious and salubrious microbial environment within the goat's gastrointestinal tract, leading to better nutrient utilization and stimulated development in growing goats.

The study emphasized the pivotal role of the rumen microbiome in influencing nutrient status. Rumen pH, crucial for fermentative activity, remained within the optimal range (6-7), except for the basal diet, which had a slightly higher pH of 7.27. This aligns with Jonova *et al.* (2021) findings, suggesting that yeast promotes lactate-utilizing bacteria growth, reducing lactate accumulation and stabilizing rumen pH. These findings are consistent with previous studies by Tzortzis *et al.* (2005) that found an increase in Bifidobacterium count and acetic acid levels, and a decrease in intestinal pH, following the addition of prebiotic inulin to pig feed. Additionally, including 2% fructo-oligosaccharides (FOS) to turkeys for eight weeks reduced intestinal acidity.

Yeast supplementation positively influenced microbial protein synthesis, as observed by decreased rumen ammonia nitrogen (NH_3-N) levels. With secondary metabolites like tannins, Chicory potentially impacted protein breakdown, complementing yeast's effects. The combined influence of yeast and Chicory appeared to synergistically regulate nitrogen metabolism synergistically, supporting Samanta *et al*. (2013) and Wang *et al*. (2021) findings.

The acetate, propionate, and butyrate fermentation patterns were influenced by yeast and Chicory, leading to changes in rumen fermentation pathways. Elevated acetate concentration in T1- suggested improved fibre breakdown, while the inverse correlation between acetate and Chicory levels hinted at increased propionate production from Chicory's fermentable sugars. The acetate-to-propionate (A: P) ratio variations indicated potential shifts in fermentation pathways, potentially enhancing energy use and microbial protein synthesis, in line with Dias *et al*.(2018) observations.

Notably, yeast significantly reduced methane emissions, which is consistent with previous studies by Janssen (2010) and Gong *et al*. (2013). However, the interactive effect of yeast and Chicory on methane generation was not significant in this study, emphasizing the need to consider various components in diet formulation for ruminant animals. Concisely, the study provides comprehensive insights into the impact of Chicory and yeast supplementation on weaned dairy goats' nutritional and physiological aspects. Chicory emerges as a promising protein source, and the additive effects with yeast offer potential benefits for nutrient accessibility, improved fermentation, and reduced methane emissions. These findings contribute to formulating diets that enhance protein content, improve nutrient utilization, and promote optimal rumen conditions, aligning with sustainable and efficient livestock management practices.

6.2 Conclusions

i. Rhodes grass hay supplemented with 30% Chicory and yeast has the highest crude protein content, superior ash profile and highest gas degradability.
ii. The optimal concentration of Chicory for promoting the growth of dairy goats is 30% when supplemented with 10g/goat/day of yeast.
iii. The results showed that yeast and Chicory levels significantly affected several parameters, including pH, ammonia nitrogen, acetate, propionate, butyrate, acetate to propionate ratio, and methane emissions. There were no significant synergistic impact on methane emissions. However, adding yeast reduced methane emissions.

6.3 Recommendations

i. Rhodes grass hay supplemented with 30% Chicory has excellent potential as a feed and should be utilized in dairy goat’s production.
ii. Chicory at 30% inclusion level and yeast at 10g/goat per day should be used for low-quality forages to enhance growth performance.
iii. Yeast and Chicory levels significantly affected several rumen parameters. Therefore, they should be included in the animal diet particularly those subsisting on low quality forage

6.4 Areas for further research

i. Further investigation is needed to explore the possible long-term effects and economic feasibility of adding Chicory and yeast to the diet of lactating dairy goats.

ii. More studies on the impact on milk quality (fat, protein, lactose) and quantity in dairy goats consuming the chicory and yeast mixture.

iii. Studies to assess the economic feasibility of incorporating chicory and yeast into the diet, taking into account the cost of these ingredients versus potential benefits should be carried out.

REFERENCES

Agbabiaka, A. (2019). *Five Best Pasture Crops Combination for Cattle, Goat and Sheep*. https://justagric.com/5-best-pasture-crops-combination-for-feeding-cattle-goat-and-sheep/.

Alade, N. K., Mbap, S. T., & Aliyu, J. (2008). Genetic and environmental factors affecting growth traits of goats in semi-arid areas of Nigeria. *Global Journal of Agricultural Science*, *7*(1), 85–91. https://doi.org/10.4314/gjass.v7i1.2365

Alugongo, G. M., Xiao, J. X., Chung, Y. H., Dong, S. Z., Li, S. L., Yoon, I., & Cao, Z. J. (2017). Effects of *Saccharomyces cerevisiae* fermentation products on dairy calves: Performance and health. *Journal of Dairy Science*, *100*(2), 1189–1199. https://doi.org/10.3168/jds.2016-11503

Amin, A. B., & Mao, S. (2021). Influence of yeast on rumen fermentation, growth performance and quality of products in ruminants: A review. *Animal nutrition*, *7*(1), 31-41.

Anya, M. I., Ayuk, A. A., Usung, P. O., NSA, E. E. & Edet, G. D. (2011). Compensatory growth in growing West Africa in Dwarf kids in the humid zone of Nigeria. *International Journal of Plant, Animal and Environmental Sciences*, *1*, 253-260.

AOAC, (1990). *Official Method of Analysis of the Association of Official Analytical Chemists (AOAC).* (15th Edition), AOAC, Washington DC, USA.

AOAC, (2005). *Official Method of Analysis of the Association of Official Analytical Chemists (AOAC).* No. 934.06, (15th Edition), AOAC, Washington DC, USA.

Armato, L., Gianesella, M., Morgante, M., Fiore, E., Rizzo, M., Giudice, E., & Piccione, G. (2016). Rumen volatile fatty acids× dietary supplementation with live yeast and yeast cell wall in feedlot beef cattle. *Acta Agriculturae Scandinavica, Section A—Animal Science*, *66*(2), 119-124.

Axe, J. (2018). *Goat Milk Benefits are Superior to Cow Milk*. Rachael Link, MS, RD https://draxe.com/nutrition/goat-milk/ . Accessed on November 5, 2022.

Ayichew, T., Belete, A., Alebachew, T., Tsehaye, H., Berhanu, H., & Minwuyelet, A. (2017). Bacterial probiotics their importance and limitations: a review. *Journal of Nutritional Health Sciences*, *4*(2), 202. https://doi.org/10.15744/2393-9060.4.202

Bakhashwain, A. A. (2010). Fodder yield and quality of Rhodes grass-Alfalfa mixtures as affected by sowing rates in Makkah region. *Journal of King Abdulaziz University-Meteorology, Environment and Arid Land Agriculture Sciences,* 21(1), 19–33. https://doi.org/10.4197/Met.21-1.2

Bernardine, M. (2011). *Kenya: Upgraded Goats Rake in Earnings. Prolasur Corporation*. Daily nation on the web. Accessed on July 15, 2022

Birch, I. (2018). *Agricultural Productivity in Kenya: Barriers and Opportunities*. K4D Helpdesk Report. Institute of Development Studies, Brighton, UK:

Birmani MW, Nawab A, Ghani MW et al (2019). A review: role of inulin in animal nutrition. *Journal of Food Technology*. *Research 6*,18–27.https://doi.org/10.18488/journal.58.2019.61.18.27

Bizna, R. (2018). *Types of breeds for profitable dairy goat farming in Kenya*. https://biznakenya.com/dairygoat-farming-in-kenya/.

Chaucheyras-Durand, F., & Durand, H. (2010). Probiotics in animal nutrition and health. *Beneficial Microbes, 1*(1), 3-9.

Chung, Y. H., Walker, N. D., McGinn, S. M., & Beauchemin, K. A. (2011). Differing effects of 2 active dried yeast (*Saccharomyces cerevisiae*) strains on ruminal acidosis and methane production in non-lactating dairy cows. *Journal of Dairy Science*, *94*(5), 2431-2439. https://doi.org/10.3168/jds.2010-3711

Conte, G., Ciampolini, R., Cassandro, M., Lasagna, E., Calamari, L., Bernabucci, U., & Abeni, F. (2018). Feeding and nutrition management of heat-stressed dairy ruminants. *Italian Journal of Animal Science*, *17*(3), 604-620. https://doi.org/10.1080/1828051X.2017.1404944

Deribe, B., & Taye, M. (2013). Evaluation of growth performance of Abergele goats under traditional management system in Sekota District, Ethiopia. *Pakistan Journal of Biological Sciences*, *16*, 692–696. https://doi.org/10.3923/pjbs.2013.692.696

Di Grigoli, A., Todaro, M., Di Miceli, G., Genna, V., Tornambè, G., Alicata, M. L., & Bonanno, A. (2012). Effects of continuous and rotational grazing of different forage species on ewe milk production. *Small Ruminant Research*, *106*, S29-S36.

Dias, A. L. G., Freitas, J. A., Micai, B., Azevedo, R. A., Greco, L. F., & Santos, J. E. P. (2018). Effect of supplemental yeast culture and dietary starch content on rumen fermentation and digestion in dairy cows. *Journal of Dairy Science*, *101*(1), 201-221. https://doi.org/10.3168/jds.2017-13493

Edward group. (2018). *Is Goat Milk Better Than Cow Milk? Here is a list of Health Benefits.* www.globalhealingcenter.com/natural-health/goat-milk-benefits/ . Updated on March 7, 2018.

Elghandour, M. M., Abu Hafsa, S. H., Cone, J. W., Salem, A. Z., Anele, U. Y., & Alcala-Canto, Y. (2022). Prospect of yeast probiotic inclusion enhances livestock feeds utilization and performance: An overview. *Biomass Conversion and Biorefinery*, *12*(5), 1-13. https://doi.org/10.1007/s13399-022-02770-1

Esmail, SH (2018). *Water requirements of livestock: 7 factors to consider*. Https://www.allaboutfeed.net/compound-Feed/Articles/2018/6/water-requirements-livestock-7-factors-to-consider-300895E/ .

FAO. (2010). *A dairy goat production handbook for farmers.* Food and Agriculture Organization of the United Nations, Rome, Italy, pp.5–8.

FarmersTrend. (2016). *Success story of Shamba Dairies in Murang'a*. https://farmerstrend.co.ke/ .

Flores-Najera, M. J., Vélez-Monroy, L. I., Sánchez-Duarte, J. I., Cuevas-Reyes, V., Mellado, M., & Rosales-Nieto, C. A. (2020). Milk yield and composition and body weight of offsprings of mixed-breed goats on semi-arid rangelands with different rainfall. *Tropical Animal Health and Production*, *52*, 3799-3808.

Ganai, A. M., Sharma, T., & Dhuria, R. K. (2015). Effect of yeast (*Saccharomyces cerevisiae*) supplementation on ruminal digestion of Bajra (*Pennisetum glaucum*) straw and Bajra straw-based complete feed *in vitro*. *Animal Nutrition and Feed Technology*, *15*(1), 145–153.

Gasparotto, S. (2015). *Minerals and vitamins in goats: Deficiencies and toxicity*. Tennessee Meat Goats. http://www.tennesseemeatgoats.com/articles2/vitaminmineral06.html

Getachew, G., Crovetto, G. M., Fondevila, M., Krishnamoorthy, U., Singh, B., Spanghero, M., ... & Kailas, M. M. (2002). Laboratory variation of 24 h in vitro gas production and estimated metabolizable energy values of ruminant feeds. *Animal Feed Science and Technology*, *102*(1-4), 169–180.

Getaneh, G., Mebrah, A., Wubie, A., & Kendie, H. (2016). Review on goat milk composition and its nutritive value. *Journal of Nutrition Health Sciences*, *3*(4), 401. https://doi.org/10.15744/2393-9060.3.401

Gibson, G. R., Scott, K. P., Rastall, R. A., Tuohy, K. M., Hotchkiss, A., Dubert-Ferrandon, A., ... & Buddington, R. (2010). Dietary prebiotics: current status and new definition. *Food Science and Technology Bulletin: Functional Foods*, *7*(1), 1–19.

Gitau, K. J. (2013). *Factors influencing milk production among small scale dairy farmers in Mirangine in Nyandarua county and Mauche in Nakuru county* (PhD thesis, University of Nairobi, Kenya).

GoK, (2013). *The National Dairy Development Policy. Sessional Paper No. 5 of 2013*. The Government of Kenya,Ministry of Agriculture, Livestock and Fisheries.

Gong, Y. L., Liao, X. D., Liang, J. B., Jahromi, M. F., Wang, H., Cao, Z., & Wu, Y. B. (2013). *Saccharomyces cerevisiae* live cells decreased *in vitro* methane production in intestinal content of pigs. *Asian-Australasian Journal of Animal Sciences*, *26*(6), 856. https://doi.org/10.5713/ajas.2013.13107

Gore, D. L. (2021). *Reproductive performance and genetic response to selection of dairy goats in Kenya following incorporation of reproductive technologies and genomic selection* (PhD thesis, Egerton University, Kenya).

Guedes, C. M., Gonçalves, D., Rodrigues, M. A. M., & Dias-da-Silva, A. (2008). Effects of a *Saccharomyces cerevisiae* yeast on ruminal fermentation and fibre degradation of maize silages in cows. *Animal Feed Science and Technology*, *145*(1-4), 27-40.

Günay, E., Güneşer, O., & Karagül Yüceer, Y. (2021). A comparative study of amino acid, mineral and vitamin profiles of milk from Turkish Saanen, Hair and Maltese goat breeds throughout lactation. *International Journal of Dairy Technology*, *74*(3), 441-452.

Haenlein, G. F. W. (2004). Goat milk in human nutrition. *Small Ruminant Research*, *51*(2), 155-163. *https://justagric.com/nutritional-requirements-for-cattle-goat-and-sheep/* .

Henderson, G., Cox, F., Ganesh, S., Jonker, A., Young, W., & Janssen, P. H. (2015). Rumen microbial community composition varies with diet and host, but a core microbiome is found across a wide geographical range. *Scientific Reports, 5, 14567.*

Janssen, P. H. (2010). Influence of hydrogen on rumen methane formation and fermentation balances through microbial growth kinetics and fermentation thermodynamics. *Animal Feed Science and Technology*, *160*(1-2), 1-22.

Jonova, S., Ilgaza, A., & Zolovs, M. (2021). The impact of inulin and a novel synbiotic (yeast *Saccharomyces cerevisiae* strain 1026 and inulin) on the development and functional state of the gastrointestinal canal of calves. *Veterinary Medicine International*, *2021*.

Kashongwe, B. O. (2013). *Effect of adding yeast culture to urea-treated and supplemented wheat straw diets on nutritive value and animal performance* (MSc thesis, Egerton University).

Kechagia, M., Basoulis, D., Konstantopoulou, S., Dimitriadi, D., Gyftopoulou, K., Skarmoutsou, N., & Fakiri, E. M. (2013). Health benefits of probiotics: A review. *International Scholarly Research Notices*, *2013*, Article ID 481651. https://doi.org/10.1155/2013/481651

Kenana, R. (2022). *Performance of Red Maasai sheep fed on Brachiaria and Rhodes grass hay supplemented with Calliandra leaves* (MSc thesis, Egerton University, Kenya).

Ki, K. S., Lim, Y. S., Jim, Z. L., Lee, H. J., Kim, S. B., Lee, W. S., Yang, S. H., Cho., W. M., Kim, H. S. & Jeo, J. M. (2009). Effect of crude protein and total digestible nutrients levels on intake, digestibility, nitrogen, and energy utilisation of growing dairy goats. *Journal Korean Grassland Forage Science*, 29, 269–276.

Lamidi, A. A., & Ologbose, F. I. (2014). A threat to sustainable ruminant animal production in Nigeria. *Journal of Agriculture and Social Research, 4*(1). https://doi.org/10.4314/jasr.v4i1.5

Laws, D., & Genever, L. (2016). *Using Chicory and plantain in beef and sheep systems*. AHDB Beef & Lamb Stoneleigh Park, Kenilworth, UK.

Lepczyński, A., Herosimczyk, A., Barszcz, M., Ożgo, M., Michałek, K., Grabowska, M., &Skomiał, J. (2021). Diet supplemented either with dried chicory root or chicory inulin significantly influence kidney and liver mineral content and antioxidative capacity in growing pigs. *Animal*, *15*(2), 100129. https://doi.org/10.1017/S1751731120002488

Liu, H., Ivarsson, E., Dicksved, J., Lundh, T., & Lindberg, J. E. (2012). Inclusion of Chicory (*Cichorium intybus* L.) in pigs' diets affects the intestinal microenvironment and the gut microbiota. *Applied and Environmental Microbiology*, *78*(12), 4102-4109.

Luginbuhl, J.-M. (2006). Pastures for meat goats. In T. A. Gipson, R. C. Merkel, K. Williams, & T. Sahlu (Eds.), *Meat goat production handbook*. Langston University. ISBN 1-880667-04-5.

Luo, J., & Shuang, S. (2018, October). Research progress on reproductive physiology and breeding technology of dairy goats. In *Proceedings of the 4th International Asian-Australasian Dairy Goat Conference* (pp. 62-71).

Mahmoud, Y. M. (2021). Effect of Supplementation of Dried Chicory (*Cichorium Intybus* L.) Leaves in Diets on Performance of Dairy Goats. *Egyptian Journal of Nutrition and Feeds*, *24*(1), 1-11. https://doi.org/10.21608/ejnf.2021.170297

Malik, J. K., Prakash, A., Srivastava, A. K., & Gupta, R. C. (2019). Synbiotics in animal health and production. In: *Nutraceuticals in Veterinary Medicine* (pp. 287-301). Springer, Cham.

Malmuthuge, N., & Guan, L. L. (2016). Gut microbiome and omics: a new definition to ruminant production and health. *Animal Frontiers, 6*(2), 8–12. https://doi.org/10.2527/af.2016-0024

Mangwe, M. C. (2020). *Strategic management of chicory (Cichorium intybus L.) for improved milk quality and nitrogen utilization in dairy farm systems* (PhD thesis, Lincoln University, USA).

Marete, A. G., Jung'a, J. O. & Mosi, R. O. (2011). *An analysis of breeding levels and factors affecting growth and reproduction traits in the Kenya Alpine dairy goats*. https://profiles.uonbi.ac.ke/joseghjung'a/publication/ . Accessed on February 29, 2020.

Markowiak, P., &Śliżewska, K. (2018). The role of probiotics, prebiotics and synbiotics in animal nutrition. *Gut Pathogens*, *10*(1), 1-20.

Masanetz, S., Wimmer, N., Plitzner, C., Limbeck, E., Preißinger, W., & Pfaffl, M. W. (2010). Effects of inulin and lactulose on the intestinal morphology of calves. *Animal*, *4*(5), 739-744.

Mathew, N., & Kalyanasundaram, M. (2001). A high performance liquid chromatographic method for the estimation of diethylcarbamazine content in medicated salt samples. *Acta Tropica*, *80*(2), 97-102.

Matovu, M. (2016). *Feed and feed supply characterization on peri-urban smallholder dairy farms with improved breeds in the Tigray region, Northern Ethiopia* (PhD thesis, Katholieke Universiteit Leuven, Belgium).

Mbinyo, C. M., Gitao, G., & Peter, S. G. (2017). Constraints affecting dairy goats milk production in Kenya. *Tropical Animal Health and Production*, *50*, 1-10. https://doi.org/10.1007/s11250-017-1310-1

Mbuku, S. M., Okeyo, A. M., Kosgey, I. S., & Kahi, A. K. (2015). Optimum cross-breeding systems for goats in low input livestock production systems in Kenya. *Small Ruminant Research*, *123*, 55-61. https://doi.org/10.1016/j.smallrumres.2014.10.001

Mburu, M., Muyendi, B., Makhoha, A., & Muhohi, S. (2014). Factors affecting Kenya Alpine dairy goat milk production in Nyeri region. *Journal of Food Research*, *3*, 160-167. https://doi.org/10.5539/jfr.v3n6p160

Mdukatshani, (2015). *Goat Production Handbook*. Department of Agriculture and Rural Development Heifer international Africa and Kwazulu- Natal. https://d1lds9cvq82c7x.cloudfront.netcontent/uploads/2017/10/Goat-production-handbook.pdf.

Menke, K. H., & Steingass, H. (1988). Estimation of energetic feed value from feed obtained from chemical analysis and in vitro gas production using rumen fluid. *Animal Research and Development*, *28*, 7-55.

Migwi, P. K., Bebe, B. O., Gachuiri, C. K., Godwin, I., & Nolan, J. V. (2013). Options for efficient utilization of high-fiber feed resources in low-input ruminant production systems in a changing climate: A review. *Livestock Research for Rural Development*, *25*, Article No. 87.

Miller, B. A., & Lu, C. D. (2019). Current status of global dairy goat production: An overview. *Asian-Australasian Journal of Animal Sciences*, *32*(8), 1219. https://doi.org/10.5713/ajas.19.0465

Minneé, E. M. K., Waghorn, G. C., Lee, J. M., & Clark, C. E. F. (2017). Including Chicory or plantain in a perennial ryegrass/white clover-based diet of dairy cattle in late lactation: Feed intake, milk production, and rumen digestion. *Animal Feed Science and Technology*, *227*, 52-61.

Ministry of Agriculture, Livestock and Fisheries (MoALF). (2018). *Annual report 2018*. State Department of Livestock Production.

Moss, A., Jouany, J. P., & Newbold, J. (2000). Methane production by ruminants: Its contribution to global warming. In *Annales de Zootechnie* (Vol. 49, No. 3, pp. 231-253). https://doi.org/10.1051/animres:2000119

Muia, J. M. K., Kariuki, J. M., Mbugua, P. N., Gachuiri, C. K., Lukibisi, L. B., Ayako, W. O., & Ngunjiri, V. W. (2011). Smallholder dairy production in high altitude Nyandarua milk-shed in Kenya: Status, challenges and opportunities. *Livestock Research for Rural Development*, *23*, Article 108. http://www.lrrd.org/lrrd23/5/muia23108.htm

Mulwa, R. & Kabubo-Mariara, J., 2022. Rural households' income diversification, climate change, and food security in Kenya. In M. Kassie & M. Jaleta, eds. *Handbook of Behavioural Economics and Climate Change*. Cheltenham: Edward Elgar Publishing, pp. 226-240.

Murney, R., Burggraaf, V., Mapp, N., Ganche, E., & King, W. (2019). The effect of cultivated mixed-species green fodder on intake, milk production, and milk composition of housed dairy goats. *Animal*, *13*(12), 2802-2810.

Murphy, S.R., Lodge, G.M. & Brennan, M.A. (2010). Tropical grasses capture winter rainfall. In: *The Proceedings of the 25th Annual Conference of the Grassland Society of NSW. Eds C Waters, D Garden*. NSW Grassland Society Inc., Orange. pp. 137–140

Musyoki, M. (2017). Kenyan National Bureau of Statistics Study Reveals Counties with Lowest Poverty Rates. www.kenyans.co.ke. Accessed on 23rd August 2022.

Ngunjiri, V. W. (2020). *Evaluation of Performance of Growing Dairy Goats Fed Rhodes Grass Hay, supplemented with Dried Calliandra Leaves and Common Vetch Hay* (MSc Thesis, Egerton University, Kenya).

Niderkorn, V., Martin, C., Bernard, M., Le Morvan, A., Rochette, Y., & Baumont, R. (2019). Effect of increasing the proportion of Chicory in forage-based diets on intake and digestion by sheep. *Animal*, *13*(4), 718-726.

Nirajan, B., Neema, A.G., Manaraj, K.A. & Soroj, S. (2019). *Breeds and Breeding Systems of Indigenous and Cross-Bred Goats in Nepa*l. https://www.intechopen.com/online-first/breeds.

National Research Council (NRC). (2001). *Nutrient requirements of dairy cattle* (7th ed.). National Academies Press.

National Research Council (NRC). (2007). *Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids* (3rd ed.). National Academies Press.

Nwafor, I. C., Shale, K., & Achilonu, M. C. (2017). Chemical composition and nutritive benefits of chicory (Cichorium intybus) as an ideal complementary and/or alternative livestock feed supplement. *The Scientific World Journal*, 2017. https://doi.org/10.1155/2017/2571865

Nziku, Z. C. (2022). Essentials for sustainable dairy goat breeding program in Tanzania.

Ocak, N., Kop Oozbay, C. & Akdaĝ., A. (2018). *Voluntary Feed Intake, Grazing Behavior and Plant Preferences of Ruminants.* www.researchgate.net>publication>329268569_voluntary-feed-intake.

Ogbuewu, I. P., & Mbajiorgu, C. A. (2022). Meta-analytic effect of Saccharomyces cerevisiae on dry matter intake, milk yield, and components of lactating goats. *Frontiers in Veterinary Science*, *9*, 1014977.

Ørskov, E. R. & McDonald, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighed according to rate of passage. *Journal of Agricultural Sciences*, *92*, 499-503. https://doi.org/10.1017/S0021859600063048

Osuga, I. M., Abdulrazak, S. A., Muleke, C. I., &Fujihara, T. (2012). Effect of supplementing Rhodes grass hay (*Chloris gayana*) with *Berchemiadiscolor* or *Zizyphusmucronata* on the performance of growing goats in Kenya. *Journal of Animal Physiology and Animal Nutrition*, *96*(4), 634-639. https://doi.org/10.1111/j.1439-0396.2011.01164.x

Pakistan, J. Z. (2013). Feeding behaviour, voluntary intake and digestibility of various summer fodders in sheep and goats. *Pakistan Journal of Zoology*, *45*, 53–58.

Pakpahan, S., & Furqon, A. (2023). Crossbreed or Purebred, Which Is Better?. In *Goat Science-From Keeping to Precision Production*. IntechOpen.https://doi.org/10.5772/intechopen.111153

Patel, S., & Goyal, A. (2012). The current trends and future perspectives of prebiotics research: A review. *3 Biotechnology*, *2*, 115–125. https://doi.org/10.1007/s13205-011-0037-5

Pedreira, C.G.S, Braga, G.J & Portela, J. (2017). Herbage accumulation, plant-part composition, and nutritive value on grazed signal grass *(Brachiaria decumbens)* pastures in response to stubble height and rest period based on canopy light interception. *Crop and Pasture Science*, *68*(1), 62–73. https://doi.org/DOI 10.1071/CP16333

Perović, J., Šaponjac, V. T., Kojić, J., Krulj, J., Moreno, D. A., García-Viguera, C., & Ilić, N. (2021). Chicory (*Cichorium intybus L.*) as a food ingredient–Nutritional composition, bioactivity, safety, and health claims: A review. *Food Chemistry*, *336*, 127676.

Petkova, N., M. Ognyanov, M. Todorova and P. Denev, 2015. Ultrasound-assisted extraction and characterisation of inulin-type fructan from roots of elecampane (*Inula helenium* L.). *Acta Scientifica Naturalis*, *1*(1): 225-235.

Poursakhi, N., Razmjoo, J., & Karimmojeni, H. (2020). Nutritional qualities, chemical compositions, and yield of chicory genotypes. *Agronomy Journal*, *112*(1), 344-351.

Pradhan, S. K., Choubey, M., Patel, V. R., Kharadi, V. B., & Dabas, V. S. (2018). Effect of dietary supplementation of yeast on growth, feed conversion efficiency and cost of feeding in Surti goat kids *International Journal of Current Microbiology and Applied Sciences, 7*(9), 2032-2035.

Rahimi, J., Fillol, E., Mutua, J. Y., Cinardi, G., Robinson, T. P., Notenbaert, A. M., & Butterbach-Bahl, K. (2022). A shift from cattle to camel and goat farming can sustain milk production with lower inputs and emissions in north sub-Saharan Africa's drylands. *Nature Food*, *3*(1), 1-9. https://doi.org/10.1038/s43016-022-00537-9

Rebolé, A., Ortiz, L. T., Rodríguez, M., Alzueta, C., Treviño, J., & Velasco, S. (2010). Effects of inulin and enzyme complex, individually or in combination, on growth performance, intestinal microflora, cecal fermentation characteristics, and jejunal histomorphology in broiler chickens fed a wheat-and barley-based diet. *Poultry Science*, *89*(2), 276-286.

Reddy, J. (2017). *Goat farming: Goat feeding management information*. Goat Farming. https://www.goatfarming.in/goat-feed-information

Reddy, J. (2018). Goat farming in Kenya information. *Goat Farming*. https://www.goatfarming.in/goat-farming-in-kenyainformation

Roodposhti, P. M., & Dabiri, N. (2012). Effects of probiotic and prebiotic on average daily gain, fecal shedding of *Escherichia coli,* and immune system status in newborn female calves. *Asian-Australasian Journal of Animal Sciences*, *25*(9), 1255. https://doi.org/10.5713/ajas.2012.12010

Safaa, A., Abdalla, Ibrahi, A. & Mohamend-Kchair, A. (2015). Genetic and environmental factors affecting reproduction of Saanen goats raised under Sudan conditions. *American Journal of Agricultural Science, 2,* 75-79. https://doi.org/10.12691/ajas-2-5-3

Salah, N., Sauvant, D., & Archimède, H. (2014). Nutritional requirements of sheep, goats and cattle in warm climates: a meta-analysis. *Animal*, *8*(9), 1439-1447.Salem, A. Z., Adegbeye, M. J., Elghandour, M. M., Ponce-Covarrubias, J. L., Martinez, A. G., Ruiz, P. E., & Tirado-González, D. N. (2023). Yeast as a source of exogenous enzymes in ruminant feeding. *Exogenous Enzymes as Feed Additives in Ruminants*, 1-27. https://doi.org/10.1007/978-3-031-27993-5_1

Samal, L., & Behura, N. C. (2015). Prebiotics: an emerging nutritional approach for improving gut health of livestock and poultry. *Asian Journal of Animal and Veterinary Advances*, *10*(11), 724-739. https://doi.org/10.3923/ajava.2015.724.739

Samanta, A. K., Jayapal, N., Senani, S., Kolte, A. P., & Sridhar, M. (2013). Prebiotic inulin: Useful dietary adjuncts to manipulate the livestock gut microflora. *Brazilian Journal of Microbiology*, *44*, 1-14. https://doi.org/10.1590/S1517-83822013000100001

SAS. (2002). Statistical Analysis System. *SAS Institute Inc.-Users Installation Guide*. Statistical Analysis Institute, Inc., Cary, NC. USA.

Sawsan, M., Tawila, M. A., Abou Ward, G. A., Salama, R., & El-Naggar, S. (2012). Determine the proper level of yeast with different levels of roughages to improve the nutritive value of lamb's ration. *Life Science. Journal*, *9*(3), 1773-1780.

Shehata, A. A., Yalçın, S., Latorre, J. D., Basiouni, S., Attia, Y. A., Abd El-Wahab, A., ... & Tellez-Isaias, G. (2022). Probiotics, prebiotics, and phytogenic substances for optimizing gut health in poultry. *Microorganisms*, *10*(2), 395 https://doi.org/10.3390/microorganisms10020395

Shurson, G. C. (2018). Yeast and yeast derivatives in feed additives and ingredients: Sources, characteristics, animal responses, and quantification methods. *Animal Feed Science and Technology, 235,* 60-76.

Soliman, S. M., El-Shinnawy, A. M., & El-Morsy, A. M. (2016). Effect of Probiotic or Prebiotic Supplementation on the Productive Performance of Barki Lambs. *Journal of Animal and Poultry Production*, *7*(10), 369-346.

Spencer, R. (2021).*Nutrient Requirements of Sheep and Goats*. Alabama Cooperative Extension System. Retrieved November 10, 2022, from https://www.aces.edu/blog/topics/livestock/nutrient-requirements-of-sheep-and-goats /.

Tanmay, R. (2014). *What to feed goats. Successful farming*. https//www.agriculture.com/livestock/what-to feed-goats-275_ar41207.

Temu, V.W., Rude, B.J. & Baldwin, B.S. (2014). Nutritive value response of native warm-season forage grasses to harvest intervals and durations in mixed stands. *Plants*, 3, 266–283. https://doi.org/10.3390/plants3020266

Thobile, F. M., Olivia, N. M., Keabetswe, T. N., Edgar, F. D., Tlou, C. M., Farai, C. M., & Khanyisile, H. (2021). Goat farmers' production objectives and trait preferences in the North West province of South Africa: An approach to identify selection criteria for a community-based breeding program. *International Journal of Livestock Production*, *12*(2), 64–75.

Tripathi, M. K., & Karim, S. A. (2011). Effect of yeast cultures supplementation on live weight change, rumen fermentation, ciliate protozoa population, microbial hydrolytic enzymes status and slaughtering performance of growing lamb. *Livestock Science*, *135*(1), 17-25. https://doi.org/10.1016/j.livsci.2010.06.007

Tzortzis, G., Goulas, A. K., Gee, J. M., & Gibson, G. R. (2005). A novel galacto-oligosaccharide mixture increases the bifidobacterial population numbers in a continuous in vitro fermentation system and in the proximal colonic contents of pigs in vivo. *The Journal of Nutrition*, *135*(7), 1726-1731. https://doi.org/10.1093/jn/135.7.1726

Umucalilar, H. D., Gulsen, N., Hayirli, A., & Alatas, M. S. (2010). Potential role of inulin in rumen fermentation. *Revue de Medecine Veterinaire*, *161*(1), 3-9.

Uyeno, Y., Shigemori, S., & Shimosato, T. (2015). Effect of probiotics/prebiotics on cattle health and productivity. *Microbes and Environments*, *30*(2), 126-132. https://doi.org/10.1264/jsme2.ME15030

Van Soest, P. J. (1994). *Nutritional Ecology of the Ruminant* (2nd ed.). Cornell University Press, New York.

Van Soest, P. V., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fibre, neutral detergent fibre, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Vandeputte, D., Falony, G., Vieira-Silva, S., Tito, R. Y., Joossens, M., Raes, J. (2017). Stool consistency is strongly associated with gut microbiota richness and composition, enterotypes, and bacterial growth rates. *Gut, 65*(1), 57-62. https://doi.org/10.1136/gutjnl-2015-310769

Vandermeulen, S., Singh, S., Ramírez-Restrepo, C. A., Kinley, R. D., Gardiner, C. P., Holtum, J. A., & Bindelle, J. (2018). *In vitro* assessment of ruminal fermentation, digestibility, and methane production of three species of Desmanthus for application in northern

Australian grazing systems. *Crop and Pasture Science*, *69*(8), 797-807. https://doi.org/10.1071/CP17131

Vlassa, M., Filip, M., Țăranu, I., Marin, D., Untea, A. E., Ropotă, M., & Sărăcilă, M. (2022). The yeast fermentation effect on content of bioactive, nutritional and anti-nutritional factors in rapeseed meal. *Foods*, *11*(19), 2972. https://doi.org/10.3390/foods11192972

Vohra, A., Syal, P., & Madan, A. (2016). Probiotic yeasts in livestock sector. *Animal Feed Science and Technology*, *219*, 31-47.

Wang, Y., Nan, X., Zhao, Y., Jiang, L., Wang, H., Hua, D., & Xiong, B. (2021). Dietary supplementation with inulin improves lactation performance and serum lipids by regulating dairy cows' rumen microbiome and metabolome. *Animal Nutrition*, *7*(4), 1189-1204. https://doi.org/10.1016/j.aninu.2021.03.004

Xiao, J. X., Alugongo, G. M., Chung, R., Dong, S. Z., Li, S. L., Yoon, I., & Cao, Z. J. (2016). Effects of *Saccharomyces cerevisiae* fermentation products on dairy calves: Ruminal fermentation, gastrointestinal morphology, and microbial community. *Journal of Dairy Science*, *99*(7), 5401-5412. https://doi.org/10.3168/jds.2016-11170

Xu, Q., Qiao, Q., Gao, Y., Hou, J., Hu, M., Du, Y., & Li, X. (2021). Gut microbiota and their role in health and metabolic disease of dairy cow. *Frontiers in Nutrition*, *8*, 701511. https://doi.org/10.3389/fnut.2021.701511

Zeitz, J. O., Ineichen, S., Soliva, C. R., Leiber, F., Tschuor, A., Braun, U., & Clauss, M. (2016). Variability in microbial population and fermentation traits at various sites within the forestomach and along the digestive tract as assessed in goats fed either grass or browse. *Small Ruminant Research*, *136*, 7-17. https://doi.org/10.1016/j.smallrumres.2016.01.001

Zhou, M., Hünerberg, M., Chen, Y., Reuter, T., McAllister, T. A., Evans, F., ... & Guan, L. L. (2018). Air-dried brown seaweed, Ascophyllum nodosum, alters the rumen microbiome in a manner that changes rumen fermentation profiles and lowers the prevalence of foodborne pathogens. *MSphere*, *3*(1), 10-1128.

Zhu, L., Qin, S., Zhai, S., Gao, Y., & Li, L. (2017). Inulin with different degrees of polymerisation modulates the composition of intestinal microbiota in mice. *FEMS Microbiology Letters*, *364*(10), fnx075. https://doi.org/10.1093/femsle/fnx094

Zhu, W., Wei, Z., Xu, N., Yang, F., Yoon, I., Chung, Y., & Wang, J. (2017). Effects of *Saccharomyces cerevisiae* fermentation products on performance and rumen fermentation and microbiota in dairy cows fed a diet containing low quality forage.

Journal of Animal Science and Biotechnology, *8*(1), 1-9. https://doi.org/10.1186/s40104-017-0165-8

APPENDICES

Appendix A. NACOSTI Permit

License No: NACOSTI/P/23/30726

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **229653**

Date of Issue: **03/November/2023**

RESEARCH LICENSE

This is to Certify that Mr.. Kipkorir Bett Josphat of Egerton University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nakuru on the topic: Evaluation Of Growth Perfomance Of Weaner Dairy Goat Fed Rhodes Grass Hay And Supplemented With Chicory And Yeast for the period ending : 03/November/2024.

License No: **NACOSTI/P/23/30726**

229653

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix B. Ethical Clearance

EGERTON UNIVERSITY

TEL: (051) 2217808
FAX: 051-2217942

P. O. BOX 536
EGERTON

EGERTON UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICS REVIEW COMMITTEE

EU/RE/DIR/009
Approval No. EUISERC/APP/248/2023 ***19th June*** **2023**

Kipkorir Josphat Bett
Egerton university
Department of Animal Sciences,
P.O Box 536-20115,
Egerton
Telephone: 0726304530
Email: kipkorir.bett.kb@gmail.com

Dear Josphat,

RE: ETHICAL APPROVAL: EVALUATION OF GROWTH PERFORMANCE OF WEANER DAIRY GOAT FED RHODES GRASS HAY AND SUPPLEMENTED WITH CHICORY AND YEAST

This is to inform you that ***Egerton University Institutional Scientific and Ethics Review Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUISERC/APP/248/2023.*** The approval period is ***19th June, 2023 –20th June, 2024***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. You are required to adhere Institutional Experimental Animals Use and Care policy.
iii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Institutional Scientific and Ethics Review Committee***.
iv. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Institutional Scientific and Ethics Review Committee*** within 72 hours of notification
v. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to

Egerton University Institutional Scientific and Ethics Review Committee within 72 hours.

vi. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.

vii. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

viii. Submission of an executive summary report within 90 days upon completion of the study to ***Egerton University Institutional Scientific and Ethics Review Committee***.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

EGERTON UNIVERSITY
Date 19/06/2023
RESEARCH ETHICS

Yours sincerely.

Prof. Raphael M. Ngure
CHAIRMAN, EGERTON UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICS REVIEW COMMITTEE
RMN/BK/

Appendix C: Publications

Objective One

Home | Journals | Submit Paper | Archive | Payment | Testimonial | Contact

Researchjournali's Journal of Agriculture

The In-vitro Organic Matter Digestibility Of Rhodes Grass Hay Supplemented With Different Levels Of Chicory; With Or Without Yeast (saccharomyces Cerevisiae) And Evaluation Of Growth

by J B Kipkorir P K Migwi J O Ondiek

Researchjournali's Journal Of Agriculture Jan, 2024 Views: 3 super premium

This study evaluated the in-vitro organic matter digestibility of Rhodes grass hay supplemented with different levels of Chicory- with or without brewer's yeast (Saccharomyces cerevisiae). The feeds were formulated into eight diets and offered using a CRD with a (4x2) factorial design. The diets were Rhodes grass hay and chicory supplementation at (T1:0, T2:10, T3:20, and T4:30%) as the main effects and yeast (+) and without yeast (-) as interaction levels. The proximate analysis was done to determine the chemical composition of the ingredients in terms of dry matter (DM), crude protein (CP), ether extract (EE), organic matter (OM), and ash using the AOAC's recommended methods.

Download

Objective Two

International Journal of Veterinary Sciences and Animal Husbandry

Vol. 9, Issue 3, Part G (2024)

The effect of supplementing different levels of chicory and yeast to growing dairy goats fed on *Rhodes grass* basal diet on feed intake and weight gain

Author(s): JB Kipkorir, PK Migwi and JO Ondiek

Abstract:
This study explored the impact of supplementing Chicory and yeast in varying proportions to the diets of weaned dairy goats primarily fed a *Rhodes grass* basal diet. The study was conducted at Egerton University's Tatton Agricultural Park (TAP), Njoro. The feeds were formulated into eight diets and offered to 24 crossbred (Saanen × Toggenburg) weaned dairy goats (14±0.5 Kg) using a CRD with a (4x2) factorial design. The diets were *Rhodes grass* hay and chicory supplementation at (T1:0, T2:10, T3:20, and T4:30%) as the main effects and yeast, with (+) and without yeast (-) as interaction levels. The findings suggest that including yeast and Chicory has a significant effect ($p<0.05$) on ADG and Voluntary feed intake. Average daily gain (ADG) was notably higher in supplemented goats, with the highest observed in diets containing 30% Chicory and yeast. The findings suggest a synergistic impact of Chicory and yeast on feed intake, and nutrient digestibility, contributing to improved growth performance in growing goats. Non-supplemented diet *Rhodes grass* (T1-) recorded a negative ADG at -7.14 g/day. Yeast addition to the basal diet (T1+) boosted the ADG to 28.21 g/day. However, there were variations in treatment T2+ and T3+, which were not significantly different. The addition of yeast at this level might not have influenced the weight gain. The study recommends the incorporation of Chicory at a 30% inclusion level and yeast supplements at 10 g/day in growing goat diets for optimal feed utilization and robust growth, offering a promising avenue for sustainable and efficient goat farming practices.

DOI: 10.22271/veterinary.2024.v9.i3g.1463

PAGES: 484-488 | 135 VIEWS 10 DOWNLOADS

Appendix D. Research Pictorials

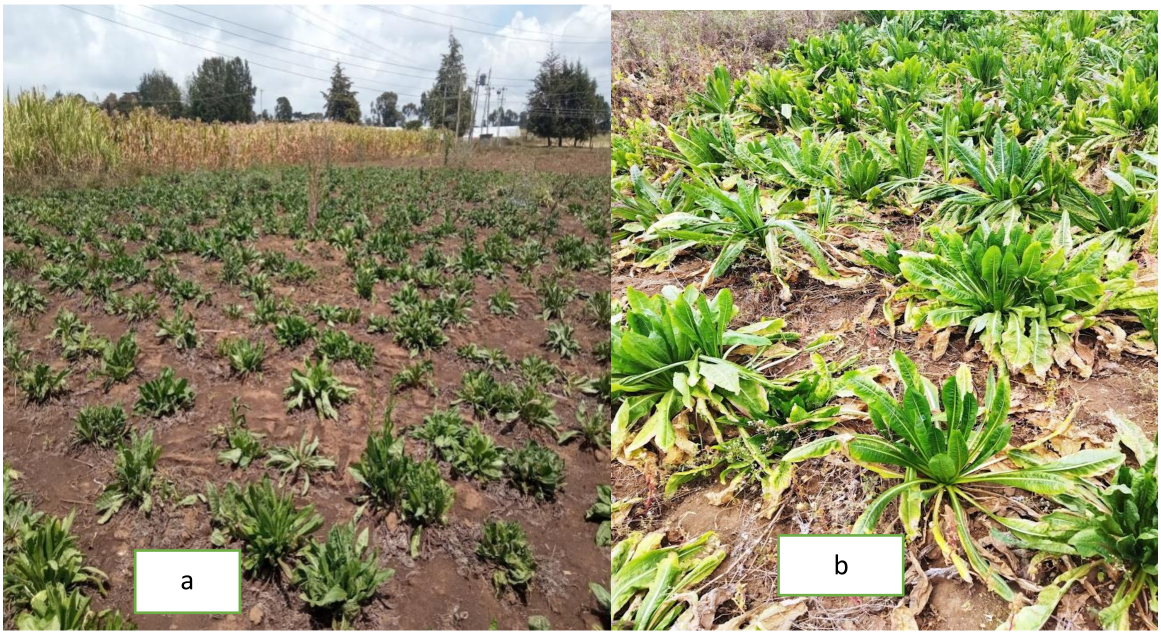

Plate 1: Chicory in the farm in the wet (a) and dry (b) season

Plate 2: Goats feeding on diets

Plate 3: Provision of feed and water to the goats

Appendix E. ANOVA Tables

Class Level Information		
Class	**Levels**	**Values**
Levels	4	T1 T2 T3 T4
Yeast	2	Negative Positive

Number of Observations Read	24
Number of Observations Used	24

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.87031500	0.12433071	9.11	0.0001
Error	16	0.21826600	0.01364163		
Corrected Total	23	1.08858100			

R-Square	Coeff Var	Root MSE	DM Mean
0.799495	0.122290	0.116797	95.50850

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Levels	3	0.70444350	0.23481450	17.21	<.0001
Yeast	1	0.10140000	0.10140000	7.43	0.0149
Levels*Yeast	3	0.06447150	0.02149050	1.58	0.2343

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Levels	3	0.70444350	0.23481450	17.21	<.0001
Yeast	1	0.10140000	0.10140000	7.43	0.0149
Levels*Yeast	3	0.06447150	0.02149050	1.58	0.2343

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	341.9192656	48.8456094	533.35	<.0001
Error	16	1.4653263	0.0915829		
Corrected Total	23	343.3845919			

R-Square	Coeff Var	Root MSE	CP Mean
0.995733	1.985725	0.302627	15.24011

The SAS System

The GLM Procedure

Dependent Variable: CP

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Levels	3	338.6209342	112.8736447	1232.48	<.0001
Yeast	1	1.8888568	1.8888568	20.62	0.0003
Levels*Yeast	3	1.4094746	0.4698249	5.13	0.0112

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Levels	3	338.6209342	112.8736447	1232.48	<.0001
Yeast	1	1.8888568	1.8888568	20.62	0.0003
Levels*Yeast	3	1.4094746	0.4698249	5.13	0.0112

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	330.6664450	47.2380636	29.74	<.0001
Error	16	25.4142419	1.5883901		
Corrected Total	23	356.0806869			

R-Square	Coeff Var	Root MSE	OMD Mean
0.928628	4.570406	1.260313	27.57553

Dependent Variable: OMD

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Levels	3	308.9473110	102.9824370	64.83	<.0001
Yeast	1	12.7262934	12.7262934	8.01	0.0121
Levels*Yeast	3	8.9928406	2.9976135	1.89	0.1725

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Levels	3	308.9473110	102.9824370	64.83	<.0001
Yeast	1	12.7262934	12.7262934	8.01	0.0121
Levels*Yeast	3	8.9928406	2.9976135	1.89	0.1725

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	0.013642
Critical Value of Studentized Range	4.04606
Minimum Significant Difference	0.1929

The GLM Procedure

Tukey's Studentized Range (HSD) Test for DM

Means with the same letter are not significantly different.			
Tukey Grouping	**Mean**	**N**	**Levels**
A	95.71925	6	T2
A	95.61875	6	T1
B	95.41625	6	T3
B	95.27975	6	T4

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	1.58839
Critical Value of Studentized Range	4.04606
Minimum Significant Difference	2.0818

Means with the same letter are not significantly different.				
Tukey Grouping		**Mean**	**N**	**Levels**
	A	30.9918	6	T2
B	A	29.3464	6	T3
B		28.3900	6	T4
	C	21.5738	6	T1

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	0.013642
Critical Value of Studentized Range	2.99786
Minimum Significant Difference	0.1011

Means with the same letter are not significantly different.			
Tukey Grouping	**Mean**	**N**	**Yeast**
A	95.57350	12	Positive
B	95.44350	12	Negative