PERFORMANCE OF NGUNI GOATS SUPPLEMENTED WITH SWEET POTATO VINES

By

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Declaration

I declare that this dissertation is the product of my work and effort; the results are my own independent investigations and research. I further declare that all sources of information used or quoted were acknowledged.

I acknowledge that I have read and understood the University's policies and rules applicable to post graduate research, and I certify that I have, to the best of my knowledge and belief, complied with their requirements

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Supervisor's Declaration

I am satisfied that I have given the candidate the necessary supervision in respect of this dissertation and that it meets the requirements of the university in respect of postgraduate research dissertation.

I have read and approved the final version of this dissertation and it is submitted with my consent.

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Dedication

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List of papers submitted for publication

1. Knowledge and perception of small holding farmers on supplementation and feeding of sweet potato vines to goats
2. The effects of cutting frequency on chemical composition and *in vitro* digestibility of vines from four sweet potato cultivars and yield of tubers.

List of papers to be submitted for publication

3. The effect of feeding sweet potato vines on goat intake, growth parameters and gastro-intestinal nematode infestation

List of conference papers

4. LUTHULI, C., FON, F. & KUNENE, N. 2017. Knowledge and perception of small holding farmers on feeding sweet potato vines to goats at KwaMthethwa community area, Kwambonambi local municipality, KwaZulu-Natal. South African Society of Animal Sciences, 50th Congress "Golden Innovations for Sustainable Animal Agriculture" Boardwalk Conference Centre, Port Elizabeth, Eastern Cape, from 18 -21st September 2017.

Abstract

Goats are small ruminants that play a major role in food security, especially as their meat and milk serve as vital sources of protein in most rural houses in developing countries. Goats in developing countries mostly depend on veld as feed that often does not provide the nutrient requirements necessary for optimum production. Supplementary feeds available are often expensive especially for emerging farmers but crop residues like banana leaves, cassava, sweet potato vines and other indigenous crop residues not exploited may be used as a cheaper source of feed supplement. More rural emerging farmers in Northern KZN communities seem to be farming sweet potatoes which implies that the vines could be available cheaper for supplementary feeding if found with feed potential. Thus, the aims of this study were to survey the knowledge and perception of indigenous forage supplementation especially sweet potato vines, the effect of vine cutting frequency on the chemical composition and *in vitro* digestibility as well as sweet potato yields of different sweet potato cultivars and the final aim looked at the effect of vine supplementation on goat's intake and performance as well as its anthelminthic potential, if any.

The survey was conducted in 7 wards of KwaMthethwa community area under Umfolozi local Municipality, where 15 farmers were interviewed per ward using a questionnaire. The effect of vine cutting frequency (after 60, 75 and 125 days) on the vine chemical composition (crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent ADL, condensed tannin (CT)) and *in vitro* digestibility (apparent digestibility (APD), true digestibility (TD), microbial yield (MY)) as well as sweet potato yields of the different cultivars (Beauregard (BRGT), 1990, A40 and A45) were done at Owen Sithole College of Agriculture (OSCA) farm and University of Zululand Agriculture laboratory. Goats (32) of similar average weight, were categorised into four groups of eight and placed in individual pens. They were given hay *ad libitum* and supplemented with four different rations (0kg, 1.5kg, 2kg and 3kg) of sweet potato vines (SPV) from 1990 as best cultivar. The effect of 1990 supplementation on goats' hay intake (total feed intake (TFI) and *in vitro* digestibility (DMD) and performance (weight gain (WG), average daily weight gain (AVD) and feed conversion ratio (FCR)) were measured. Anaemic condition of goats was monitored as well as egg counts for *haemonchus contortus* infestation. The survey results showed that farmers seem to have an idea of supplementing, however majority fed maize in the afternoons, for goats to be able to come back for kraaling without a header. Most farmers agreed that goats were losing condition due to diseases and malnutrition, but rural farmers rejected the use of sweet potato vines as feed supplement even when it was available because they believed it causes fatal diarrhoea.

It was found that nutrient status of vines was reduced ($P<0.05$) as the plant matures, and fibre (NDF and ADF) increased as vine matured. The CP concentration was decreased ($p<0.05$) and CT increased ($p<0.05$) as the plant matured, with an exception of A45 cultivar that had lower tannin concentration even at 120 day after planting (DAP). Furthermore, harvesting vines at 75 DAP improved ($P<0.05$) the yields of sweet potato tubers and vines. The Cultivar 1990 was considered the best because it produced the highest yields of forage materials as well as tubers hence not compromising its original purpose of production for human consumption. It was observed that goats given 3kg SPV (T4) had the highest ($p<0.05$) final weight (FW), total weight gain (TWG) and average daily gain of 26.05kg, 4.18kg and 74.56g/day, respectively. Moreover, the feed intake increased ($P<0.05$) with increasing feed levels of sweet potato vines. Most interestingly, the egg per gram (EPG) was reduced in all groups of goats fed sweet potato vines but not for the control group. The results from these studies showed that sweet potato vines have a feed potential as well as anthelminthic potential and rural farmers can be advised to apply it at T4 levels after 75 days of harvest and no diarrhoea signs were observed.

Keywords: Farmers, helminth, nutrients, supplement, sweet potato

Table of Contents

Declaration i
Supervisor's Declaration i
Acknowledgements ii
Dedication iii
List of papers submitted for publication iv
List of papers to be submitted for publication iv
List of conference papers iv
Abstract v
Abbreviations xii
Chapter 1 1
1. Introduction 1
1.1 Problem statement 3
1.2 Objectives 4
1.3 Hypotheses 4
1.4 Contribution to the body of knowledge 5
Chapter 2 6
2. Literature review 6
2.1 Introduction 6
2.2 Protein supplementation 8
2.2.1 Rumen microbial proteins 8
2.2.2 Protein-energy relationship 9
2.3 Origin of sweet potato and its establishment 9
2.3.1 Sweet potato origin and distribution 9
2.3.2 Cultivation of sweet potatoes and adaptability 10
2.4 Sweet potato production in South Africa 11
2.5 Constraints in sweet potato production 12
2.6 Uses of sweet potatoes 13
2.7 Sweet potato vines as stock feed supplement 13
2.8 Nutritional value of sweet potato forage 15
2.8.1 Inhibitors in sweet potatoes 16
2.8.2 Tannins in sweet potato plants 16
2.8.3 Interaction between forage chemical composition and its digestibility 19
2.9 Goats' nutritional requirements 20
2.10 Effects of sweet potato vines on gastro-intestinal nematodes 21
2.10.1 Anthelmintic resistant in goats 22
2.10.2 Effect of proteins on gastro-intestinal nematodes 23

2.10.3 Anthelminthic effect of condensed tannins 24
Chapter 3 25
3.0 Abstract 25
3.1 Introduction 26
3.2 Methodology 29
3.2.1 Study area 29
3.2.2 Farmer selection procedures 29
3.2.3 Data collection 29
3.2.4 Statistical Analysis 30
3.3 Results 30
3.3.1 Demographic information of participants 30
3.3.2. Livestock inventory 31
3.3.3 Purpose of goat farming 31
3.3.4. Supplement source for goats 32
3.3.5 Farmers' perception on use of sweet potatoes vines as feed supplement for goats 32
3.3.6 Farmers' perception on feeding sweet potato vines to goats 34
3.3.7 Causes of goat losses in the rural community 34
3.4. Discussion 36
3.4.1 Biodata of farmers 36
3.4.2 Livestock ownership and population 36
3.4.3 Reasons for keeping livestock including goats 37
3.4.4 Farmers practising supplementary feeding and source of supplements 38
3.4.5 Farmers cultivating sweet potato and application of sweet potato 38
3.4.6 Uses of sweet potato vines and perception of farmers towards its application as feed 39
3.4.7 Goat losses, and treatment methods used by farmers 39
3.5 Conclusion 40
Chapter 4 42
4.0 Abstract 42
4.1 Introduction 43
4.2 Materials and Methods 44
4.2.1 Study site 44
4.2.2 Ethics and consent 45
4.2.3 Experimental samples, experimental design and vines planting procedure 45
4.2.4 Sample preparation and chemical analysis 45
4.2.5 In vitro digestibility and microbial yield of sweet potato vines 48
4.2.6 Statistical Analysis 49
4.3 Results 50

4.3.1 Effect of clipping time on nutrient composition of cultivar stems 50
4.3.2 Effect of clipping dates on petioles' nutrient values of cultivars 50
4.3.3 Effect of clipping dates on potato leaves nutrient composition of cultivars 51
4.3.4 Effect of clipping dates on vine nutrient value of cultivars 52
4.3.5 Effect of clipping dates on vines and stem digestibility of cultivars 53
4.3.6 Petioles and leaves digestibility of cultivars clipped at different dates 54
4.3.7 Vine and tuber yields 55
4.4 Discussion 55
4.5 Conclusion 58
Chapter 5 59
5.0 Abstract 59
5.1 Introduction 60
5.2 Materials and methods 62
5.2.1 Study area 62
5.2.2 Ethics and consent 62
5.2.3 Performance of goats 62
5.2.4 Anthelminthic effect of sweet potato vines and body condition of goats 64
5.2.5 Statistical Analysis 65
5.3 Results 65
5.3.1 The feed intake, dry matter digestibility, average daily gain of goats fed sweet potato vines 65
5.3.2 The effect of feeding sweet potato vine on goat's live weights 66
5.3.3 The anthelminthic properties of sweet potatoes vines fed to goats 66
5.4 Discussion 67
5.5 Conclusion 70
Chapter 6 71
6.1 General Summary 71
6.2. General conclusion 74
6.3 Recommendations 75
7. References 76
Appendix A (a) 85
Appendix A (b) 89

List of Tables

Table 2.1 Ruminants' distribution in South Africa (in thousands) …………………………...6
Table 2.2 Yield and quality of petiole, stem and vines ………………………………...........15
Table 2.3 Gastro-intestinal nematodes of farm animals (sheep, goats and cattle) ……………………………………………………………………………………………………22
Table 3.1 Demographic characteristics of participants ……………………………….........30
Table 3.2. Livestock inventory (cattle, sheep and goats) in percentage …………………...31
Table 3.3. Uses of sweet potato vines ………………………………………………………...34
Table 3.4. Goat losses, causes and diseases affecting goats…………………………….....35
Table 3.5. The remedies used to fight worms ………………………………………………...35
Table 4.1 Stems' nutrient value of different cultivars as affected by clipping dates …………………………………………………………………………………………………...50
Table 4.2: Petioles' nutrient value of different cultivars as affected by clipping dates ……………………………………………………………………………………………51
Table 4.3. Leaves' nutrient value of different cultivars as affected by clipping dates ……………………………………………………………………………………………………52
Table 4.4 Vines' nutrient value of different cultivars as affected by clipping dates ……………………………………………………………………………………………………53
Table 4.5 Vines and stem digestibility clipped at different dates …………………………...54
Table 4.6 Petioles and leaves' digestibility of different cultivars as affected by clipping dates ……………………………………………………………………………………………………54
Table 4.7 Effects of clipping dates on the yield of fresh vines and tubers………………….55
Table 5.1 The nutrient composition of diet (sweet potato vines and hay) fed to goats………………………………………………………………………………………….63
Table 5.2 Carrying capacity for sweet potato fed at different levels ………………………………………………………………………….............................63
Table 5.3 Effect of different feeding levels on feed intake, dry matter digestibility and average daily gain of goats……………………………………………………………………………66
Table 5.4 Changes in goats' live weights with increasing portions of sweet potato vines as a supplement ……………………………………………………………………………………….66
Table 5.5 Comparison of goat body condition, anaemic level and haemonchus infestation on goats fed SPV as a supplement ………………………………………………………………..67

List of Figures

Fig. 3.1 Purpose of goat farming……………………………………………………………31

Fig. 3.2 The percentage of farmers practising supplementary feeding…………………......32

Fig. 3.3 Showing material used as a source of feed for supplementary purposes………32

Fig. 3.4 The percentage of farmers who cultivate sweet potatoes or not ………………..33

Fig. 3.5 Reasons farmers cultivate sweet potatoes…………………………………………33

Fig. 3.6 Perception of farmers towards feeding sweet potato vines to goats..................34

Abbreviations

Abbreviation	Explanation	Abbreviation	Explanation
Ab_{550}	Absorbance at 550nm	FI	Feed intake
ADF	Acid detergent fibre	FW	Final weight
ADL	Acid detergent lignin	Hemi	hemicellulose
ADS	Acid detergent solution	IBCS	Initial body condition score
APD	Apparent degradability	IEPG	Initial egg per gram
AVDG	Average daily gain	IFAM	Initial FAMACHA
AVFI	Average feed intake	IW	Initial weight
BRG	Beauregard	Moist	Moisture
BW	Body weight	MY	Microbial yield
Cellu	Cellulose	NDF	Neutral detergent fibre
CT	Condensed tannin	%RED	Percentage reduction
CP	Crude protein	SPV	Sweet potato vines
DAP	Days after planting	T1	Treatment one
DM	Dry matter	T2	Treatment two
DMD	Dry matter digestibility	T3	Treatment three
FBCS	final body condition score	T4	Treatment four
FCR	Feed convention ratio	TD	True digestibility
FEG	Faecal egg count	TFI	Total feed intake
FEPG	Final egg per gram	TWG	Total weight gain
FFAM	Final FAMACHA		

Chapter 1

1. Introduction

Goats are small ruminants mostly owned by small holding farmers and pastoralists who play an essential role in the economy and food security of poor communities in developing countries (Kabir, 2004; Tolera, 2000; Windsor, 2018). Goats are often called the poor man's cow, since they have low status and are cheaper to manage as well as sell (Cheeke, 2005). They are multipurpose animals reared for production of meat, milk, skin and hair. Their meat and milk contribute to the supply of animal protein for human consumption. Furthermore, they are known to produce high quality meat and milk (Kabir et al., 2004). In countries like Rwanda, Kenya and Uganda goats' milk has gained popularity as it is claimed to be a healing drink for HIV-AIDS patients and now is called miracle food (Peters, 2008). Due to this popularity, the demand for goat milk is increasing and has led to an increase in prices of goat milk compared to cow milk in these countries (Peters, 2008). Thus, goat production demands may result in the increase in production returns, employment and improvement of livelihood especially in these countries.

Goats are mostly kept under extensive management systems where they solely depend on natural pastures as their source of feed. The nutritional status of these natural pastures often decreases rapidly during winter (dry season) hence affecting the performance of goat production systems (Kabir et al., 2004; Kebede et al., 2008). Most forage grasses have a crude protein percentage of less than 6 which is lower than the animal requirement (Kariuki et al., 2001). As a result, production is adversely affected such that weight loss and kid mortality increases until the beginning of the new growing or wet season (Kebede et al., 2008).

Poor feeding management results in deterioration of goats' genetic potential as well as production efficiency (Kabir et al., 2004; Kebede et al., 2008). These losses can be overcome or prevented through supplementation either by using grain concentrates or forage legumes to improve the digestive and metabolic condition of ruminants (Kabir et al., 2004; Kebede et al., 2008). However, supplementing livestock feed with the above mentioned concentrates is very expensive as costs are escalating and unaffordable for emerging or subsistence farmers (Abonyi et al., 2014). According to Tolera et al. (2000) these feed supplements are expensive because these same grains are being used by humans for food. This implies that ruminant production is somehow indirectly competing with human beings for the same raw materials, especially maize concentrates.

There is a growing demand for livestock products as reported by Scott (1992) which is becoming increasingly problematic due to shortages of fodder. Thus there is a need to increase fodder material to ensure enough quantity and quality feeding (Etela et al., 2008). Feed supplementation is primarily conducted with an aim of correcting deficiencies in animal diets and also to stimulate intake, thus improving digestion. It is also very important that supplementation is conducted correctly to avoid negative effects such as reduced digestion of fibre and intake (Tainton, 2000a; Tainton, 2000b). In semi-arid areas, the main nutrient constraints are low protein and energy content, and seasonal fluctuations in supply of these nutrients is also a major concern (Abonyi et al., 2014). The major nutrient deficiency during drought or winter is protein especially in tropical and sub-tropical areas (Tainton, 2000a). This situation can be improved by drought tolerant fodder plants while optimal use of indigenous crop species as fodder can also play a role. However, these fodder crops are often very expensive and not available or there are shortages when found. As a result, there is a need for researchers to investigate other less expensive but more nutritious feeds to meet the nutritional requirement for goats and other ruminant production systems.

Maize stovers are the most common feed supplement utilised in larger quantities with an aim of closing fodder flow gap when it comes to energy provision. The major setback of maize stovers utilization is its low nutrient quality (especially crude protein) and digestibility. Hence, it will fail to provide rumen microbes and host animals with the required nutrients if not supplemented. Some forage made from traditional crops (crop residues) have relatively higher amounts of dietary crude protein which may be comparable to conventional supplements such as concentrates or legumes that have been used to improve poor pastures. These traditional crop residues may be utilised during drought or winter seasons as well as during periods of high nutrient demand such as growing animal, late pregnancy and lactation in livestock. Traditional food crop forages such as cassava and sweet potatoes, tend to have a comparable effect on growth, feed intake and digestibility in ruminants as energy supplements (Anbarasu et al., 2004).

Sweet potato is a traditional root crop which does well in tropical and subtropical environments of Africa. It is available or accessible to all farmers and its cultivation is increasing in Southern Africa especially in KwaZulu-Natal (Omotobora, 2013). Sweet potatoes are increasingly being used in developing countries such China, Uganda, Kenya and Nigeria. as a feed supplement for livestock due to increased cultivation for human consumption (Kebede et al., 2008). According to Etela et al. (2008) in a study conducted in Ibadan, Nigeria, sweet potato forage remains green during drought or winter season and can be fed with little or no treatments unlike other cereal crop residues. Using sweet potato vines as forage may also encourage crop-livestock integrated farming systems. They also emphasized that harvesting time for sweet potatoes did coincide with the season where feed shortages are often experienced hence the planting was mainly for human consumption. Sweet potato is also said to be highly productive in terms of tuber yields with low growth input requirement (Megersa et al., 2013) but information about vine quantity and quality as potential feed crop residues was limited. Therefore, a critical review on indigenous crop residue supplements especially sweet potato vines will be discussed in the literature review section.

1.1 Problem statement

Goats play a very important role in the livelihood of humans due to their high productivity (fertile and gives multiple births) and they are also regarded as the healthiest produce in terms of meat and milk. Their milk is regarded as good food for HIV-AIDS patients. These animals depend on natural pastures for nutrients, but the nutritional status of such pastures is affected by climatic conditions and seasons. Their nutritional status deteriorates and becomes deficient of nutrients especially during drought or winter. This situation becomes very difficult for rural farmers who raise their animals in poor conditions with less protein, energy and vitamins, whereas goats require highly nutritious feed. According to Tainting (2000), veld is available for utilization by livestock from October to May especially in sour and mixed veld areas, meaning in winter to early spring there is less or no forage for livestock. Thus, there is need to manipulate feeding strategies through supplementation of grain concentrates and legumes during these periods of forage shortages. Supplementation and manipulation with commercial supplements can improve the nutritional status of goats but they are expensive and unaffordable for small holding or subsistence farmers especially in developing countries. In developing countries there is a shortage of nutritious feed with acceptable levels of energy and protein. Therefore, there is need to identify alternative traditional feed stuff or crops that can be grown at a lower cost with the potential to produce high yields of crop residues. These crops should be adapted to tropical or subtropical climates and available to farmers. Sweet potato is one of the traditional crops that are extensively grown in developing countries, especially in South Africa where more community farmers are getting involved. In northern KwaZulu-Natal (KZN), lots of traditional households have been observed to be planting sweet potatoes mainly for consumption without any plans for the crop residue. Sweet potato appears to have feed potential which could be used to improve the performance of livestock. It is said to be grown at lower cost with low labour requirements and it is relatively drought resistant (Laurie, 2010). This implies that there is need to survey the farming of sweet potatoes by small scale farmers in a particular region of northern KZN as well as the different varieties that are being used. It will also be useful to investigate the nutritional quality of the sweet potato vines (crop residues) as well as their effect on goat performance especially in winter when there is nutritional deficiency in the veld.

1.2 Objectives

The main objective of this study was to determine the performance of Nguni goats supplemented with sweet potato vines.

The specific objectives were:

1.2.1 To assess the knowledge of small scale farmers concerning supplementary feeding with indigenous forages and nutritional disease affecting goats during winter or drought;

1.2.2 To evaluate the nutrient value and effect of cutting frequency on chemical composition of sweet potato vines and yields of sweet potato tuber, from four different sweet potato varieties; and

1.2.3 To determine the effect of feeding sweet potato vines on intake and growth parameters of goats as well as on gastro-intestinal nematodes.

1.3 Hypotheses

1.3.1 It was hypothesised that small scale farmers that are keeping goats, have limited knowledge regarding supplementary feeding, as well as sweet potato vines as feed;

1.3.2 It was hypothesized that potato varieties and cutting frequency will not have effects on the chemical composition of sweet potato vines and tuber yields; and

1.3.3 It was hypothesized that the feeding of sweet potato vines will not have an effect on goats' performance and gastro-intestinal nematode control.

1.4 Contribution to the body of knowledge

Sweet potato vines are mostly burnt or discarded as waste during harvesting, however in this research they will be utilized as animal feed and that will provide more information about whether they have feed potential for livestock or not. Though some humans eat leaf portion of vine, it is in minute amount and they are interested in fresh leaves. If results reveal sweet potato vines as potential feed, it will therefore reduce competition for feed among human beings and livestock. As a result, the success of this study will mean more feed available for livestock.

This research will help farmers to improve the management of their livestock:

- Feeding sweet potato vines as a feed supplement to livestock will improve intake of poor forages, which may then result in improvement of the amount of energy available for goat production. Thus, increasing food available for human consumption hence improving food security and hunger alleviation strategies.
- It will also contribute in the sustainable use of agricultural resources since a by-product of sweet potato (sweet potato vines) will be used as feed for animals.

Knowledge to be gained from this research will also improve livestock production and profitability especially among rural farmers in northern KwaZulu-Natal who are not currently using sweet potatoes since the production cost might be reduced due to the low cost of crop residues. Using sweet potato vines as feed supplement will also reduce atmospheric contamination thus contributing in environmental management strategies, since sweet potato vines that could have been burnt or left to rot and produced gases or become a habitat for pests and diseases will be used.

Chapter 2

2. Literature review

2.1 Introduction

The goat is scientifically called *Capra aegagrus hircus* and was one of the first animals to be domesticated by humans more than 9000 years ago. There are now more than 200 different breeds (Coffey et al., 2004). Goats constituted 0.7 billion out of 1.8 billion of the world's small ruminants (Jackson et al., 2011). However, a survey by DAFF (2018) shows that global goat production has increased to more than 1.84 billion which implies that the number has doubled from 2011. According to Meissner et al. (2013), South Africa has more than ±5, 998, 000 goats whereas KwaZulu-Natal has ±788, 000 of these goats (Table 2.1). This implies that more

Table 2.1 Ruminants' distribution in South Africa (in thousands)

Province	Beef cattle		Dairy Cows	Sheep		Goats	
	Comm	Other		Comm	Other	Comm	Other
Western Cape	219	232	323	2368	336	62	152
Northern Cape	603	208	13	5361	758	144	355
Eastern Cape	1531	1272	348	6410	906	643	1588
KwaZulu-Natal	1409	1116	268	676	95	227	561
Free State	1232	911	198	4271	604	67	165
Mpumalanga	868	603	60	1534	217	25	61
Limpopo	650	433	12	226	31	349	861
Gauteng	321	245	44	91	13	11	27
North West	1035	713	102	612	86	202	498
Total	7868	5733	1368	21561	3046	1720	4268
National Totals	13601		1368	24607		5998	

Source: Meissner et al., (2013), Comm = commercial farmers and other= small scale and communal farmers

research is required to sustain the high number of goats in this province (about 50% of all goats in South Africa) which is why this study was initiated. Goats can be raised in an integrated system with sheep and cattle and may be used to control bush encroachment (Coffey et al., 2004). Goats are raised in conditions which do not allow them to achieve their maximum performance nor express their genetic potential. They are raised on poor quality feeds, with low energy and protein content. For goats to perform to their full potential as small ruminants, they require highly nutritious feed. Goats' feed must be of higher quality than that of cattle because they are naturally browsers. It is also advisable that during high producing periods e.g. breeding, gestation and lactation, goats must be supplemented with proteins, energy and vitamins and their supplementation can be done using fresh green feeds, protein blocks or vitamin supplements (Cheeke, 2005).

According to Coffey et al. (2004) the main aim of feeding animals is to meet their nutritional requirements and ensure they remain in good productive condition and this whole process must be economical for every farmer to be able to make profit. An animal's productivity may be monitored through evaluation of its body condition using a body condition score. The body condition score cannot only be used to assess body condition but also the nutritional status of goats. Animal conditions are often scored from 1 to 5 whereby 1 represents the lowest score indicating emaciation, 3 indicating average condition and 5 being the highest indicating that the animal is obese (Kunene et al., 2015). Depriving animals of high-quality feed especially during high producing periods will lead to usage of body reserves. Thus, animals lose body weight and condition especially during early lactation. Nutrient requirements for goats may also be affected by factors such as, feedstuff, environment, physiology, behaviour, and disease, thus affecting nutrient availability and feed intake (Cheeke, 2005). Therefore, there is need to choose the right fodder or crop residues that will meet these nutritional requirements. Sweet potatoes seem to be one of the more popular energy tubers that more farmers in the KZN province are getting involved in its cultivation. Therefore, there is a need to also get a closer look at the quantity and quality of the vine production for possible feed supplementation.

Sweet potatoes are regarded as one of the food crops preferred by farmers for cultivation, because it is easy to propagate as well as producing high tuber yields for human consumption (Tewe et al., 2003). Sweet potato vines, leaves and surplus tubers or any waste from sweet potato may be fed to most domesticated animals such as cattle, sheep, goats, pigs, rabbits and chickens. The scientific name for sweet potatoes is *Ipomea batatas* and they belong to the morning glory family called *Convolvulaceae* (Adewolu, 2008; Unigwe et al., 2014). The genus *Ipomea* consist of 600 to 700 species (Omotobora, 2013). Khalid et al. (2013) reported that sweet potatoes' green portion makes a very valuable and cheap feed for animals due to high protein content, effective rumen dry matter degradability, crude protein digestibility and nitrogen retention. However, the characteristics may also vary with different varieties or cultivars. Sweet potato vines are also said to be rich in Vitamins A, B and C as well as minerals like phosphorous, iron and calcium (Omotobora, 2013). These are all important minerals that may be manipulated by nutritionists to the advantage of farm animals. The quantity of forage to be fed depends on age of the animal, type and quality of forage. Some animals may not be interested in sweet potato forage, thus adaptive measures may be required to familiarise the animal with a new diet. One of the adaptive measures that have been used include putting feed at the bottom of a feed concentrate bowl to increase acquaintance and acceptability before increasing the quantity gradually (Khalid et al., 2013). Acceptability is very important before diverting the focus on the benefit and constraints in using sweet potato vines. Furthermore, some forages are believed to be bioactive that could reduce or eliminate gastro-intestinal nematodes. Sweet potatoes are also suspected to possess such properties as they are said to contain smaller amounts of phenolic compounds. It will be very important to look at the need for protein supplementation, possible sources of protein to ruminants (goats), importance of sweet potatoes to both human and animals in terms of chemical composition, varieties, anthelminthic potential if any in the literature and to conclude on the findings and possible research ideas from the gaps found in the literature.

2.2 Protein supplementation

Most tropical pastures are of lower quality and similar to what occur during drought or winter (Poppi and McLennan, 1995). These production systems cause poor growth rate and reproductive performance, which in turn results in severe economic losses (Kabir et al., 2004). According to Tolera et al. (2000), the main nutrient restricting goat production is protein and energy. Cheeke (2005), indicated that protein requirement for livestock is less than 15% dry matter of their diet. However, their protein need may differ with species, stage of growth and type of production. Tolera et al. (2000) articulates that if the protein content of the pasture is below 6 to 7% of dry matter during winter, rumen microbes' growth and digestibility may be restricted thus adversely affecting the absorption of energy and protein in ruminants. Therefore, there is always a need to make sure that the protein requirements of different livestock, including goats, are met.

2.2.1 Rumen microbial proteins

The major source of protein for ruminants is microbial proteins, which is manufactured from feed amino acids and protein as well as from non-protein nitrogen such as ammonia and urea (Owens and Basalan, 2016). However, these microbes are required for the provision of required energy (Thompson and Cheeke, 2005) because they are crucial for digesting and extracting nutrients from feedstuff or forage. Low rumen microbial protein synthesis and intestinal amino acid absorption can restrict feed intake and prejudice animal performance (Tolera et al., 2000). Rumen microbes are also important for the formation of water soluble vitamins and vitamin K, hence there is no need for supplementing these vitamins (Cheeke, 2005). Thus, the restriction of protein in the diet could result in the deficiency of water-soluble vitamins and vitamin K as well since they are very important for microbial protein synthesis and growth in population.

2.2.2 Protein-energy relationship

The use of protein can be restricted by energy metabolism, since rumen microbes require energy to synthesise protein (Hoste et al., 2005). According to Cheeke (2005) energy is necessary for the formation of new tissues, such as muscle using protein. For instance, amino acids require chemical energy to form a bond between each other to completely form a protein. Thus energy supplements to ruminants and supplements of high escape protein would be equally beneficial (Poppi and McLennan, 1995). The major source of energy is carbohydrate, followed by fat and rarely protein (Cheeke, 2005). Tolera et al. (2000) encourage supplementation with forage plants (herbaceous, shrubs and trees) because they are relatively richer in crude proteins and soluble carbohydrates which can possibly enhance microbial growth in population hence the utilization of low-quality roughages in small holding farms. Sweet potato availability might be an important source of legume for supplementation.

2.3 Origin of sweet potato and its establishment

2.3.1 Sweet potato origin and distribution

Sweet potatoes originated from countries like Mexico, South America, Central America and Asia and have been distributed to many other countries including tropical and subtropical countries of Africa (Jata et al., 2011; Khalid et al., 2013). According to Unigwe et al. (2014) sweet potatoes are cultivated by more than 100 countries in the world and ranked as fifth among the most important food crops in tropical countries. In Sudan there is an increasing interest in maximising the utilization of crops that can produce food both for humans and livestock at farm level in order to reduce input cost and encourage integrated farming systems. Thus, the utilization of sweet potato vines for animal feeding may contribute significantly to the profits of such production systems.

Animal production is gradually increasing globally to meet the demands for meat and milk in human diets. However, in developing countries, there is a shortage of forages or feedstuff that are rich in nutrients to meet the demand for livestock production. In view of the worldwide demand for additional feed source, the exploitation of traditional crops which are grown with lower inputs, and are largely adapted wide range of climatic conditions, would be a step towards better resource utilization. There is insufficient information about sweet potato production, crop residues (leaves and vines) utilization and marketing in developing countries due to socio-cultural habits of the farmers and high cost of production of root and or tuber crops (Khalid et al., 2013).

In Uganda, more than 50% of livestock farmers use food crop by-products such as cassava and sweet potato, as feed for their animals and that in turn does not only improve animal production performance but reduces waste disposal problems which affect most cities in developing countries (Katongole et al., 2009). Sweet potatoes in developing countries are mostly grown for tuber production (Khalid et al., 2013). Thus, sweet potato vines are only available for a short period (4 to 6 months depending on the cultivar) meaning their availability as feed is seasonal. This can be overcome by cropping sweet potato all year round in tropical areas since they are drought resistant and can survive during winter in frost-free areas (Chakrabarti et al., 2014). Conserving sweet potato vines as hay and/ or silage can also extend the availability of sweet potato vines for forage.

Sweet potato vines are often retained on the fields as mulch (Lam and Ledin, 2004) or considered as waste product from harvesting. Therefore, it has been underutilised in most communities especially in KZN. Other examples of developing countries that produce sweet potato as feed are China, Nigeria, and Kenya (Madziga et al., 2017; Peters, 2018). In these countries sweet potato vines are grown by small holding farmers as a dual-purpose crop. The vines have been reported to be fed to livestock especially rabbits and tubers for human consumption (Khalid et al., 2013; Chakrabarti et al., 2014).

2.3.2 Cultivation of sweet potatoes and adaptability

Sweet potatoes are tropical or subtropical crops that grow in areas with 750mm average rainfall per annum and ideal temperature of 20 to 25^{o}C (Omotobora, 2013). They are sensitive to cold temperatures and their growth may be retarded (Drost and Farley, 2010). Sweet potatoes can be cultivated in a wide variety of soils ranging from sandy-loam to clay-loam soils (Omotobora, 2013). Clay soils should be avoided as much as possible (Chakrabarti et al., 2014), as they can retard root development, resulting in growth cracks and poor root shape. Soil pH should range from 5.6 to 6.6 as described in the study by Omotobora (2013).

Sweet potatoes may be propagated using vine cuttings of 20 to 25cm length on ridges at an interspacing of 30 to 40cm at a rate of 50 000 to 62 000 cuttings per hectare. It is harvested at four months (120 days after planting) or five months (i.e. 150 days after planting) but may vary with cultivars and environment in which they grow (farmers week, 2010; Chakrabarti et al., 2014). Vines should be removed 6 days before harvesting to enable easy tuber harvesting (Chakrabarti et al., 2014). According to Tewe et al. (2003) sweet potatoes may be planted two times per year. For example, a first planting should be done between February and March and a second between October and December especially in tropical and subtropical countries. Potato farms should be weeded once after six weeks of planting, after which sweet potatoes would have formed a canopy that will supress weeds until harvesting. Etela et al. (2008) also reported that sweet potato can remain green during the dry season with little or no treatments compared to other crops such as cereals that need some maintenance to survive drought. Thus, sweet potato vines may be available for goats especially during droughts and winter periods if feed potentials of cultivars are established. Planting in February to March in tropical or subtropical countries is advantageous as sweet potato vines will be available to animals, since mid-May to mid-August are often periods of forage shortages. In other developing countries sweet potatoes are intercropped with other crops such as rice, cassava or maize. Sweet potatoes in these areas are often planted on ridges while other crops are planted in furrows (Tewe et al., 2003). Sweet potatoes are known as very hardy crops which can tolerate harsh conditions, such as heavy winds like hurricanes, thus providing protection to companion crops.

2.4 Sweet potato production in South Africa

Sweet potato is regarded as an important food crop in both Eastern and Southern Africa which is mostly grown at a small scale to ensure food security (Ewell and Mutuura, 1991). Sweet potatoes were introduced to South Africa in 1652 and are now widely grown in KwaZulu-Natal, Limpopo, Western Cape, Northern Cape and Mpumalanga Provinces of South Africa (Omotobora, 2013). They are mostly used for human consumption and there is very little or no information about the utilisation of sweet potato as animal feed in these provinces. South Africa is regarded as the smallest producer and exporter of sweet potatoes compared to other countries in tropical and subtropical regions. A study conducted by Laurie et al. (2017), indicated that South Africa can produce up to 62.00 ton per hectare and marketable yields of up to 49.60 tons per hectare of sweet potatoes.

Sweet potatoes are found in two broad categories, firstly, the staple type that has white or purple skin with white flesh (has high starch and dry content) and secondly, the desert type with orange skin and orange flesh (has high sugars and beta carotene content). The following are the common varieties of sweet potatoes found in South Africa; Blessbok, Bosbok, Ribbok and Koedoe (Omotobora, 2013). However, there are three types of sweet potatoes available for commercial production in South Africa; 1. Orange or copper skin with orange flesh (cultivars are Beaureguard, Hernmandez, Beerwah Gold, NC-3, LO-323, Centennial, Darby and Jewel), 2. White or cream with white or cream flesh (varieties are Hawaii, Kestel and Blessbok) and 3. Red or purple skin with white or cream flesh (varieties are Koedoe', Northern Star, Red Abundance and Rojo Blanco). Most varieties are selected based on the market demand especially in the case of commercial farmers. They have also been assessed based on their root shape and uniformity, marketable yield, skin and flesh attractiveness and plant vigour (Omotobora, 2013).

2.5 Constraints in sweet potato production

Developing countries experience low yields of sweet potato as a result of socio-economic, biotic and abiotic constraints (Kivuva et al., 2014). Yields may be reduced due to poor post-harvesting handling and storage facility, lack of processing skill, use of diseased varieties and a poor seed distribution system (Kivuva et al., 2014). Sweet potatoes that are cultivated between October and December are often affected by weevils because farmers rarely use pesticides for weevil control (Tewe et al., 2003; Kivuva et al., 2014). Rats and grasshoppers are also problematic when sweet potatoes are planted late. Most community farmers use traps to control rats and grasscutters (Tewe et al., 2003). It is advisable for farmers to use disease resistant cultivars and avoid fields that are infested with nematodes or other sweet potato diseases.

According to Unigwe et al. (2014), sweet potatoes vine also contain anti-nutritional effects such as trypsin inhibitors as well as cyanide, tannins oxalate and phytate. These anti-nutrients limit both human beings and livestock's utilization especially monogastrics if utilised raw. However, inhibitors may be destroyed through sun drying, boiling, steaming or grinding before utilization. Phytates are the same as phytic acid that have been found to accumulate in the seed of cereal grains, legumes and other plants. Phytic acids have the ability to bind proteins and minerals making it unavailable to animals due to lack of the enzyme phytase especially in monogastrics. In sweet potatoes phytate is also found in leaves of which are the fraction of sweet potato vines, (Unigwe et al., 2014). Phytic acid also inhibits gastrointestinal tyrosinase, trypsin, pepsin, lipase and amylase (Akande et al., 2010).

Cheeke (2005) reported that mould in sweet potatoes may restrict tuber or vine utilisation. Mouldy sweet potato tubers or vines are toxic to animals, due to 3-substituted furans (for example hepatotoxic sesquiterpene ipomeamarone) (Abonyi and Mochebe, 2014) produced as stress metabolite responding to fungal infestation (Thompson and Cheeke, 2005). Some farmers leave sweet potato vines on the field after harvesting as planting material for the following season or manure. This can easily become a habitat for pests, viruses and disease which has been reported to reduce production by 50% (Kivuva et al., 2014). Thus, usage of certified planting material is essential for yield production and storage but often problematic to rural farmers since not available or expensive to afford especially during the planting season.

2.6 Uses of sweet potatoes

Sweet potatoes have many potential applications and benefits in both human and animal's diets. Hence, they can be processed and utilised in many forms as food. Sweet potato roots are boiled and eaten or chipped dried and milled to flour which can be used to prepare snacks or used for making baby weaning food (Kivuva et al., 2014). Farmers may utilise almost all the parts of sweet potatoes. Apart from being food for human consumption or feed for animals, some sweet potatoes are rich in vitamin A such as orange fleshed sweet potatoes which helps in vision, skin and mucous membrane protection, proper cell growth and reproduction (Kivuva et al., 2014). In some developing countries sweet potatoes are used as raw material to produce starch, natural colorants and fermented products such as wine, ethanol, lactic acid, acetone and butanol (Duvernay et al., 2013; Kivuva et al., 2014). Thus, demand for sweet potatoes may increase especially in South Africa with a growing human population.

2.7 Sweet potato vines as stock feed supplement

Sweet potatoes are regarded as a high yielding crop, having acceptable palatability and are nutritious. Sweet potato vines are also believed to have medium to high amounts, which ranges from 10.82% to 20.58% depending on the cultivar and that might be enough to meet some livestock requirements especially ruminants (Baba et al., 2018). These characteristics, in addition to its high energy and moisture content, make it a suitable feed supplement for animals that are receiving low quality forage with lower moisture especially during drought and or winter. The tubers have a high carbohydrate content while the leaves are said to be richer in protein (Abonyi et al., 2014). The vines constitute of leaves, petioles and stems and the crude protein content in the leaves is higher, ranging from 260 to 330g/kg dry matter compared with 100 to 140g/kg dry matter in the stems (Abonyi and Machebe, 2014). It has been shown that the leaves make up approximately half of sweet potato vines' biomass. Thus if the leaves could be separated from the stems, a considerable improvement would be expected with respect to the dietary protein and amino acid supply (Khalid et al., 2013).

The intake of sweet potato vines may be high as they are believed to be easily fermented in the rumen (An, 2004; Khalid et al., 2013). Since sweet potatoes contain non-notable amounts of anti-nutritional factors, supplementation with sweet potato vines can help small holding farmers to cut down goats' production costs. Sweet potato containing feeds may provide enough crude protein and metabolizable energy to sustain goat growth rate and milk production even during drought, thus increasing production efficiency (Chakrabarti et al., 2014). Kariuki et al. (2001) reported an increase in grass feed crude protein percentage when supplemented with sweet potato vines. An increase in feed protein content may result in an increase in feed intake and rumen ammonia as well as the digestibility of protein, energy and organic matter. Thus, protein rich forages have the potential to improve utilization of poor quality grasses and crop residues.

It has also been reported that farmers producing sweet potato vines as forage should start defoliation (sweet potato vines harvesting) 20 days after planting. After defoliation, the sweet potato vines may be harvested at 20 days' interval. It is also suggested that sweet potato vines defoliation should be 50% of the total branches, to prevent excessive reduction of vines. Excessive defoliation might lead to reduction of tuber production (especially yield and size), thus there won't be tubers available for human consumption and marketing which is often the main reason for cultivation. Vines and leaves can also be pruned at day 75 after planting to harden tubers which may result in increased tuber production. Sweet potato vines for supplementary feeding may be available twice per annum i.e. 75 days after planting and at harvesting. This is more important especially when the farmer is focusing on growing sweet potatoes for tuber production and to prevent yield reduction when vines are frequently harvested (Lam and Ledin, 2004; Chakrabarti et al., 2014). Surplus tubers can also be fed to livestock, hence it could make a good source of energy (Megersa et al., 2013), and they can be fed fresh or as chips depending on the type of animal (Etiela, 2008). However, sweet potato tubers contain trypsin inhibitors therefore they should be boiled before feeding to monogastrics (Thompson and Cheeke, 2005).

2.8 Nutritional value of sweet potato forage

Sweet potato varieties vary in their feed potential for livestock. The variation has been reported in chemical composition among species, cultivars and plant components of a given variety (Aregheore, 2004; Hadgu et al., 2014). The chemical composition of forage species also vary with regions due to soil fertility, climate and farming practices (Kariuki et al., 2001). The nutritive value of forage may also be affected by factors such as variety, foliage component, voluntary intake and digestibility (Jata et al., 2011). Lam and Ledin (2004) also reported variation in nutrient value of sweet potato vines, based on level of maturity. It was found that, 20 days after planting, sweet potato vines had low dry matter and high protein content (9.25 and 23.6%, respectively) whereas at harvesting dry matter increased and crude protein content was reduced (18.1 and 17.2%, respectively). Therefore, it is essential to conduct chemical composition analysis more frequently during feeding to ensure the quantity and quality of nutrients that being fed to goats (Lam and Ledin, 2004).

Sweet potato vines are often available at both research stations, farmers' yards or abandoned on farms especially by rural farmers because there is little information regarding these varieties as feed for livestock and their chemical composition in South Africa. Therefore there is a need to evaluate the feed potential of sweet potato vines where chemical analysis of *in vitro* and *in vivo* digestibility will reveal its nutritive value (Antia et al., 2006; Hadgu et al., 2014). Dry matter production potential per hectare of certain varieties, ranges from 4.3 to 6 ton of sweet potato vines per hectare. In Table 2.2, Orodho et al. (1995) found that sweet potato vines contain up to 18.5% crude protein (CP), 42.0% nutrient detergent fibre (NDF) and 29.3% acid detergent fibre (ADF).

Table 2.2 Yield and quality of sweet potato leaves, petiole, stem and vines

Nutrient	Leaf	Petiole	Stem	Vines
DM tons/ha	0.78	0.52	1.17	2.47
Moisture%	81.8	93.0	84.5	86.4
Crude protein%	26.3	8.0	8.4	18.5
NDF%	35.6	29.4	48.6	42.0
ADF%	22.0	28.8	39.2	29.3
ADL%	6.2	2.7	6.8	6.6
K%	4.8	7.5	5.5	5.6
Ca%	0.9	0.8	0.5	0.7
P%	0.5	0.3	0.3	0.4

Source: Orodho et al. (1995)

Sweet potato vines may also have a digestibility that is greater than 62% depending on the variety (Khalid et al., 2013). Orodho et al. (1995) reported that sweet potato vines have the potential of being a milk replacer for calves. This confirms that sweet potato vines may be used to feed lactating does which may reduce the amount of milk required by kids per day. Feeding sweet potato vines as a milk supplement may reduce the demand for milk production burden from does during drought or winter periods. Thus, animals' body condition may improve, allowing it to conceive and nourish foetus with less lactating stress.

According to Hadgu et al. (2014), sweet potato vines have a dry matter content of about 20% as compared to the 17.2% reported by Orodho et al. (1995). This may supress feed intake due to lower dry matter. It may be recommended to wilt vines a bit before feeding or else adding some additives when ensiling. However, high moisture content can be an advantage in dry areas or during seasons where there is a shortage of water, hence will reduce water required by goats (Hadgu et al., 2014).

2.8.1 Inhibitors in sweet potatoes

Trypsin is an enzyme that is found in the digestive system and is primary necessary for protein hydrolyses. There are several compounds that are found in sweet potatoes and other forages (legumes, browse species, grains etc.) that are strong inhibitors of trypsin. Trypsin inhibitors are those compounds that hinder the metabolism of proteins hence nutritionally unfavourable to animals. However, according to Akande et al. (2010), trypsin inhibitors have no adverse effects on ruminants because they are degraded in the rumen. Trypsin inhibitors are much higher in raw soybeans than boiled ones. Different processing methods such as drying, boiling and grinding can inactivate protease inhibitors (Zhang et al., 2012; Unigwe et al., 2014). In other legumes, trypsin inhibitors may be rarely found in amounts higher than acceptable quantities for animals. Sweet potato tubers contain about 28% (3.5 to 7.0mg/g) of trypsin inhibitor which is similar to that of raw soybean while in sweet potato vines they are said to be very low (<1mg/g) (Zhang et al., 2012). Therefore, trypsin inhibitors in sweet potato vines may have less or no detrimental effect on animal feeding.

2.8.2 Tannins in sweet potato plants

Some fodder crops contain anti-nutritional factors such as tannins (Phale and Madibela, 2006). The name tannins was derived from a French word tan meaning the bark of a holm oak and other trees used for tanning (Frutos et al., 2004). In tanning, tannins (acid chemical compound) are used for treating skin and hides making them more durable and less susceptible to decomposition (Covington, 1997). Tannins are plant secondary metabolites which are also called proanthocyanidins. Tannins are widely distributed throughout the plant kingdom, especially among trees, shrubs and herbaceous legume plants. They are richer in plants around the tropics and semi-arid areas. Tannins are mostly found in abundance in plant parts that are more likely to be eaten by herbivores e.g. new leaves and flowers (Frutos et al., 2004), hence tannins are produced mainly to protect plant herbivory.

Tannins are classified into two groups called condensed and hydrolysable tannins (McSweeney et al., 2001; Makkar, 2003). These tannins occur in different structures which may be found combined in other plants (McSweeney et al., 2001). Tannins have both adverse and beneficial effects on animals. These effects depend on their concentration and nature as well as other factors such as animal species, physiological state of an animal and composition of the diet (Makkar, 2003). Environmental and seasonal factors have an effect on the concentration of tannins in plants. Factors such as high temperatures, water stress, extreme light intensities and poor soil quality increase the tannin content of plants (Frutos et al., 2004). The concentration of tannins also increase as the plant matures (Waghorn, 2008). High tannin concentration can cause gastritis and damage to the intestinal mucous membranes (Silanikove et al., 1996).

According to McSweeney et al. (2001) tannins have the ability to bind with dietary protein, polymers such as cellulose, hemicellulose and pectin, and even minerals which can affect the digestion of these compounds or absorption of the minerals. Tannins in ruminants might result in a decrease in nutrient utilization particularly protein, growth, palatability and feed intake as well as enzyme activities (Makkar, 2003). Hydrolysable tannins may be degraded in the digestive tract to phenols and sugar. The release of phenols can be absorbed and cause toxicity in animals (Waghorn, 2008). Some fodder plants can remain green and maintain high levels of proteins during drought. These plants produce tannins as a protective strategy against herbivory. As a result, feeding such crops as feed supplement may have a negative effect on animal productivity (Phale and Madibela, 2006). However, the quantities and type (condensed or hydrolysable) of tannins may have a positive or negative impact on animal performance.

2.8.2.1 Condensed tannins

Condensed tannins synthesis occurs in the cell cytoplasm from phenylalanine and acetate precursors to form catechin units in a vacuole (Waghorn, 2008). Condensed tannins are widespread in dicotyledonous species, thus there is a possibility to be present in sweet potatoes too. It is often found in seed coats of temperate species. In tropical species condensed tannins may be found in high amounts that may exceed 300g/kg dry matter. The quantities of tannins may differ from one plant to the other (Phale and Madibela, 2006). According to Waghorn (2008), plants do not synthesise condensed tannins only to provide protection against herbivory but also for defence against diseases. Tannins are also necessary to preserve energy to be used when required and also crucial for preservation of nitrogen.

The interaction between condensed tannins and protein complex is influenced by many factors such as pH, composition and molecular weight of both the condensed tannin and proteins (Woodward et al, 1989; Barnick, 2002). Condensed tannins bind to protein by hydrogen bonding at near pH i.e. 6.0 to 7.0, in the rumen to form condensed tannin-protein complexes. Condensed tannin-protein complexes then dissociate and release bound protein at a pH less than 3.5 in the abomasum. Thus, condensed tannins may create a protective mechanism against the degradation of protein in the rumen and increase amino acid supply to the abomasum and small intestine. Hence resulting in an improved nutritional status of an animal (Min and Hart, 2003).

Tannins may also form complexes with starch, cellulose and hemicellulose. Tannins can reduce fibre and organic matter digestibility by forming indigestible complex with cell wall carbohydrates. Neutral detergent fibre digestibility may also be reduced due to high tannin concentration in plant forages, and negative effects on protein metabolism can occur (Woodward and Reed, 1989). Although condensed tannins do interact with carbohydrates, predominantly starch, their affinity for carbohydrates seem to be much less than that for proteins (Min and Hart, 2003). Higher condensed tannin concentrations may significantly depress feed intake, digestibility and animal production. Since condensed tannins have a potential to bind and precipitate protein, digestive enzymes that are protein in nature are not omitted hence inhibiting digestive enzyme activities and ruminal bacteria growth and metabolism.

Tannins can be beneficial if the level is low in feed because bound proteins in the rumen will be released in the abomasum hence increasing the amount of degradable protein and supply of essential amino acids to the alimentary canal (Kongmanila et al., 2012). Phale and Madibela (2006), reported values of 67.7g/kg condensed tannins in sweet potato vines which can be regarded as a lower value compared to *Accacia nilotina* that contains about 100g/kg condensed tannins. The normal range of tannins recommended in animal forage is 100g/kg and below although animals have been found browsing on plants with a much higher concentrations of tannins. Thus, sweet potato vines can be used as supplement with anticipation of minimal detrimental effects on goats.

2.8.3 Interaction between forage chemical composition and its digestibility

The nutritive value of a feed is the function of its chemical composition, intake and digestibility. The digestibility of forage species is limited mostly by high fibre content, lignin and other phenols such as tannins (Sanon et al., 2008). Digestibility is the difference between the amount of feed ingested and the amount of feed excreted. Digestibility and digestible energy are expressed as a fraction or percentage of the original amount ingested (feed intake). Digestibility is positively related to the concentration of nutrients in forage and its intake. Hence the larger the quantity of nutrients in the feed, the easier the feed can be digested. The digestibility of tropical and subtropical species is lower than that of temperate species due to high cell wall content (Tainton, 2000b). Lower digestibility is as a result of structural characteristics such as higher lignification, low proportion of mesophyll to parenchyma and bundle sheath material (Tainton, 2000b).

Neutral detergent fibre (NDF) consists of four main chemical components i.e. cellulose, hemicellulose, lignin and cutin. Cellulose and hemicellulose form the largest in quantity (Mokoboki et al., 2005; Singh et al., 2010). Cellulose, lignin and silica contents together form the acid detergent fibre (ADF) (Singh et al., 2010). Neutral detergent fibre components are potentially digestible but due to their complex chemical structures, they are not easily digested by rumen microbes. Lignin and cutin are indigestible in both the rumen and lower intestines. Lignin and cutin inhibit the digestion of cellulose and hemicellulose either by physical or chemical shielding. Thus as the lignin and cutin levels increase in the forage, the digestibility of its fibre will decrease (Mokoboki et al., 2005). Polysaccharides such as cellulose, hemicellulose and pectin are highly digestible by rumen microbes (Cordron et al 2006). Lignin and phenols also contribute to the rigidity of plant cell walls but present a limiting effect on carbohydrate digestion. Lignin restricts the access of microbes and enzymes to carbohydrates rather than protecting specific carbohydrate components (Singh et al., 2010).

The intake of dry matter depends on the proportion of fibre, lignin and nitrogen levels in foliage. The digestibility of fibre is very low when compared to other forage nutrients because of its complex structure. As fibre content increases the nutrient value and palatability of feed decreases, thus limiting its digestibility. High levels of lignin limit microbial digestion which in turn influences the overall digestibility of cell wall components hence a decrease in forage take (Sanon et al., 2008). The variation in organic matter, crude protein and fibre content may be due to differences in plant growth and maturity. The differences in availability and growth of forage species may as well contribute in factors influencing the nutrient content in different seasons. Some indigenous forage species possess high nutrient content and dry matter digestibility which may increase the need of using them as a forage supplement for livestock production (Sanon et al., 2008).

2.9 Goats' nutritional requirements

Rashid (2008) suggest that feeding plans should meet the protein, energy, vitamins and mineral requirements of goats. The condition of goats prior diet formulation should be taken into consideration. It is essential to supply sufficient nutrients especially protein required by ruminants for rumen microbe functioning. Deficiencies in nitrogen may impair rumen function and reduce microbial protein availability as a result the animal may lose appetite hence intake reduction (Katongole et al., 2009). Active microbial population in the rumen is essential for digestion and extraction of nutrients found in the feed stuff. During drought or winter the protein content of feed can be lower than 6% which indirectly limits growth of rumen microbes hence digestion. A decrease in digestion implies restriction of protein and energy absorption by an animal (Tolera et al., 2000).

The nutrient requirement of goats is determined by age, sex, breed, production system, body size, climate and physiological state and stage (Rashid, 2008). It is very important to plan feeding strategies so that they meet the nutrient requirements of animals. Supplementary or intensive feeding of goats is essential during growth, lactation, pregnancy and winter periods. A proper nutrition plan is required especially during lactation where the demand of protein for does and growing kids is high (Rashid, 2008). According to Hadgu et al. (2014), crude protein in feed stuff for ruminants should be more than 8% to be able to cater for minimum ammonia (70mgN/L) required by rumen microbes for optimum digestion. Lower crude protein intake might lead to reduced feed intake. Actually, goats require a minimum of 11.3% crude protein for growth and 12% crude protein during lactation. Ruminants also require less than 30% NDF and 19% ADF for healthy rumen (Hadgu et al., 2014). Some plants tend to have high tannin concentrations which adversely affect the performance of livestock hence tannin concentration affects feed intake, growth and digestibility. However, according to Turner et al. (2005) goats can tolerate and perform well when browsing on plants with relatively high levels of tannins compared to cattle and sheep.

2.10 Effects of sweet potato vines on gastro-intestinal nematodes

Gastro-intestinal nematodes are major problems in small ruminant production systems especially in developing countries where subsistence farmers can hardly afford chemicals for treatment of their livestock. This reduces productivity as well as profitability in goats' production system. Even when famers try to buy medicine to treat their animals, the treatment still become less effective as gastro-intestinal nematodes tend to become resistant with time because of repeated chemical treatments (Coffey et al., 2004). It is also always advisable to use less chemical treatment to reduce environmental pollutions. Thus, making it more limited and costlier to try and combat gastro-intestinal parasites using chemicals. It is, therefore, important to investigate other methods of fighting nematodes that are less dependent on chemotherapy. This will assist in stimulating the immunity of the host animal against gastro-intestinal nematode infestation thus reducing mortality especially in kids so as to increase productivity (Knox et al., 2006; Etela et al., 2008). That is why there is more ongoing research on natural plant products that can kill worms to reduce the use of chemicals and anthelmintic drug resistance (Laudato and Capasso, 2013). Examples of such natural plants includes Acacia species, Alfalfa, Chicory (Laudato and Capasso, 2013; Peña-Espinoza, 2016).

Gastro-intestinal nematode infections adversely affect feed intake and efficiency of feed utilization in the host animal, depending on the type of parasite and location in the gastro-intestinal tract (GIT) (Coop et al. 2001). The extent to which the parasitized host animal can resist infection is greatly affected by nutrition. Body protein is necessary for repair, replacement and reaction to damage or lost tissue which implies that an animal's body condition will be affected. Thus, growth and production performance of a parasitized host animal may be induced by improved nutrition. Hence immunity against the parasites may be affected by stages of growth and nutrient intake limitation (Coop and Kyriazakis, 1999). Thus, nutrient manipulation may be necessary to influence a host animal's ability to maintain a reasonable level of productivity in the face of parasitic challenge (resilience) and host animal's ability to limit the establishment, growth rate, fecundity and/ or persistence of parasitic population.

Gastro-intestinal nematodes in ruminants are mostly helminthic parasites. They impair health by decreasing appetite, inducing diarrhoea, anaemia and in severe cases death. Nematodes also reduce productivity as a result of poor growth and production e.g. the reduction in body-weight gain by < 70% within a few weeks of infection (Athanasiadou et al., 2005). Jackson et al. (2011) reported that about 28% of the money spent on animal health worldwide goes to pesticide purchases. Therefore, it is essential to introduce healthy and less expensive means of fighting nematodes in ruminants.

Table 2.3 shows the different types of gastro-intestinal nematodes that affect ruminants and their side effects. It is essential to check whether sweet potato may be one of the bioactive forages that contain compounds which are active against pathogens or parasites affecting goats. According to Coffey et al. (2004), it is crucial to know how parasite infestation occurs. Parasites infestation occurs when the animal consumes the infective larvae stage of the parasite from contaminated pasture and/ or hay. Larvae often develop from an egg that was passed through the faeces of an infected animal. If the goat has no adult worms, then no infestation can occur.

Table 2.3 Gastro-intestinal nematodes of farm animals (sheep, goats and cattle)

	Site infected	Nematode	Consequences of parasitism
Sheep and goat	Abomasum	*Haemonchus contortus*	Anaemia
		Teladorsa circumcincta	Reduced feed intake
		Nematodirus battus	Dehydration
	Small intestine	*Trichostrongylus colubriformis*	Reduced feed efficiency
		Trichostrongylus vintrinus	Reduced feed efficiency
Cattle	Abomasum	*Haemanchus placei*	Anaemia reduce feed intake
		Osertagia ostertagi	Reduced feed intake
	Small intestine	*Cooperia oncophora*	Reduced feed efficiency
		Cooperia punctate	

Source: Athanasiadou et al. (2005)

2.10.1 Anthelmintic resistant in goats

Anthelmintic resistance may be defined as a condition where the normal dosage of anthelmintic drug does not stimulate reduction in worms or excreted eggs (Silvestre et al., 2002). According to Paolini et al. (2005) there had been a constant development and widespread diffusion of anthelmintic resistance within worm population worldwide. This constitutes a major constraint especially in small stock mostly in regions like South and Central America as well as South Africa where worm infestation is more prevalent and the cost of treatment may be very high (Jabbar et al., 2006).

There are several factors that may contribute to the development of anthelmintic resistance; 1.Treatment frequency (especially in regions where animals are dewormed regularly), 2. Continuous use of single anthelmintic may also lead to development of anthelmintic resistance, 3. Under-dosing also contributes in anthelmintic resistance since it may allow the survival of heterozygous resistant worm, 4. The use of poor quality drugs may also contribute in anthelmintic resistance, 5. Other factors such as moving animals from one place to another and keeping goats and sheep flock together may increase chances of anthelmintic resistance (Jabbar et al., 2006). However, anthelmintic resistance may be minimized by applying an integrated parasitic management approach. This approach may include use of resistant animal breeds, nutritional and parasite interaction, grazing management and anthelmintic treatments.

2.10.2 Effect of proteins on gastro-intestinal nematodes

According to Hoste and Torres-Acosta (2011), there is too little information concerning the relationship between dietary protein and gastro-intestinal nematodes. Resistance and resilience to nematode infection are influenced by diet, particularly by metabolizable protein supply (Etter et al., 2000). Protein supplementation during the course of parasitic infection has been reported to reduce the level of parasitism in sheep, by enhancing their ability to improve immunity against parasites (Athanasiadou et al., 2005). An increase in the level of digestible protein in the diet has been associated with improvement in resistance and resilience of animals (Etter et al., 2000; Athanasiadou et al., 2005). According to Hoste and Torres-Acosta (2011), feeding protein supplements to does or ewes around parturition might alleviate nematodes partly or even totally. Improving level of protein in nutrition before weaning may have a significant benefit in maintaining live-weight gain and lower faecal egg counts. Hence feeding high level of nutrition (energy and protein) could help to improve resilience (especially against *H. contortus* infections) of goats consuming low quality forage species during both wet and dry seasons (Hoste and Torres-Acosta, 2011). Etter et al. (2000) reported that lambs infected with *Trichostrongyle* nematode (such as *Teladorsagia circumcincta*, *Teladorsagia colubriformis* and *H. contortus*), may have a better immune response when supplemented with protein. This was due to the observation of decreased worm fecundity and/or to a reduction in worm populations in their digestive tracts. Therefore, indigenous forages that can improve protein concentrations in goats' diet can potentially improve animal health as well as their body condition.

2.10.3 Anthelminthic effect of condensed tannins

According to Min et al., (2003) and Waghorn, (2008) condensed tannins have anthelminthic effects. The consumption of forage containing tannin may reduce gastro-intestinal nematode numbers and improve animal performance, through direct and indirect mechanism. Plant secondary compounds may be of short term or long-term solution in the control of parasites in ruminants. Short term implies that animals will be fed forages rich in secondary metabolites before returning to their conventional grazing fields (Athanasiadou et al., 2005). The anthelminthic value of condensed tannins is a benefit to ruminants (especially small ruminants such as sheep, goats and deer) since it helps to reduce the intestinal parasite burden, that might affect their productivity. Condensed tannins effectively reduce adult *Haemonchus contortus* numbers in herbivores and lower the fecundity of Cooperia curticei (Waghorn, 2008). Athanasiadou et al., (2005) and Waghorn (2008), reported that condensed tannins consumption (of up to 60g/kg of dry matter) can reduce faecal egg counts (FEC), worm fecundity and worm numbers in parasitized sheep. Condensed tannins may also reduce worm fecundity and numbers in goats infected by either *T, colubriformis* or *Teladorsagia circumcincta* or *H. contortus* (Waghorn, 2008). Tannins have a direct and indirect effect towards gastro-intestinal nematodes. Condensed tannins binding to protein reduces the nutrients available to larvae which may lead to larvae death. The binding of tannins to larvae through the cuticle (rich in glycoprotein) might result in larvae death as well. Condensed tannins are not absorbed in the digestive tract but are released with faeces that may affect hatchability of nematode eggs hence reduce pasture contamination (Iqbal et al., 2007).

Parasitized goats fed *Sericea lespedeza* containing 46g extractable condensed tannins per kg dry matter lowered daily faecal egg count from 173 x 10^4 to 45 x 10^4 and reduced egg development to L3 larvae from 99 to 58%. Coffey et al. (2004) suggest that farmers should know how the parasite infestation occurs to better understand its management. It was also suggested that farmers should be able to use clinical symptoms to identify sick animals on farms using FAMACHA. FAMACHA was developed in South Africa for the identification and grading of anaemic animals caused by *H. contortus*. This method scores animals from 1 to 5 based on their eyelid colour where; 1 = no infection, 2 = no infection but on border line, 3 = infected and dangerous 4 = infected and fatal and 5 = severe infection. Thus, management is a crucial tool for sustainable control of gastro-intestinal nematodes because only sick animals will be treated, hence limiting resistance.

Chapter 3

Knowledge and perception of small holding farmers on supplementation and feeding of sweet potato vines to goats

3.0 Abstract

This study assessed the knowledge and perception of goat farmers on indigenous forage supplementation especially sweet potato vines to goats. The data were gathered by administering a total of 105 structured questionnaires using face-to-face interviews. The questionnaire investigated the following about the rural farmers, biodata and some background, livestock inventory, supplementary feeding and perception towards sweet potato vines and cause of any losses incurred. The results revealed that majority (56.2%) of the farmers were males and 43.8% were female. The majority (71.4%) of households reared goats for socio-cultural purposes whereas few, (15% and 9%) reared for income generation and consumption, respectively. Majority of farmers (71.4%) were aware and practice some sort of supplementary feeding but it was mainly to lure animals to the kraal. some farmers bought feed (34.3%) while others used crop residues (26.7%) or indigenous trees branches (9%). It was confirmed that most farmers (72.4 %) cultivated sweet potatoes for different purposes such as income generation (53.3%), consumption (27.5%) or both (8%). Sweet potato vines were being discarded as waste or burnt (32.4%), left on the field as manure (25.7%), conserved as propagation material (8.6%) or randomly fed to livestock (7.6%). Nevertheless, most of the farmers (78.1%) rejected the use of sweet potato vines as feed for livestock. These surveys indicate that more interventions are required to develop farmer's knowledge on vines feeding which is possible through training and workshops for them to be able to supplement in a profitable manner and eradicate the myth of vines being fatal to goats or making them diarrhoea prone.

Keywords: Crop residues, feed, Ipomoea batatas, supplementation, sweet potatoes vines, traditional knowledge

3.1 Introduction

Livestock is a major role player in supplying protein to people in the form of meat, milk and skin especially in rural communities where plant protein sources are scarce and expensive (Hodges et al., 2014). Livestock also contribute enormously to employment globally which is not different in South Africa where the livestock sector employs more than 245 000 workers (Meissner, 2013). Small ruminants (goats and sheep) are very important animals to human kind because they are easy and cheap to manage. Most of the goat products (such as hides, meat and milk) are valuable, and may be efficiently used for income generation. In northern KZN, the skin is very important for traditional ceremonies as well as clothing. In fact, goats are multipurpose animals, used for providing household income, traditional ceremonies, meat and fibre. Chevon (goat meat) is consumed mostly in rural areas of semi-arid areas of Africa; as a result, it is regarded as poor men's meat. It is also on rare occasions consumed in urban areas (Dubeuf et al., 2004). Goats' dung and urine play a crucial role as an alternative to synthetic fertilizer in crop production (Messier et al., 2013). Some farmers sell goats to purchase inputs (such as seeds, herbicides, fertilisers etc) for crop production, making its role in the food production chain more crucial. The income from goat production also contributes towards the education of children within the rural poor community (Kusina et al., 2002). Furthermore, goats are used for control of bush encroachment in areas where bush or forests dominate. They have been recorded to consume shrubs protected by thorns and phenolic compounds (Alvarez-Martinez et al., 2016). Goats are also used for cultural ceremonies such as lobola, wedding gifts, damages etc. and also kept for prestige which restores family importance and respect in the community (Messier et al., 2013), thus enhancing the social status of the family.

Most goats in Southern sub-Sahara are found in rural areas. There are several different breeds of goats; however, the most common breeds of Southern Africa are Nguni, Matebele, Mashona, Tswana and Landim (Gwaze et al., 2010). These breeds are also regarded as indigenous, with Nguni breed mostly found in the KwaZulu-Natal and Eastern Cape provinces of South Africa. The main challenges for goat production in rural areas are shortages of feed, diseases especially caused by helminths, poor management and lack of marketing strategies (Gwaze et al., 2010). Lack of knowledge on subsistence farming systems being the major challenge as well as farmers' traditional beliefs (e.g. witchcraft) around their production system which also need attention since it affects livestock management practices (Hesterberg et al., 2007).

Addressing the issue of limited forage for goats may have a positive impact in resolving the above-mentioned constraints. There are traditional food crop residues such as cassava, banana, nuts haulm, sweet potato etc. that could be a solution if exploited and managed properly. However, they are limited in certain areas, therefore, application will greatly depend on what is available in a particular area. Sweet potatoes are utilised as a food crop almost in the whole world due to its high energy status, but the residues (vines) are not properly exploited especially in Southern Africa. However, sweet potato residues are being utilised as feed in some countries of Africa, especially those in the western part e.g. Kenya, Rwanda, Uganda, Nigeria, and Ethiopia (Peters, 2008; Okereke, 2012; Hadgu et al., 2014). Apart from use as animal feed, the leaves of *Ipomea* species are recorded to have medicinal properties (Meira et al., 2012). Moreover, there is very little or no information about farmers feeding sweet potato to ruminants in the northern KwaZulu-Natal region, yet there seems to be more households getting involved in its farming. This information needs to be investigated to confirm the number of farmers practicing supplementary feeding especially with sweet potato vines to ruminants. If the latter is not the case, a further investigation to justify non-existence should be conducted or a need for application. Furthermore, farmers in subsistence environments are less involved in the cultivation of pastures for livestock feeding (Maassa et al., 2013), therefore more interventions are required.

Literature shows that several studies have been conducted (Hesterberg et al., 2007), to realise the potential of goat commercialisation and the efficacy of goat meat as animal protein. However, some studies suggest employing different goat production strategies such as feeding nutritional feed in the form of concentrate or legumes or other comparable nutritious crop residues such as banana leaves, cassava residues and sweet potato residues which can improve goat production as well as meat quality (Mergesa et al. 2013). It is also important to consider beliefs and ways in which farmers do things in their farming business. Hence small holding farmers may have management strategies that differ with commercial farmers in certain ways to suit their limited resources (Dossa et al., 2007). Therefore, there is a possibility of blending this information for a better production system strategy if investigated.

Apart from the lack or shortage of resources such as land in a small holding environment, Maassa et al. (2013) regarded lack of farmers' readiness to cultivate forage for livestock as a serious constraint to animal nutrition and consequently production. It was said to be very expensive to produce since most inputs such as seeds and fertilisers had to be purchased. The shortage of water may also be a challenge, as irrigation may be required to supplement rainwater in certain fields especially in winter. Installing irrigation systems and maintaining them is expensive, thus making it impossible for the small-scale farmers to consider cultivating pastures for livestock. Cultivated pastures are also labour intensive. However, there are some food crops that serve a dual purpose, such as feeding humans and livestock. Food crops such as grain produce, which is edible for both humans and livestock, are more nutritious than grass. Stovers produced from grain crops, may be utilised as feed for livestock where farmers are properly informed. Crop residues play a crucial role in livestock production as a source of feed especially during periods of shortage such as in drought and winter. It increases the amount of fodder available per animal unit, thus increasing overall fodder production (Rao, 2003). Some food crop cultivars can withstand harsh conditions such as drought, hence they are available to be utilised by livestock when there is a shortage of feed. Natural pastures seem to be reduced due to increasing human and livestock population, which also contributes to the shortage of fodder (Mekoya et al, 2008). As a result, various fodder development strategies are being employed to ensure there is enough quality fodder available per animal unit. Water is said to be a source of life in a living organism, thus required for growth, development and performance of goats. However, its unavailability and quality had been a constraint in some parts of South Africa including KwaZulu-Natal especially due to drought (Tsheole, 2016). Drought results in very hot sunny days that make the demand for water rise in both human and animals, as a result, some animals die due to lack of water. Therefore, alternative feed sources with high moisture can play a vital role. The marketing of goats both live and chevon is a challenge. The market price is not clear and often informal. It is mostly controlled by consumers' needs based on gender, colour and age, not mass and quality as for other livestock products (Tsheole, 2016). Chevon is not readily accessible in both commercial and informal markets, thus more studies and interventions are required to overcome the aforementioned constraints to ensure great performance and profitability in goat production.

Lastly, rural farmers' general knowledge on goat production may be limited, since access to information on goat production and reproduction is also a challenge (Meissner et al., 2013). As a result, goats may not perform to their full potential. Farmers, especially in a rural area or on small holdings, have their knowledge, beliefs, experiences and way of doing things concerning livestock production which includes feeding, breeding, animal health and overall caring of the animal. Their farming system is often controlled by the availability of their limited resources. Thus, there is need to study and validate information that might be of help in the farming community at large. Therefore, the objective of this study, was to determine the knowledge and perception of small holding farmers, concerning feed supplementation and feeding sweet potato vines to goats.

3.2 Methodology

3.2.1 Study area

Data for the survey was collected at KwaMthethwa Area (seven wards), a community of Umhlathuze Municipality, in the KwaZulu-Natal province of South Africa which is found at 28°31'S latitude and 31°51'E longitude. KwaMthethwa receives rainfall of about 900 mm per annum and has a mean temperature of 26°C per annum (Kunene et al., 2015).

3.2.2 Farmer selection procedures

The focus of this study was more on community farmers who owned livestock. A total of 105 farmers, from fifteen homesteads from each of the seven wards were chosen randomly with the help of google maps for interview. They were interviewed with the aim of evaluating the knowledge of farmers on supplementary feeding and their perceptions towards feeding sweet potato vines to goats. The farmers were chosen with the help of extension officers who informed them about the visit. In a subsequent meeting, they were presented with an informed consent form translated in isiZulu and the interview was conducted in IsiZulu which is the farmers' vernacular language.

3.2.3 Data collection

Data was collected using a structured questionnaire that involved four sections labelled as A, B, C, D. Section A: the biodata and some background information of the farmer, Section B included livestock inventory to find out the type and quantity of livestock a farmer owns. Section C consisted of questions in connection with supplementary feeding as well as farmers' perception towards sweet potato vines as animal feed. Lastly, Section D was about the type of diseases in the area. Questionnaires were written in English and translated into isiZulu (farmers' local language).

A meeting with community leaders (chief and counsellors), extension officers, veterinary officers and ward counsellors was conducted prior to a survey requesting a permit to conduct the survey and after to validate information collected. Farmers' participation was voluntary, and they were allowed to withdraw at any time during the survey if they wished to do so. Interviews were only conducted after consent forms had been signed indicating their willingness to participate freely as stipulated by the Ethical clearance number UZREC171110-030 PGM 2016/292. Data collection was done by the researcher to ensure correctness of data and assisted by extension officer and research colleagues from Owen Sithole College of Agriculture (OSCA) Research Station.

3.2.4 Statistical Analysis

A frequency procedure of SPSS (2015) was used to compute descriptive statistics pertaining to household demographics and household duties in livestock activities. A chi-square test was used to determine the association between nutrition and diseases (to check whether goat performance is linked to nutrition or diseases).

3.3 Results

3.3.1 Demographic information of participants

Demographic information of participants is presented in Table 3.1. The results showed that the number of males practising agriculture was significantly higher as compared to the females. In this study, the number of participants varied according to age group, age group 56-65 had the highest participants while 18-28, 26-35 and 36-45 had the least. The literacy level was also high as most of the participants had done primary and high school studies.

Table 3.1 Demographic characteristics of participants

	No of farmers	***Percentage (%)***
Gender		
Male	59	56.2
Female	46	43.8
Total	105	100.0
Age of Respondent		
18-25	16	15.2
26-35	16	15.2
36-45	16	15.2
46-55	18	17.1
56-65	22	21.0
65+	17	16.2
Total	105	100.0
Level of Education		
Never	26	24.8
Primary level	31	29.5
High School	48	45.7
Total	105	100.0
Occupation		
Farmer	99	94.3
Other	6	5.7
Total	105	100.0

3.3.2. Livestock inventory

The livestock inventory is shown in Table 3.2. Out of 105 farmers interviewed 45.7% of them owned between 1 and 10 number of cattle. Most farmers had no sheep while goats were the most farmed animal though it was in small numbers per household.

Table 3.2. Livestock inventory (cattle, sheep and goats) in percentage

Livestock Numbers	Cattle %	Sheep %	Goats %
0	54.4	92.4	6.6
1-10	40	4.75	51.5
11-20	4.75	1.9	26.7
21-30	0.95	-	9.5
31-40	-	0.95	1.9
41-50	-	-	1.9
51+	-	-	1.9
Total	100	100	100

3.3.3 Purpose of goat farming

The reasons for keeping goats varied from prestige to income then consumption as shown in Figure 3.1. The majority of farmers kept goats for tradition or prestige followed by those who were making income from goat production while the least number of farmers kept goats for consumption.

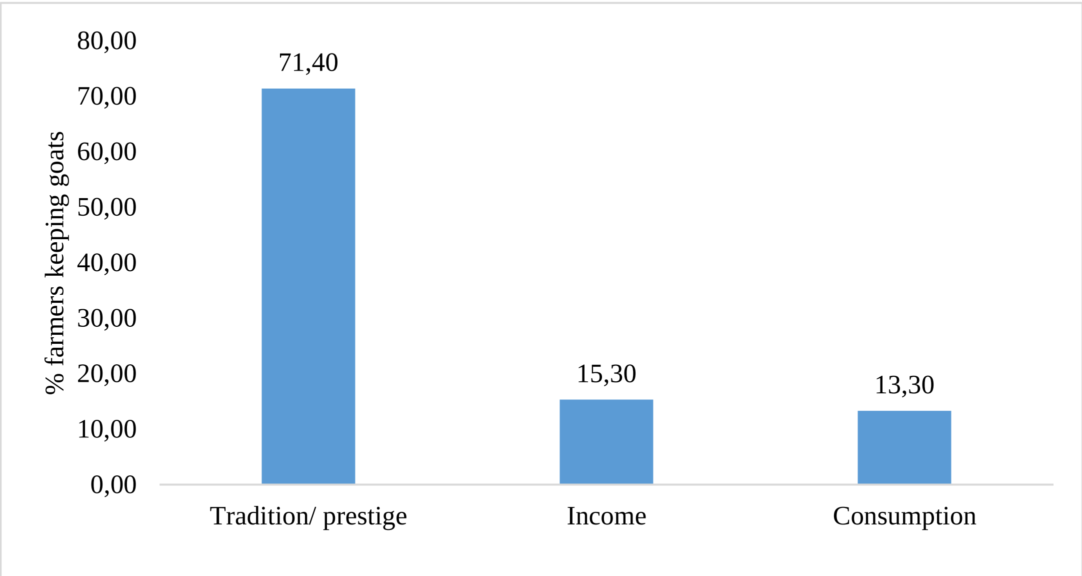

Fig. 3.1 Purpose of goat farming

The results from supplementary feeding showed that most farmers were aware and do practice some sort of supplementary feeding, whereas only a few of the farmers were not supplementing (Fig. 3.2).

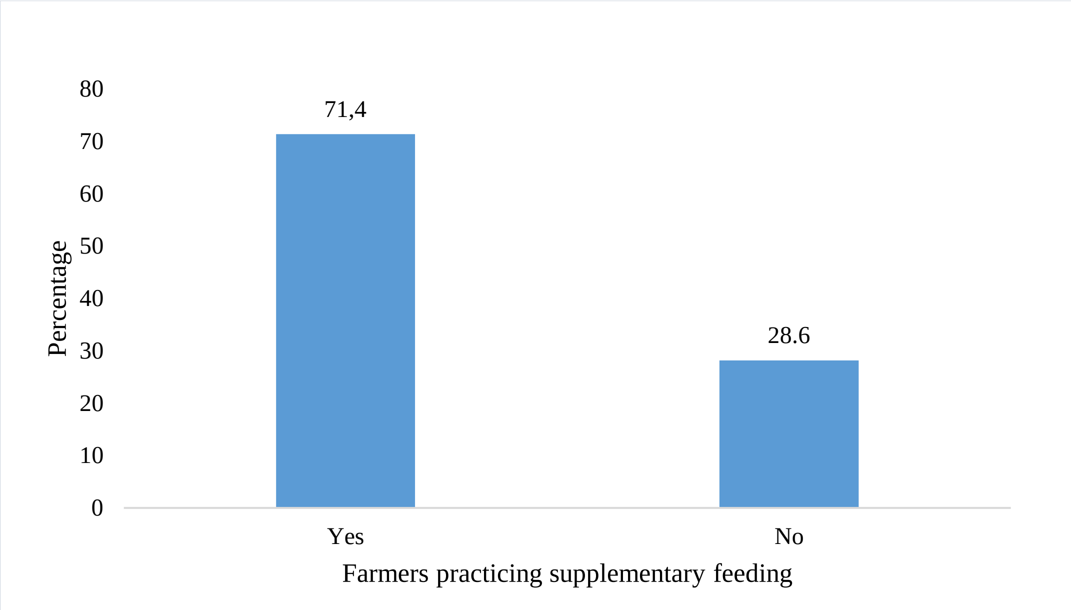

Fig. 3.2 The percentage of farmers practising supplementary feeding.

3.3.4. Supplement source for goats

The participants were using supplementary feed from different sources of feed. Supplementary feeds used by farmers were either bought or from crop residues or from indigenous trees (Fig. 3.3). Supplementary feed was bought by a few farmers.

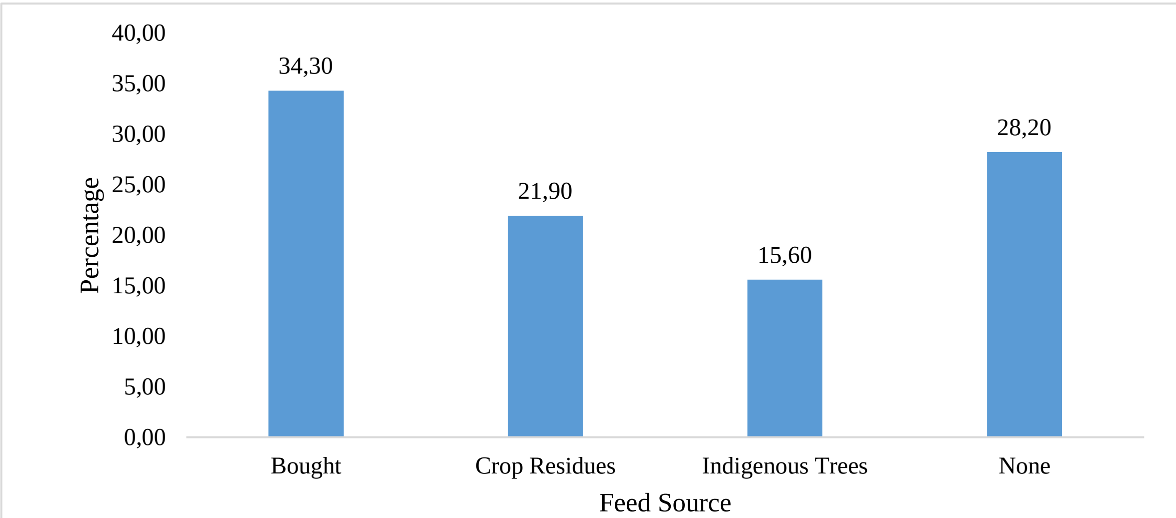

Fig. 3.3 Showing material used as a source of feed for supplementary purposes.

3.3.5 Farmers' perception on use of sweet potatoes vines as feed supplement for goats

The majority of the farmers were cultivating sweet potatoes, whereas only a few of them did not (Fig. 3.4).

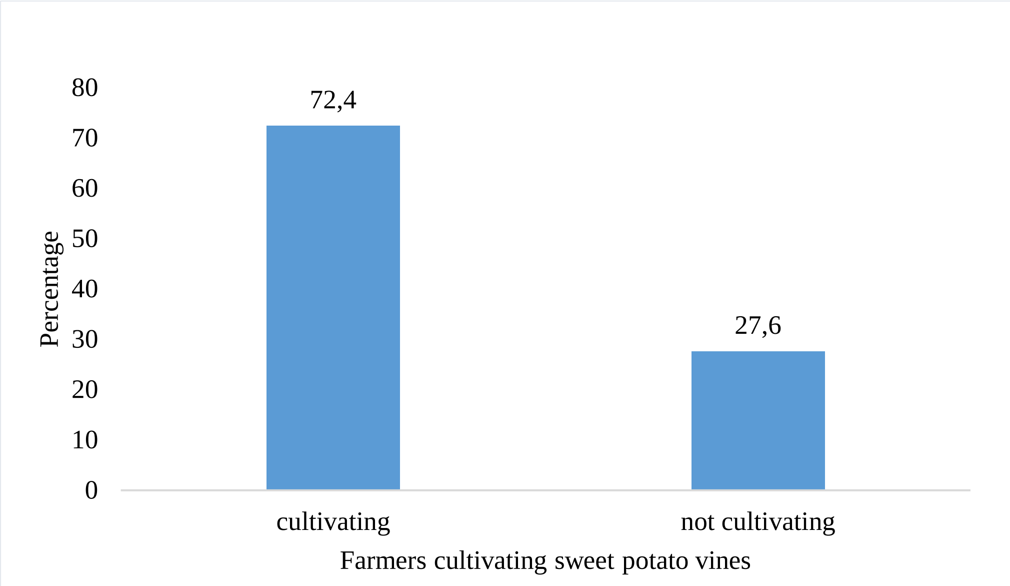

Fig. 3.4 The percentage of farmers who cultivate sweet potatoes or not

The possible reasons reported by farmers for cultivating sweet potatoes are presented in Figure 3.5. Most of the farmers were cultivating sweet potatoes for consumption (51.3%) while some were using it as a source of income (25.5%). However, only a few of them were cultivating it for both consumption and income.

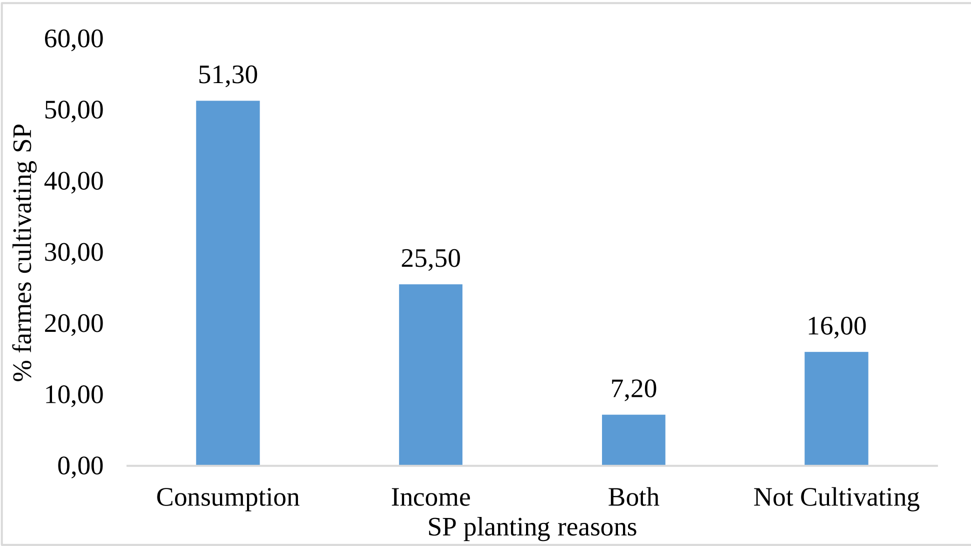

Fig. 3.5 Reasons farmers cultivate sweet potatoes

Farmers reported that they were either leaving vines as manure or mulch or burning them. Uses of sweet potato vines again varied amongst farmers (Table 3.3). A significant percentage (32.4 and 25.7%) of farmers was throwing away vines or leaving them on the field as mulch (or manure) whereas very few farmers were preserving it as propagation material or feeding it to livestock.

Table 3.3. Uses of sweet potato vines

Uses for SPV	No of Farmers	Percent
None	27	25.7
Feed to livestock	8	7.6
Leave as mulch or manure	27	25.7
Throw away or burnt	34	32.4
Preserve as propagation material	9	8.6
Total	105	100.0

SPV = sweet potato vines

3.3.6 Farmers' perception on feeding sweet potato vines to goats

It was observed that farmers had different views about the use of sweet potato vines as feed (Fig 3.6). A significantly high percentage of farmers disagreed with the use of vines as feed for goats, whereas a few agreed.

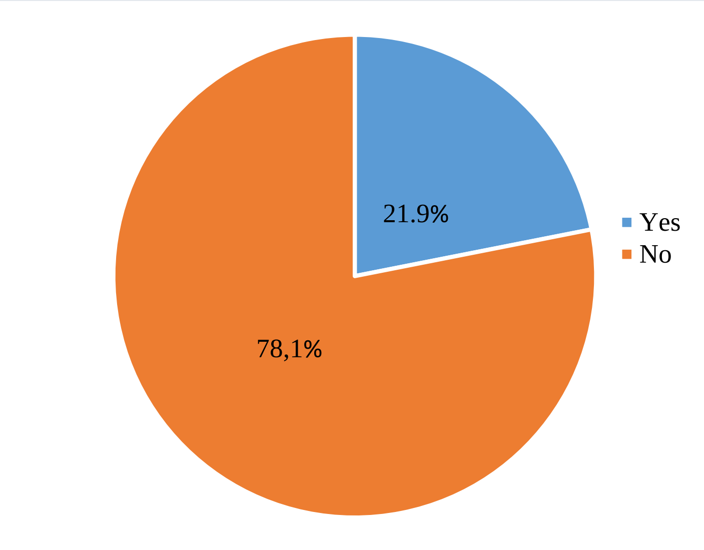

Fig. 3.6 Perception of farmers towards feeding sweet potato vines to goats.

3.3.7 Causes of goat losses in the rural community

Farmers had different views as to whether there were losses or not, in their goat herds (Table 3.4). According to the results, a significant percentage (71.8) of respondents agreed that they experienced goat losses in the area. It was also observed that farmers had varied reasons concerning the causes of loss. It was perceived that goats died due to malnutrition or disease or theft or other. Most farmers thought that disease was the major cause of losses and that they were due to helminthis, abortion, foot-rot and lice/tick-borne disease.

Table 3.4. Goat losses, causes, diseases affecting goats

Goat losses	No of Farmers	Percentage
Yes	67	63.8
No	38	36.2
Total	**105**	**100.0**
Loss causes		
None	20	19.0
Malnutrition	7	6.7
Disease	51	48.6
Theft	17	16.2
Other	10	9.5
Total	**105**	**100.0**
Cause of diseases		
Worms	33	31.4
Abortion	59	56.2
Foot-rot	8	7.6
Lice/ticks	1	1.0
Other	4	3.8
Total	**105**	**100.0**

Most respondents (48.6%) treated worms using traditional remedies, followed by those who used drugs (25.7%) and the lowest percentage (1.0%) of farmers used both drugs and traditional methods. A few (24.8%) of the farmers claimed they have never treated their animals for worms.

Table 3.5. The remedies used to fight worms

Worm treatment	**No of Farmers**	**Percentage**
Yes	84	80.0
No	21	20.0
Total	**105**	**100.0**
Treatment period		
Never	24	22.9
Once a year	16	15.2
Twice a year	12	11.4
Thrice a year	16	15.2
> thrice a year	20	19.0
When required	17	16.2
Total	**105**	**100.0**
Remedy used		
Drug (D)	27	25.7
Traditional remedies (T)	51	48.6
None	26	24.8
Both D&T	1	1.0
Total	**105**	**100.0**

3.4. Discussion

3.4.1 Biodata of farmers

Domination of males in the livestock production sector is still high compared to the number of females that were observed. Male dominion seemed to be above the national statistical average of 52.1% males and 41.18% females heading agricultural households that was reported by Statistic South Africa (Statistic South Africa, 2013). However, in this survey, a little improvement had been demonstrated in male to female ratio when compared with the results reported by Mahanjana et al. (2004) which reported more male to female ratio (68:32). Therefore, interventions measures are still required to ensure involvement of more women in livestock agriculture.

The level of education also varied across the ages of respondents. Respondents below the age of 45 years were educated compared to those above this age. This as well is a good indication that most people in the community have sought some sort of education post-apartheid compared to before. It is also important to note that technology changes or advances demand people to have some basic form of education. Agriculture on its own, demands people in farming business to have basic education, for them to be able to utilise relevant information available at their disposal. In addition, supplementary feeding needs someone who can understand the nutritional requirements of the animals, to be able to measure the required feed proportions correctly. Hence, educational level may have had an influence on farmers' lack of application of indigenous crop residues such as sweet potatoes vines (Maassa et al., 2012). However, most farmers that were participating in livestock production were above the ages of 41. According to the findings by Thornton (2008), youth openly said that they were not interested in agriculture and they do not see it as a modernized thing that can be an alternative to social grants. This may be attributed to lack of knowledge, passion or modelling system that may encourage or motivate youth to engage in agricultural industries. Some of the youth also prefer to go searching for jobs in urban areas to get immediate salaries than to take the risk. In addition, older people uphold the indigenous knowledge and methods of ensuring sustainability of their minimum agricultural resources whilst trying hard to transfer it to the modernized youth of today (Agyepong et. al., 2009).

3.4.2 Livestock ownership and population

In this study, there was a variation in flock size of livestock in KwaMthethwa community, which may be due to their farming practices, diseases, theft, lack of knowledge of breeding and other socioeconomic factors. Most farmers had livestock which corresponds with findings of Reddy et al. (2016) who reported that in Limpopo and Mpumalanga almost all households own livestock, which ensure that small holding farmers have somehow secured food or a major source of good protein. In this study goats were dominant followed by cattle then sheep which contradicts finding by Monyai (2012), who reported cattle were more dominant in rural communities. This may be attributed to the fact that most farmers lost most of their cattle due to drought in the previous years that caused starvation. This was because of the reduction of natural pasture available for livestock and less rainwater received for the cultivation of both food and fodder crops.

This study was conducted when certain parts of KwaZulu-Natal were experiencing drought which resulted in a huge number of livestock loses, hence some did not or have a smaller number of goats. Farmers revealed that they had been using dams developed by KZN DARD as a source of water for their livestock. However due to the drought most of the dams dried-up, and some of the dams needed to be cleaned (remove sediments) to ensure its constant supply of water. Reddy et al. (2016) suggested that policies should be drawn, supporting goat keeping to fight the effect of drought since goats are the most resistance animals that can withstand harsh conditions.

3.4.3 Reasons for keeping livestock including goats

According to Rao, (2008) and Meissner et al. (2013), livestock are supposed to serve as a capital investment and a major source of protein in tropical and semi-arid areas especially in the continent (Africa) where the majority of the livestock are found in rural poor communities. This was not expected to be different in this study. Goats are also used as a surety by rural communities, especially during times of need (Meissner et al., 2013). However, this study showed that most farmers in KwaMthethwa community area kept their goats for socio-economical (traditional and prestige) reasons and income generation. These results concur with the findings of Munyai (2012) who reported that 76% of farmers keep livestock for prestige and 16% for income generation purposes. Socio-economic status seems to be a barrier in the production system and development of small-scale farmer since livestock is less utilised towards the generation of income. Livestock production with an aim of income generation may assist in purchases of forage especially during winter or drought, medicines, household income thus food security (Kunene et al., 2006). However, this is most visible during a drought period where farmers lose most of their livestock due to forage shortages, disease and high rates of abortions as a result of malnutrition, thus affecting the country's GDP. According to Munyia (2012), farmers end up practicing pastoralism, whereby farmers themselves had to herd or hire herder to move from one area to another in search of forages for livestock, and that practice may be costlier. This statement coincided with a report by farmers during the survey, whereby they said they had to move their cattle to areas along the coast e.g. Mandlazini, Sokhulu (outside Richardsbay) etc. in search of forage for cattle. Therefore, farmers need to be encouraged to sell or cull their male animals, old females and less productive livestock, to ensure good investments in the smallholding farming business (Tsheole et al, 2016). Income received may be used towards building and taking care of their breeding (producing) stock to ensure they can earn good profits and grow to commercial farming thus increase a country's economy.

3.4.4 Farmers practising supplementary feeding and source of supplements

Most farmers knew about supplementation but have little understanding concerning the concept of supplementation, since most were giving maize to goats every afternoon for goats to come back for kraaling in the afternoons without a herder. Most farmers were buying maize as a source of supplementary feed, followed by crop residues and then tree leaves. However, a certain number of people were not practising supplementation at all. These results again contradicted the findings of Munyai (2012) who reported that most small holding farmers use crop residues for supplementary feeding. This was attributed to the fact the KwaZulu-Natal province was going through a severe drought and most farmers were not cultivating any food crops, hence most farmers were buying maize which would have been very expensive if bought specifically for supplementing other than kraaling.

3.4.5 Farmers cultivating sweet potato and application of sweet potato

In this study, most farmers cultivated sweet potatoes which corresponded to the report of Naidoo et al. (2016), which said that sweet potato was grown as a staple food by most poor communities in South Africa especially in KwaZulu-Natal, Limpopo, Western Cape and Mpumalanga. This agrees with the current results observed where most farmers used sweet potatoes for consumption primarily followed by income generation, while the least number of farmers cultivated for both consumption and income generation. It also shows that most farmers work towards generating their own food security. The statistics by DAFF (Department of Agriculture, Forestry and Fisheries), (2011) showed that there is a huge production of sweet potatoes in South Africa which surpasses consumption as a result surplus is being exported to other countries such as

United Kingdom, Netherlands, France and others. This is an indication that there is a potential for growth in small holding farmer if proper interventions are employed and policies being developed to increase sweet potato production in South Africa.

3.4.6 Uses of sweet potato vines and perception of farmers towards its application as feed

Previous studies which are in line with the current study, revealed that farmers use some of their crops residues from the fields as feed (Munyai, 2012). Hence, sweet potato is one of the crop being produced by emerging farmers in the country (SA). Sweet potatoes are mostly used as a staple food in most developing countries including South Africa. Nevertheless, this survey revealed that most farmers that grew sweet potatoes tend to throw away or burn sweet potato vines, whereas a few left them in the fields as mulch, others do not use vines in any way since they do not cultivate sweet potato and the least number of respondents feed vines to livestock. The possible reasons for discarding vines may rely on their perceptions and experiences. Saheli et al. (2014) explained that discarding of crop residues instead of utilising as feed is a result of insufficient knowledge and skills (‘technical know-how’) which was one of the possible reasons for not applying vines in this study. There was also an assumption that it courses fatal diarrhoea to goats which may not be true if they were aware of the right proportion of supplementation and the quality of such vines. However, this assertion is worth investigating scientifically. Mekoya et al. (2008) reported two factors that limited the use of exotic multipurpose trees as fodder i.e. awareness and approach. Farmers believe in each other’s experiences and successes as a result farmer to farmer approach method of introducing and adaptation to new technology will work well. However, awareness about new technology needs to be created by taking into consideration that not everyone will easily adapt to it.

3.4.7 Goat losses, and treatment methods used by farmers

The majority of farmers accepted losing their livestock to diseases which is in agreement with the findings of Reddy et al. (2016) . They attributed their lose to limited knowledge on diseases management. As a result, diseases may be diagnosed wrongly and not properly taken care of, that might worsen the animal condition or put animals’ life at risk, as wrong treatment may be administered. Abortion was reported as the leading cause of loses due to lack of quality feed which was attributed to drought and this concurs with a report by Tsheole et al. (2016). However, there are two types of abortion i.e. contagious abortion and non-infectious abortion and it could have been either one or both. Contagious abortion occurs as a result of bacterial infection and can be transferred from one flock to the other since goats from neighbouring farmers graze together on the same pasture hence disease contamination. Infectious abortion may be due to feed stress (Mohale, 2013). The second cause of the loss through abortion is worm infestation which also was attributed to the shortage of grazing material, forcing animals to utilise on overgrazed pastures (and recovery was very slow due to drought) which are highly contaminated. Tsheole at al. (2016) suggests that there should be interventions such as educating farmers on selection and animal health, as well as strategies for nutritional improvements. However, the death of goats was mostly attributed to non-infectious causes in this study, as it occurred during the time when there was no forage or grazing due to drought.

Most farmers were treating goats for worms using different methods of treatment such as traditional and drug treatment at different times of the year. This concurs with the findings by Hesterberg (2007) which revealed that livestock farmers use traditional herbal medicines to cure livestock diseases. Further investigation is required on pharmacological properties of traditional medicines. Some of the farmers were treating their goats against worm infestation whilst others did not, and the treatment dates differ from one farmer to another. This revealed that farmers had no treatment programme that they follow. A program is very important so as to lower resistant strains since all these animals graze together in communal fields. Drugs and traditional medicine were used by most of the farmers to treat worms. Though a certain number of farmers used drugs only, others used traditional means only and the least number of farmers used both. Farmers that were using drugs mostly used valbazin which may be a challenge. This is because using one kind of medicine (medicine with same active ingredient) over and over may result in resistance, which may be the reason why worm infestation is one of the most prevalent causes of goat death in the area (Hesterberg, 2007). Farmers also treated their goats with traditional remedies prepared from plants such as *Aloe greenii* (traditionally called icena) and umqoqongo. Therefore, there is a need to understand these herbs and how they might be mixed with pharmacetical drugs to reduce anthelmithic resistance.

3.5 Conclusion

The involvement of women and youth in livestock agriculture remains a challenge since males are still dominating the industry. Most farmers seemed to know about or do some sort of supplementary feeding but lack basic knowledge of the importance and application of indigenous forages. Indigenous knowledge and experiences should be considered, since it is the most important tool that sustains small holding farmers. Farmers were using one active ingredient over and over for animal treatment, thus more intervention is required to assist in developing animal health programmes. There is also a need to develop goat farming business skills of smallholding farmers, to ensure proper production, reproduction and animal health and feeding strategies. However, this may be achieved in a small-scale farmer environment through encouraging the use of highly nutritious indigenous crop residues such as sweet potato vines. Vines seem to be available to all farmers as the number of rural farmers cultivating it is increasing besides being able to grow it in winter. Therefore, there is a need to investigate both the nutritional properties of sweet potato vines and potential anthelminthic benefits if any.

Chapter 4

The effects of cutting frequency on chemical composition and *in vitro* digestibility of vines from four sweet potato cultivars and yield of tubers.

4.0 Abstract

Livestock feed is still a challenge in rural small scale farmers found in developing countries of Africa, especially during winter and dry season. The supplements (concentrates, licks and cultivated pasture) that are available are expensive and exploitation of food crops residues such as banana leaves, cassava, dry beans and sweet potato vines, may be a solution. This study was conducted to evaluate the effect of defoliation on four sweet potato cultivars at different harvesting periods, on chemical composition of sweet potato vines, vine fractions (leaf, petiole and stem), and sweet potato tuber yields. The dry matter, fibre (NDF and ADF), crude protein, condensed tannins and *in vitro* digestibility of vines and vine frictions (leaf, petiole and stem) of four sweet potato cultivars (1990, A40, A45 and Beauregard), harvested at 60, 75 and 120 days after planting (DAP) were measured. The results indicated that vines and their fractions (leaf, petiole and stem) harvested at 120 DAP had the highest ($p<0.05$) DM compared to 60 and 75 DAP. The CP concentration decreased ($p<0.05$) as the plant matures and condensed tannins (CT) seemed to increase ($p<0.05$) with plant maturity, except A45 cultivar that had lower tannin concentration even at 120 DAP. The fresh vine yields (75DAP) of 68.08, 25.08, 22.04 and 14.85 t/ha were observed for 1990, A40, A45 and Beauregard cultivars, respectively. Fresh tuber yields of 56.91, 7.22, 6.84 and 15.92 t/ha for 1990, A40, A45 and Beauregard cultivars, respectively, were observed after 75DAP. In conclusion the 1990 cultivar had the highest vine and tuber yields at 75 DAP. The vine chemical components did not differ between cultivars when harvested at the same time, but for the fact that fibre was increasing with maturity and CP decreasing. The vines had a comparable nutrient value that is essential for ruminant production with the relatively suitable CP of 8% which meets the basic nutrient requirements of ruminant diets.

Keywords: digestibility, feed, livestock, nutrients, supplement

4.1 Introduction

Sweet potatoes are food crops for humans that have the potential to also be used as livestock concentrate (tuber) or forage (especially sweet potato vines) (Laurie, 2010). It is a staple food for humans in most developing countries including South Africa, where it is mostly grown in provinces such as Limpopo, Mpumalanga, KwaZulu-Natal and the Western Cape (Omotobora, 2013). Sweet potato tubers are a good source of energy, carbohydrates, and vitamins such as vitamin A (making it a good source of carotene), Vitamin B and Vitamin C, as well as minerals especially calcium and iron that are essential for body processes (Adion et al., 2007). Literature (Etela et al., 2008; Madziga et al., 2017; Khalid et al., 2013) shows that sweet potato residues have to be used as feed for livestock such as pigs, rabbits, and ruminants, due to its nutrient content that is comparable to other legume crops that have been used as supplements. Residues in this study refer to waste or leftovers, or damaged or surplus material that may not be used for human consumption or is not suitable for the market, which then may be utilised as feed for livestock.

Sweet potato vines are by-products of sweet potatoes plants that are left at the surface of the soil (leaves, petioles, stems and whole vines) after the tubers have been harvested. Vines have the potential to be utilised as a feed supplement replacing the expensive concentrate, especially in the small holding sector, as demonstrated by Megersa et al., (2013). This was further confirmed by Madziga et al., (2017) who reported that sweet potato vines can be a good source of nutrients because they are relatively richer in crude protein compared to many grass hays. They are said to have low dry matter content and high moisture content and have high fibre content (Khalid et al., (2013). However, they contain some anti-nutrients that can inhibit amino acids such as protease that can affect sweet potato vine utilisation by livestock especially small ruminants such as pigs, birds and rabbits (Madziga et al., 2017). Its utilization may be improved by sun drying, milling or cooking vines prior to feeding, to reduce the effect of phenolics. Sweet potato cultivation promotes integrated farming systems and the sustainable use of the minimum land available for farming especially in rural poor communities (Duku, 2011). It is mostly planted by using its aerial parts (vines) although tubers are randomly planted by some farmers to preserve vines for subsequent farming or when propagating vines for new potato cultivars. Thick and woody planting vines should be avoided since they sometimes do not establish and tend to have high chances of weevil (Duku, 2011). Weevil is a tiny organism that feeds on sweet potato tubers;

hence weevils multiply more at the bottom area of the vines and can be very destructive to the tubers when matured.

There are two major factors influencing the yield of sweet potatoes i.e. the cultivar type and age at harvesting (Niyeremba et al., 2013). Sweet potatoes are known to be drought tolerant or water stress tolerant. However, water stress also negatively affects sweet potato production. Drought has been observed to cause increased lignification in certain types of sweet potato cultivars which indirectly affects growth (Omotobora, 2013). According to Niyeremba et al., (2013), sweet potatoes require a minimum of 14mm of water per week for establishment and that gradually increases to 30 – 36 mm of water per week towards harvesting. However, Neduchezhiyah (2012) regarded planting time as the crucial factor that affects growth, yield and quality of roots (tubers). According to Claessens et al., (2008) the cultivation of sweet potatoes, in a crop-livestock integrated system is of benefit to farmers especially in areas where there is a shortage of land. Hence, sweet potatoes are known for producing a high amount of tubers and vines with minimal input of resources making it very cheap compared to other food /fodder crops.

Sweet potatoes may produce between four to six tons of vines per hectare (Khalid et al., 2013) and if vine clipping is managed properly at the right age, it may result in an increased yield of tubers. The crop residues can play a very important role in ruminants' fodder flow especially during demanding periods such as high producing season, winter and drought if the management is properly done not to compromise tuber production for human consumption. However, it is important to understand the chemical composition of these vines and its variation between cultivars as a potential feed. This may assist in balancing the ration of livestock to meet animal requirements be it maintenance or production (Zereu et al., 2014). Thus, the aim of this study was to evaluate the effect of defoliation at the different times on the chemical composition of sweet potato vines as well as tuber yield. It was hypothesized that defoliation at different times will not change the chemical composition of the vines as well as the yields of tubers of different cultivars.

4.2 Materials and Methods

4.2.1 Study site

The study was conducted at Owen Sithole Collage of Agriculture (OSCA), which is situated at KwaMthethwa Community Area, under Umfolozi Local Municipality, KwaZulu-Natal. OSCA is located at 28°45'S latitude and 31°53'E longitude which has an annual rainfall of 900 mm and an average temperature of 26°C (Kunene et al., 2015*)*.

4.2.2 Ethics and consent

This study was approved by the Research Ethics Committee from the University of Zululand with ethical clearance number UZREC171110-030 PGM 2016/292.

4.2.3 Experimental samples, experimental design and vines planting procedure

Four varieties or cultivars (Beauregard, 1990, A40 and A45) of sweet potato were chosen as the most popular variety used by most rural household farmers. They were cultivated using vine cuttings of 30cm length, with four nodes. Planting material was obtained from Makhathini Research Station, and cultivated on 48 small plots (hence, four cultivars and four treatments, replicated into three) of 5m x 3m. Sweet potato vines from these 4 sweet potato cultivars were planned to be harvested at 4 different periods of 20, 60, 75 and 120 days after planting (DAP). Di-amonium phosphate (20kg/ha) was applied at planting and LAN fertiliser at 100kg/ha based on recommendations from Fertrec after soil analysis.

4.2.3.1 Vine harvesting and dry matter determination

Vines were cut at 15 cm (cutting height) using hand scissors and the samples of approximately 500g wet weight, were collected from the whole vine and vine fractions such as leaf, petiole and stem for analysis. Samples were then weighed and oven dried (using Unitherm drying oven, model 3) at 60^{o}C to constant weight to determine yields (total dry matter per hectare), chemical composition and digestibility of vines and its fractions (leaf, petiole and stem).

4.2.4 Sample preparation and chemical analysis

Dried samples were milled through a 1mm sieve for determination of fibre, crude proteins, digestibility and tannin concentration. The fibre content that was analysed for milled samples were neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, and hemicellulose via ANKOM^{200} fibre analyzer using the principles of Van Soest et al (1991) as described by Mergesa et al., (2013) and Khalid et al., (2013).

4.2.4.1 Neutral detergent fibre **analysis**

Samples (1g) of sweet potato vine proportions (leaves, petioles, stems and whole vine) were washed through neutral detergent solution to determined neutral detergent fibre using ANKOM^{200} Fibre Analyser as explained by Khalid et al. (2013). Filter bags were weighed individually (W_0) before transferring a sample of about 0.45g to 0.50g into each filter bag (W_1) while ensuring samples were placed below 4mm of the filter bag before heat sealing. Blank filter bag C_1 was included in the run as a control. Filter bags were then placed on the Suspender Trays (which carry 3 sample bags per tray). Trays were stacked on the centre post of the Bag Suspender which was rotated at 120°C in relation to the tray below it, leaving an empty ninth tray on top of all trays. The neutral detergent solution (NDS) was used to determine NDF; the following reagents were used to formulate NDS:

1. Sodium Lauryl Sulphate Solution:

    150 grams of Sodium Lauryl Sulphate weighed into a 5000ml Erlenmeyer flask plus 2500ml water, heated and stirred gently to dissolve, and then 50ml of trietheylene was added.

2. EDTA and Di-sodium tetraborate solution

    93.05g of EDTA and 34.05g of di-sodium, was weighed into 1000ml of distilled water which was then heated and stirred. The solution was then poured into Sodium Lauryl Sulphate Solution.

3. Di-sodium hydrogen phosphate solution

    22.80g of di-sodium hydrogen phosphate was dissolved separately in about 500ml distilled water, and it was then added to other solutions in Erlenmeyer flask. The solution was then made to the volume of 5000ml with distilled water.

The NDS of 100ml/bag and 4.0ml of Alpha-amylase was added to the sample in the suspender vessel and the heat was turned on for agitation (for 75 min) in a sealed machine. The valve was opened slowly to exhaust the solution after the run before rinsing with about 1900-200ml of water (70-90°C) containing 4.0 ml of Alpha-amylase for 5 minutes. The rinsing procedure was repeated three times before gently hand compressing the bags to remove excess water. After which the bags were then submerged in a 250 ml beaker with acetone for 3-5 minutes before placing on a wire-screen to dry (completely evaporating acetone). Samples were oven dried at 60°C for 48 hours. Filter bags were removed from the oven and placed in a collapsible desiccant pouch to cool before weighing (W_3) them. Each sample was replicated three times with four pseudo replicates. The formula below was used to calculate NDF %,

$$\%\mathrm{NDF} = \left(\frac{\mathrm{W_3} - (\mathrm{W_1} \times \mathrm{C_1})}{\mathrm{W_2}}\right) \times \frac{100}{1}$$

4.2.4.2 Acid Detergent fibre (ADF) analysis

The acid detergent fibre (ADF) was analysed using The Acid detergent solution (ADS) following method explained by Khalid et al., (2013), using ANKOM^{200} Fibre Analyser. The NDS reagents were mixed as follows: 98.08g of 95% sulphuric acid was added to 1000ml of distilled water and made a volume of up to 2000ml, standardised. The 40g

CTAB was added into 3000ml Erlenmeyer flask and 2000ml of 1N H2SO4 (from above) was added and then stirred to dissolve.

The samples with vines proportion that were previously used for analysis of NDF, were used to analyse ADF after data collection for NDF analysis. The dried samples with vines fractions from NDF analysis were placed on the suspender trays that were stacked at the centre post of the Bag Suspender while each level was rotated at 120°C in relation to the tray below it. NDS (2000ml) was added onto the sample in the suspender vessel, water temperature was kept above 70°C before START button was pressed, and the heat was turned on for agitation (for 75 min). The ADF extraction and rinsing procedure was then carried out the same way as described in section 4.2.4.1. Thereafter sample bags were oven dried at 60°C for 48 hours. Filter bags were removed from the oven and placed on a collapsible desiccant pouch where they were flattened to cool down at ambient temperature before weighing (W_3). Each sample was replicated three times with four pseudo replicates. The formula below was used to calculate ADF%;

$$\%\mathrm{ADF} = \left(\frac{W_3 - (W_1 \times C_1)}{W_2}\right) \times \frac{100}{1}$$

4.2.4.3 Determination of Acid Detergent Lignin (ADL)

Filter bags from ADF analysis were further analysed for lignin content. The bags were submerged in a 3L beaker containing 250 ml of 75% H_2SO_4 for 3 hours while 2L beaker was used for agitation at 30 min interval. After 3 hours bags were removed and rinsed with tap water until the acid was completely removed. A final rinse with 250 ml of acetone was done and bags were oven dried at 60°C for 48 hours before weighing (W_3). Each sample was replicated three times with four pseudo replicates. The formula below was used to calculate ADL%;

$$\%\mathrm{ADL} = \left(\frac{\mathrm{W}_3 - (\mathrm{W}_1 \times \mathrm{C}_1)}{\mathrm{W}_2}\right) \times \frac{100}{1}$$

4.2.4.4 Crude protein analysis

Crude protein (CP) was determined following the method described by Cheeke (2005) modified from the Kedjehal procedure of measuring total nitrogen before converting to protein (Crude protein = nitrogen (N) x 6.25). Whereby 1g of sweet potato proportion (vines, leaves, stem or petioles) was boiled in sulphuric acid giving complete oxidation of organic material where protein was completely degraded thereby releasing ammonium ions (NH_4^+). The solution was alkalised to convert NH_4^+ to NH_3^+ and steamed with distilled water to release NH_3 which was trapped by boric acid. NH_3

molecules were measured by titration according to the method by Massey (2003). The protein concentration was calculated by multiplying nitrogen concentration by a protein factor of 6,25. Each sample was replicated three times with four pseudo replicates.

4.2.4.5 Condensed Tannin analysis

Condensed tannins from vine fraction (whole vine, stem, leave and petioles) samples were determined using a butanol-HCL assay, following the method described by Menga et al. (2014). The sample (1g) was milled through a 1 mm sieve and used to extract tannins using 8 ml methanol-water (80:20; v/v) acidified with 1% HCl, for 30 minutes in an ultrasonic bath. The mixtures were centrifuged at 2000 x g for 15 min after incubation in the bath. Supernatants of extracts (0.5ml) were mixed with 3.0ml butanol-HCL reagent (95:5; v/v) and 0.1ml ferric reagent (2% ferric ammonium sulphate, in 2.0M HCL) and boiled for 60 min in a water-bath to determine condensed tannins. After boiling, the absorbance was measured at 550nm and compared against a blank containing solvent only. Condensed tannins were then calculated as *leucocyanidin* equivalents g-1 according to the following formula:

CT% = Ab_{550nm} x 78.26 x dilution factor/ (%dry weight).

Where, Ab_{550} = Absorbance at 550nm

Dilution factor= 0.5/extract, which is = 1 hence, an extract of 0.5ml was used.

4.2.5 In vitro digestibility and microbial yield of sweet potato vines

4.2.5.1 Inoculum preparation

Rumen fluid was collected fresh, immediately after slaughter from ruminants that were raised on natural pasture before slaughtering at Eshowe abattoir. Rumen fluid was then transferred into a 5l container that was preheated to 39^{o}C and flushed with CO_2 and stored in the cooler box 39^{o}C to ensure survival of rumen microbes and the thermometer was used to monitor the rumen fluid temperature. The process of *in vitro* digestibility started immediately after arrival at the University of Zululand Laboratory as the rumen fluid with particulate matter was blended for 30 seconds in a blender (to dislodge rumen microbes from the fibrous mat) that was pre-heated to 39^{o}C and purged with CO_2 to maintain anaerobiosis. Blended rumen fluid was then filtered through a cheese cloth (folded into four) into a beaker that was also preheated and purged with CO_2.

4.2.5.2 Sample preparation for in vitro digestibility

For *in vitro* digestibility, all the feed (Beauregard (BRGT), 1990, A40 and A45) dry proportions (Leaves, petioles, and stems) were milled through a 1 mm sieve before weighing about 0.25g into the ANKOM Filter bags (Ankom® Technology, # F57) and heat sealed. There were four pseudo replicates for each portion which were replicated in three different runs. The replicates were the same for BRGT, 1990, A40 and A45. F50 filter bags were prepared by rinsing in acetone for 5 minutes to remove surfactant that may reduce microbial digestion ability before drying to use for the experiment. Bags were weighed to get W_1 and the balance scale was tarred before weighing 0.5g sample (W_2) directly into the filter bag. Bags were heat sealed and placed in a Daisy incubator digestion jar. Each jar contains 25 bags plus a sealed blank bag as a correction factor (C_1).

4.2.5.3 In vitro digestibility and microbial yield of sweet potato vines

In vitro digestibility was determined by using the ANKOM Technology-DAISYII Incubator, as explained by Zereu et al. (2014). A total of 25 sample bags including a control (empty bag) were place in each of the digestibility jars. It was then incubated for 48 hours, in an incubation mixture of 400ml rumen fluid and 1600ml of salivary buffer. Salivary buffer was made up of 1330ml Solution A (78.4g $NaHCO_4$, 29.6g $NaHPO_4$, 4.56g KCl, 3.76g NaCl, 1.04g $MgCl.6H_2O$) and 266ml of Solution B (5.03g $CaCl_2.2H_2O$) that had been pre-warmed to 39°C. After incubation, samples were washed under running tap water until water was clear with little agitation before oven drying at 60°C for 72 h. Apparent Digestibility (APD) was calculated by subtracting the feed residue after incation from the incubated mass. Furthermore, the residues were washed with NDS (See NDS method explained in section 4.2.4.1) to determine NDF which was used to calculate true digestibility. The true digestibility (TD) was calculated by subtracting NDF from NDS treatment from the dry matter. Microbial yield (MY) was determined by subtracting apparent degradability from true degradability.

4.2.6 Statistical Analysis

The data on chemical components (DM, NDF, ADF, ADL, hemi, cellu, CT) and digestibility parameters (APD, TD and MY) of different portions (stems, leaves and petioles) of sweet potato cultivars (BRGT, 1990, A40 and A40) harvested at different times (T1 = 60 days after planting, T2 = 75 days after planting and T3 = 120 days after plating) were analysed using analysis of variance (ANOVA) of SPSS (2015). Turkey's t-test was used to identify differences between treatment means at 5% significance difference where $p<0.05$.

4.3 Results

4.3.1 Effect of clipping time on nutrient composition of cultivar stems

There were differences ($p<0.05$) in feed constituents measured across all cultivar stems apart from CP (Table 4.1). The highest ($p<0.05$) dry matter content was observed in stems harvested at 120 DAP with BRG cultivar showing the highest DM. The stem had lower ($p<0.05$) fibre content (NDF, ADF and cellulose) when harvested at 60 than at 120. Beauregard had the lowest ($p<0.05$) tannin content when harvested at 60 DAP and highest CT content when harvested at 120 DAP when compared to other cultivars harvested at similar harvesting periods.

Table 4.1 Stem nutrient value of different cultivars as affected by clipping dates.

Cultivar	DM (%)	Moist (%)	NDF (%)	Hemi (%)	ADF (%)	Cellu (%)	ADL (%)	CP (%)	CT(g/kg)
1990T1	13.25^{ab}	86.75^{bc}	44.50^{a}	10.04^{ab}	34.47^{a}	17.36^{a}	16.45^{d}	16.72	39.49^{b}
A40T1	11.65^{a}	88.34^{c}	41.32^{a}	7.00^{a}	34.32^{a}	19.81^{abc}	14.51^{cd}	15.14	30.06^{ab}
A45T1	12.37^{ab}	87.63^{bc}	42.46^{a}	9.01^{ab}	33.55^{a}	18.23^{ab}	15.31^{cd}	17.01	42.75^{ab}
BRGT1	10.64^{a}	89.36^{c}	40.50^{a}	7.12^{a}	33.38^{a}	19.66^{abc}	13.72^{cd}	18.12	10.29^{a}
1990T2	12.07^{a}	87.93^{c}	57.04^{b}	22.11^{bc}	34.93^{a}	30.22^{d}	4.71^{a}	13.02	20.88^{ab}
A40T2	12.71^{bc}	87.29^{bc}	54.74^{b}	20.77^{abc}	33.97^{a}	26.89^{abcd}	7.00^{ab}	12.88	22.88^{ab}
A45T2	11.65^{a}	88.21^{c}	54.73^{b}	20.77^{abc}	35.47^{a}	19.02^{ab}	16.45^{d}	15.18	32.63^{ab}
BRGT2	13.25^{ab}	86.44^{bc}	54.90^{b}	20.40^{abc}	34.50^{b}	23.62^{abcd}	8.86^{abc}	12.71	31.29^{ab}
1990T3	17.11^{bc}	82.89^{bc}	78.38^{c}	25.36^{c}	53.02^{b}	27.43^{bcd}	25.58^{e}	12.71	41.44^{ab}
A40T3	18.15^{c}	81.85^{a}	76.50^{c}	26.83^{c}	49.67b	23.69^{abcd}	25.98^{e}	15.13	22.77^{ab}
A45T3	19.28^{c}	80.72^{a}	73.52^{c}	17.02^{abc}	56.44^{b}	29.44^{cd}	27.00^{e}	14.36	42.16^{ab}
BRGT3	21.11^{c}	78.89^{a}	75.93^{c}	24.79^{c}	51.14	23.62^{abcd}	27.52^{e}	13.78	52.46^{b}
SED	0.67	0.67	2.49	1.59	1.60	1.02	1.39	0.050	3.12
p-value	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.348	0.05

Means with different ^{abcde} (superscripts) in the same column are significant different at $p< 0.05$ and means with no superscripts are similar. BRGT, 1990, A40 and A45 were different cultivars samples with different superscripts letters in the same column were different at $p<0.05$. DM= dry matter, Moist = moisture, NDF = nutrient detergent fibre, Hemi = hemicellulose, ADF = acid detergent fibre, Cellu = cellulose, ADL = acid detergent lignin, CP = crude protein, CT= Condensed tannin. T1 = 60 days after planting, T2 = 75 days after planting, T3 = 120 days after plating

4.3.2 Effect of clipping dates on petioles' nutrient values of cultivars

Most of the petioles' nutrient composition were different ($p<0.05$) except acid detergent lignin and cellulose (Table 4.2). Beauregard showed the highest ($p<0.05$) DM when harvested at 120 days after planting. Petioles that were cut at 60 and 75 DAP had the highest neutral detergent fibre which reduced when cutting was done at 120 DAP. The acid detergent fibre results also showed the same pattern as the NDF. The results revealed high crude protein content when petioles were harvested at 120 DAP but reduced when harvested earlier (75 and 60 DAP). Tannin concentration was highest ($p<0.5$) when harvested at 120 DAP and reduced with harvesting levels. However, A40 and A45 cultivars had the least CT concentration when harvested at 75 DAP.

Table 4.2: Petioles' nutrient value of different cultivars as affected by clipping dates

Cultivar	DM (%)	Moist (%)	NDF (%)	Hemi (%)	ADF (%)	Cellu (%)	ADL (%)	CP (%)	CT(g/kg)
1990T1	12.15^{ab}	87.84^{b}	52.62^{c}	10.90^{b}	41.72^{cd}	20.79	20.93	13.26^{a}	22.27^{ab}
A40T1	12.35^{ab}	87.65^{b}	45.53^{bc}	11.08^{b}	34.45^{bc}	20.78	13.67	12.05^{a}	27.48^{b}
A45T1	12.09^{ab}	87.91^{b}	54.67^{c}	15.39^{bc}	39.28^{c}	24.87	14.41	12.11^{a}	41.22^{bc}
BRGT1	9.43^{a}	96.57^{c}	46.52^{bc}	3.49^{a}	43.04^{cd}	24.33	18.70	13.26^{a}	12.34^{a}
1990T2	11.45^{ab}	88.55^{b}	45.31^{bc}	17.74^{bc}	27.56^{ab}	15.32	12.24	16.35^{b}	16.08^{ab}
A40T2	10.00^{a}	90.00^{bc}	40.37^{b}	15.39^{bc}	24.74^{a}	19.83	7.79	15.85^{ab}	11.04^{a}
A45T2	10.27^{a}	90.00^{bc}	47.86^{bc}	18.41^{bc}	29.45^{ab}	19.83	9.62	17.06^{b}	11.40^{a}
BRGT2	11.22^{ab}	88.78^{b}	42.37^{bc}	14.22^{b}	23.15^{a}	14.48	13.68	19.80^{bc}	9.39^{a}
1990T3	16.65^{bc}	83.34^{ab}	36.36^{ab}	8.38^{ab}	27.98^{ab}	9.12	18.88	16.32^{b}	43.94^{bc}
A40T3	14.45^{ab}	85.55^{b}	36.51^{ab}	8.87^{ab}	27.64^{ab}	20.93	6.70	17.30^{b}	36.20^{bc}
A45T3	16.37^{bc}	83.63^{ab}	33.81^{a}	8.26^{ab}	25.55^{ab}	8.65	17.07	17.2^{b}	49.94^{c}
BRGT3	21.39^{c}	78.61^{a}	34.15^{a}	6.97^{ab}	27.17^{a}	7.34	19.84	17.27^{b}	55.65^{cd}
SED	0.70	0.70	1.38	1.11	1.17	1.64	0.75	0.45	3.33
p-value	0.002	0.002	0.001	0.107	0.000	0.336	0.375	0.000	0.002

Means with different ^{abcd} (superscripts) in the same column are significant different at $p< 0.05$ and means with no superscripts are similar. BRGT, 1990, A40 and A45 were different cultivars samples with different superscripts letters in the same column were different at $p<0.05$. DM= dry matter, Moist = moisture, NDF = nutrient detergent fibre, Hemi = hemicellulose, ADF = acid detergent fibre, Cellu = cellulose, ADL = acid detergent lignin, CP = crude protein, CT= Condensed tannin. T1 = 60 days after planting, T2 = 75 days after planting, T3 = 120 days after plating

4.3.3 Effect of clipping dates on potato leaves nutrient composition of cultivars

Differences ($p<0.05$) in nutrient composition were observed between leaves of all cultivars (Table 4.3). The ADF was reduced at 120 DAP but ADL concentration increased at 120 DAP. Leaves had the highest CP concentration when harvested at 60 and 75 DAP than at 120 DAP for all cultivars but CP did not differ between cultivars harvested at the same time after planting. The CT concentration in leaves increased ($p<0.05$) 120 DAP compared to day 75 and 60. However, 1990 cultivar seems to have a relatively lower concentration of CT compared to the other cultivars.

Table 4.3. Leaves' nutrient value of different cultivars as affected by clipping dates

Cultivar	DM (%)	Moist (%)	NDF (%)	Hemi (%)	ADF (%)	Cellu (%)	ADL (%)	CP (%)	CT(g/kg)
1990T1	15.60^{a}	84.40^{ab}	46.31^{b}	13.41^{a}	32.90^{c}	27.12^{bc}	5.78^{a}	26.01^{b}	25.99^{ab}
A40T1	15.25^{a}	84.75^{ab}	41.43^{ab}	11.86^{a}	29.57	23.93^{bc}	6.28^{a}	25.25^{b}	37.17^{b}
A45T1	14.03^{a}	85.97^{b}	49.52^{b}	22.60^{c}	26.93^{b}	21.21^{bc}	5.72^{a}	27.81^{b}	27.55^{ab}
BRGT1	13.77^{a}	86.23^{b}	42.25^{ab}	11.16^{a}	31.09^{bc}	24.42^{bc}	6.67^{a}	27.96^{b}	36.62^{b}
1990T2	13.38^{a}	86.62^{b}	58.06^{c}	25.78^{cd}	32.28^{bc}	20.61^{bc}	11.67^{ab}	28.19^{b}	42.41^{bc}
A40T2	14.49^{a}	85.51^{b}	58.01^{c}	27.33^{cd}	30.67^{bc}	16.34^{b}	14.33^{b}	27.08^{b}	27.55^{ab}
A45T2	12.49^{a}	87.51^{b}	57.69^{c}	27.01^{cd}	30.68^{bc}	18.98^{b}	11.69^{ab}	28.11^{b}	32.12^{ab}
BRGT2	14.18^{a}	76.03^{a}	57.29^{c}	24.54^{c}	32.75^{bc}	18.39^{b}	14.36^{b}	28.58^{b}	13.81^{a}
1990T3	19.50^{b}	80.50^{ab}	43.95^{ab}	23.50^{c}	20.44^{a}	8.28^{a}	12.16^{ab}	19.67^{a}	47.98^{c}
A40T3	20.73^{bc}	79.37^{a}	38.32^{a}	19.33^{bc}	18.99^{a}	6.83^{a}	12.16^{ab}	18.43^{a}	54.41^{c}
A45T3	20.12^{bc}	79.88^{a}	42.09^{ab}	24.16^{c}	17.93^{a}	6.36^{a}	11.56^{ab}	19.95^{a}	55.24^{d}
BRGT3	23.97^{c}	78.61^{a}	43.43^{ab}	23.87^{c}	19.56^{a}	7.40^{a}	12.15^{ab}	19.61^{a}	74.14^{e}
SED	0.67	0.67	1.38	1.13	1.05	1.34	0.71	0.73	2.89
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.000

Means with different ^{abcde} (superscripts) in the same column are significant different at p< 0.05 and means with no superscripts are similar. BRGT, 1990, A40 and A45 were different cultivars samples with different superscripts letters in the same column were different at p<0.05. DM= dry matter, Moist = moisture, NDF = nutrient detergent fibre, Hemi = hemicellulose, ADF = acid detergent fibre, Cellu = cellulose, ADL = acid detergent lignin, CP = crude protein, CT= Condensed tannin. T1 = 60 days after planting, T2 = 75 days after planting, T3 = 120 days after plating

4.3.4 Effect of clipping dates on vine nutrient value of cultivars

Significant differences (p>0.05) were displayed in vine chemical values amongst treatments (Table 4.4). The DM increased (p<0.05) when the vines were harvested at 120DAP, with 1990 having the very least DM at 75 DAP. There was variation (p<0.05) in the fibre content of vines; NDF increased in most cultivars as the vines mature with an exception of A45. The CP concentration decreased (p<0.05) with plant maturity and CT seemed to increase with plant maturity, except for A45 cultivar, which had fewer tannin concentration even at 120 DAP.

Table 4.4 Vines' nutrient value of different cultivars as affected by clipping dates

Cultivar	DM (%)	Moist (%)	NDF (%)	Hemi (%)	ADF (%)	Cellu (%)	ADL (%)	CP (%)	CT(g/kg)
1990T1	12.29^{ab}	87.71^{bc}	46.85^{ab}	9.72^{a}	37.17^{c}	25.08^{d}	12.09^{c}	20.35^{cd}	34.66^{b}
A40T1	13.27^{ab}	86.73^{bc}	44.41^{a}	10.09^{a}	34.32^{b}	23.53^{cd}	10.79^{b}	18.93^{cd}	28.63^{ab}
A45T1	13.70^{ab}	86.47^{a}	47.66^{abc}	13.06^{ab}	34.31^{b}	25.05^{d}	9.25^{ab}	18.74^{c}	30.07^{b}
BRGT1	17.02^{bc}	86.31^{abc}	51.10^{bc}	19.11^{bc}	33.55^{ab}	23.33^{cd}	10.22^{b}	16.32^{b}	20.80^{a}
1990T2	10.01^{a}	89.99^{c}	50.22^{bc}	16.53^{b}	33.87^{ab}	23.77^{cd}	10.10^{bc}	18.45^{c}	22.45^{c}
A40T2	13.00^{ab}	87.00^{bc}	49.21^{abc}	18.38^{b}	30.83^{a}	21.44^{c}	9.38^{ab}	21.10^{d}	23.46^{a}
A45T2	13.21^{ab}	87.12^{bc}	54.42^{c}	23.75^{d}	30.67^{a}	11.39^{b}	7.05^{a}	18.86^{cd}	26.46^{ab}
BRGT2	12.85^{ab}	86.31^{a}	54.66^{c}	23.22^{d}	31.45^{a}	22.41^{cd}	9.04^{ab}	19.85^{cd}	18.89^{a}
1990T3	19.10^{c}	80.90^{ab}	54.66^{c}	22.60^{c}	32.06^{ab}	12.43^{b}	19.63^{d}	12.94^{a}	37.37^{bc}
A40T3	18.94^{c}	81.72^{ab}	47.13^{abc}	15.72^{abc}	31.42^{a}	5.66^{a}	25.76^{e}	11.71^{a}	56.12^{cd}
A45T3	17.37^{bc}	83.96^{abc}	51.10^{bc}	19.11^{bc}	33.55^{ab}	23.33^{cd}	10.22^{bc}	16.32^{b}	20.82^{a}
BRGT3	20.07^{c}	79.93^{a}	54.42^{c}	15.05^{ab}	35.35^{b}	10.88^{a}	24.50^{e}	11.72^{a}	48.38^{c}
SED	0.65	0.72	0.81	0.97	0.42	1.14	1.10	0.59	2.47
p-value	0.01	0.050	0.019	0.00	0.012	0.00	0.00	0.00	0.00

Means with different ^{abcde} (superscripts) in the same column are significant different at $p < 0.05$ and means with no superscripts are similar. BRGT, 1990, A40 and A45 were different cultivars samples with different superscripts letters in the same column were different at p<0.05. DM= dry matter, Moist = moisture, NDF = nutrient detergent fibre, Hemi = hemicellulose, ADF = acid detergent fibre, Cellu = cellulose, ADL = acid detergent lignin, CP = crude protein, CT= Condensed tannin. T1 = 60 days after planting, T2 = 75 days after planting, T3 = 120 days after plating

4.3.5 Effect of clipping dates on vines and stem digestibility of cultivars

Vines and stem TD digestibility varied (p>0.05) with clipping dates between cultivars except apparent digestibility (Table 4.5). Vines from A40 and A45 cultivars had the highest vines true digestibility when harvested at 60 DAP. However, similar results were obtained in A40 when harvested at 75 DAP.

The results from stem digestibility showed differences (p<0.05) in digestibility parameters amongst cultivars (Table 4.5). The A45 cultivar had the highest true digestibility when harvested at 60 DAP.

Table 4.5 Vines and stem digestibility of cultivars clipped at different dates

	Stem Digestibility (%)					
Cultivar	**APD**	**TD**	**MY**	**APD**	**TD**	**MY**
1990T1	66.39	80.09^{de}	13.70^{c}	65.94^{ab}	75.64^{cde}	9.70^{bcd}
A40T1	69.27	83.00^{e}	13.73^{c}	67.15^{abc}	82.41^{cde}	15.26^{c}
A45T1	71.27	83.29^{e}	12.01^{bc}	78.75^{c}	86.67^{e}	7.92^{abc}
BRGT1	74.65	80.82^{de}	6.17^{abc}	69.12^{bc}	85.06^{de}	15.94^{d}
1990T2	76.49	81.73^{de}	5.24^{abc}	58.46^{ab}	67.93^{ab}	10.11^{cd}
A40T2	72.61	75.05^{bcd}	2.44^{abc}	62.84^{ab}	73.10^{abc}	10.26^{cd}
A45T2	76.92	84.15^{e}	7.23^{ab}	64.71^{ab}	66.93^{ab}	3.43^{abc}
BRGT2	70.3	71.49^{abc}	1.19^{a}	55.51^{a}	66.93^{a}	3.43^{abc}
1990T3	72.46	76.05^{cd}	3.59^{ab}	65.81^{ab}	69.76^{ab}	3.95^{abc}
A40T3	65.89	68.92^{a}	3.03^{ab}	64.91^{ab}	67.91^{ab}	2.20^{a}
A45T3	71	73.83^{abc}	2.83^{abc}	65.95^{ab}	67.91^{ab}	2.96^{ab}
BRGT3	67.67	69.66^{ab}	1.99^{a}	63.22^{ab}	65.41^{ab}	2.19^{a}
SED	1.00	1.01	0.96	1.22	1.46	0.95
p-value	0.37	0	0.05	0.06	0.008	0.001

Means with different ^{abcde} (superscripts) in the same column are significant different at p< 0.05 and means with no superscripts are similar. BRGT, 1990, A40 and A45 were different cultivars samples with different superscripts letters in the same column were different at p<0.05. APD = Apparent digestibility, TD = True digestibility, MY = Microbial yield. T1 = 60 days after planting, T2 = 75 days after planting, T3 = 120 days after plating

4.3.6 Petioles and leaves digestibility of cultivars clipped at different dates

For petioles there were no differences observed in APD and TD for all cultivars harvested at different times but for MY that varied (p<0.05) with harvesting time (Table 4.6). A40 cultivar had the highest microbial yields (MY) when harvested 60 DAP followed by other three varieties with low MY. Most varieties harvested at 120 DAP had the least microbial yields with the exception of 1990 variety which had microbial yields alike to most of the petioles from the cultivars harvested at 75 and 60 DAP.

Table 4.6 Leaf and petiole digestibility of different cultivars as affected by clipping dates

	Leaf Digestibility %					
Cultivar	**APD**	**TD**	**MY**	**APD**	**TD**	**MY**
1990T1	68.95	86.36	17.41^{b}	67.10	78.70^{bc}	11.60b^{c}
A40T1	61.69	76.13	14.44^{b}	66.04	80.51^{c}	14.47^{c}
A45T1	58.29	65.57	7.28^{b}	68.43	78.49^{bc}	10.06b^{c}
BRGT1	70.50	76.83	6.33^{b}	71.42	80.90^{c}	9.48b^{c}
1990T2	65.77	74.34	8.57^{b}	66.91	74.66^{abc}	7.75^{abc}
A40T2	73.67	80.82	7.15^{ab}	67.99	70.93^{ab}	2.94^{a}
A45T2	70.55	80.73	10.18^{b}	68.62	76.74^{abc}	8.12^{bc}
BRGT2	69.50	76.26	6.76^{b}	65.10	70.67^{ab}	5.57^{ab}
1990T3	70.62	73.87	3.25^{a}	67.97	70.68^{ab}	2.71^{a}
A40T3	66.60	68.63	2.03^{a}	69.71	76.56^{abc}	6.85^{ab}
A45T3	69.40	71.69	2.29^{a}	66.81	69.74^{a}	2.93^{a}
BRGT3	65.61	67.78	2.17^{a}	66.62	68.86^{a}	2.24^{a}
SED	1.35	0.63	1.06	0.88	0.94	0.90
p-value	0.66	0.27	0.021	0.949	0.01	0.00

Means with different ^{abc} (superscripts) in the same column are significant different at p< 0.05 and means with no superscripts are similar. BRGT, 1990, A40 and A45 were different cultivars samples with different superscripts letters in the same column were different at p<0.05. APD = Apparent digestibility, TD = True digestibility, MY = Microbial yield. T1 = 60 days after planting, T2 = 75 days after planting, T3 = 120 days after plating.

Leaf TD and MY varied with time of harvest ($p<0.05$) while APD did not (Table 4.6). Varieties harvested at 60 DAP displayed the highest APD followed by most varieties harvested 75 DAP then 120 DAP which had the least APD. A similar trend was realised in microbial yields and dry matter digestibility of most varieties.

4.3.7 Vine and tuber yields

There were differences ($p<0.05$) observed for vines and tuber yields among cultivars at 75 days after planting (DAP) but not at 60 and 120 DAP (Table 4.7). Cultivar 1990 had the highest yields ($p<0.05$) across all treatments. Sweet potato cultivar A40, had lower yields of both tubers and vines across all treatments. The variety A45 displayed good tuber yields when harvested at 120 DAP, though at the similar harvesting date vine yield remained low ($p<0.05$). The 1990 cultivar had the highest vine yields when harvested at 75 DAP and tuber yields comparable to 120 DAP when harvested at 75 DAP.

Table 4.7 Effects of clipping dates on the yield of fresh and dry vines and tubers

Fresh vine yields (t/ha)				Dry vine yield (t/ha)			Fresh tuber yields (t/ha)		
Cultivars	60	75	120	60	75	120	60	75	120
1990	34.15	68.08^{b}	32.77	5.09	8.4^{b}	5.58	35.70	56.91^{b}	62.95
A40	20.05	25.08^{a}	18.36	2.78	2.98^{a}	3.18	5.97	7.22^{a}	20.60
A45	20.85	22.04^{a}	11.58	2.45	2.86^{a}	2.53	8.14	6.84^{a}	68.91
BRG	20.14	14.85^{a}	23.76	2.82	1.63^{a}	4.23	20.60	15.92^{a}	26.28
Sig.	p>0.05	p<0.05	P>0.05	p>0.05	p<0.05	p>0.05	p>0.05	p<0.05	p>0.05

BRGT, 1990, A40 and A45 were different cultivars samples. Means with different ^{ab} (superscripts) in the same column are significant different at p< 0.05 and means with no superscripts are similar. BRGT = Beauregard

4.4 Discussion

The clipping day 20 DAP was removed from this study because there was nothing to be harvested since it was in the very early stage of sweet potato growth (fewer leaves). In addition, the setback was also attributed to the fact that KwaZulu-Natal was going through a severe drought which delayed the germination of the sweet potato, since the experiment was a rain-fed one, and there was no water for irrigation to compensate for rain based on the past low rain averages. Thus, delays in germination and growth were expected, which may as well have affected yields on other treatments.

Sweet potato vines showed very low dry matter content especially where clipping was performed at 60 and 75 days after planting due to its high moisture content which may affect feed intake if fed fresh or could be advantageous to add feed water during drought periods. This is in line with the findings by Peters (2008) who found low dry matter in vines harvested at 60-75 days after planting. Though dry matter content was a bit high at 120 DAP, it was much lower than the 83.95% that was reported by Mergesa et al. (2013). This may be due to the fact that vines were harvested while the plant was still growing vegetatively before tubers were removed. Once tubers had been removed, the vines became more lignified, dead material increased and the leaf to stem ratio was reduced as well as chlorophyll seizes (Mergesa et al., 2013). Therefore, it is right to suggest that harvesting at different periods may affect the quality of vines.

Low fibre content was witnessed amongst petiole, leaves and vines across all cultivars compared to the stem that had a higher amount of fibre, which surpasses the limit of 55 to 60% (Khalid et al., 2013). Similar results were witnessed in a study conducted by Archimède et al. (2011), who argued that fibre content varies with different cultivars and parts of the plant. This was more prominent when vines were clipped at 120 days after planting. High fibre content that was witnessed at 120 DAP may be due to increased cell wall cellulose and lignification for protection as the plant matures, which was in agreement with the report by Ali et al. (2015). Higher fibre content tends to limit voluntary feed intake in livestock (Khalid et al., 2013). It may, therefore, be recommended to feed as whole vines or leaves or petioles rather than stems. Nevertheless, separation of vine according to its portions such as stem, petioles and leaves may be labour intensive and time-consuming. Therefore, it may be of benefit to feed vines while still growing (from 60 to 75 days after planting) especially to those farmers who may be cultivating sweet potatoes with an aim of fodder making. However, this may be a problem if the primary objective of planting is for human food as it will affect tuber yields, especially if harvesting 60 DAP.

The vines harvested 60 and 75 days after planting had higher crude protein content compared to those harvested after 120 days. Furthermore, at 120 DAP CP was lower in 1990, A40, and BRG cultivars than A45. This may be attributed to the high content of fibre since its formation increased more as the plant was maturing. Its crude protein content decreased and chlorophyll also reduced as the plant got older (Megersa et al., 2013), which is not a satisfactory characteristic for a feed. The leaves had higher crude protein content which is in line with the results by Tamir et al. (2010). Their study showed that sweet potato leaves had crude protein content comparable to leguminous crops, thus can be considered as a source of protein for livestock especially in communal farms.

Apart from vines becoming more fibrous as they mature, they also tend to lose leaves, which are the most nutritious part of vines (Karachi, 1990). Loss of leaves may, therefore, contribute to the reduction of the nutritional value of vines. The plant's secondary compound (such as condensed tannins) production increased as the plant matures. This was evident in most vines' portions, almost across all cultivars condensed tannin content was increasing as sweet potato vines mature. Condensed tannins tend to bind with protein in a plant, which affects protein mobility or availability when consumed especially in ruminants. Moreover, both fibrous and tannin content of feeds tends to affect feed acceptability, palatability and digestibility in livestock. Therefore, an A45 cultivar may be fed as whole vines, though its availability is limited. Leaves also had high NDF, Lignin and tannin at 120 days after planting and show a reduction of CP, which can also be used as a guidance as to when to cut vines for feeding livestock. Vines and their portions had a good concentration of nutrients for ruminants even at maturity since more than 8% CP was presented, which is essential for microbial activity (Saheli et al., 2014 and Unigwe et al., 2014).

Digestibility seems to be more or less equal across all portions of vines and there was no difference between cultivars in treatment 1 (60 DAP). This may be attributed to the fact that vines were still tender, having low fibre content and relatively high protein content as well as low levels of condensed tannin, as shown in their chemical analysis. This observation is consistent with the results observed by Mergesa et al. (2013) that forage with high nitrogen content tends to increase digestibility. However, vines and their botanical fractions that were harvested at 120 DAP (at maturity when tubers were ready for harvesting), had digestibility levels similar to 86 and 93% which were reported in some sweet potato cultivars studied by Zereu et al. (2014). Furthermore, the low dry matter digestibility that was realised at 120 DAP may be attributed to the fact that harvesting at 120 DAP was conducted when a sweet potato had reached its maturity. Vines during that period (maturity), tend to be more fibrous, less leafy and more tanniniferous, lignin content also seemed to be higher as the sweet potato matures. Lignin content also affects cellulose digestibility as a result, the higher the lignin content the lower the digestibility (Salehi et al., 2014).

Sweet potato cultivar yields responded differently towards clipping on different dates. This variation was seen on cultivars harvested at 75 DAP. The cultivar 1990 produced higher vine (dry matter) yields compared to vine yield of 4.3 to 6 tons estimated by Khalid et al., (2013). These results were in line with the findings of Ahmed et al. (2012), who reported that clipping may improve shoot development and regeneration of new leaves, thus increasing yields. Furthermore, other varieties such as A40 and A45, seemed to be negatively affected by clipping dates, this is more evident when clipped at 60 DAP and 75 DAP as the tuber yields were reduced. This may be attributed to the fact that different cultivars respond differently towards clipping at different periods (Lam et al., 2004). However, both 1990 and A45 cultivars displayed themselves as cultivars that can perform under dry conditions, since they managed to give better yields than A40 and Beauregard cultivars. This is because it is a rain-fed experiment and plants were cultivated whilst there was drought. This concurs with the findings of Larbi et al. (2007), who argued that different cultivars respond differently towards clipping dates depending on cultivar and environment. Therefore 1990 cultivar may be utilised in the crop-livestock system, especially in a crop-livestock integrated system, where tubers may be utilised towards food production and vines used towards feed production. The hypothesis is therefore rejected because defoliation at different times affected the chemical composition of the vines as well as the yields of tubers from different cultivars.

4.5 Conclusion

Sweet potato vines presented as comparable nutritious feed for livestock especially during growing periods i.e. 60 to 75 days after planting. Though vines' nutrient content was reduced as they matured (120 days after planting), they still contained above 8% crude protein which is a minimum requirement for goats and other ruminants. A45 and 1990 produced more aerial material (vines) and had less leaf loss as the plant matured. It is also advisable to utilise the whole vine as feed rather than separating it into fractions. The 1990 cultivar produced high yields of vines when harvested 75 DAP without suppressing tuber yields that proved it to be suitable dual purpose cultivar, when compared to other cultivars such as A40, A45 and Beauregard. The chemical composition and *in vitro* digestibility have shown that vines have feed potential but require further studies on their *in vitro* digestibility. Also, if vines are only harvested twice, i.e. 75 DAP and at maturity, there will be a challenge for vine storage since they have a short life span once harvested. Therefore, a follow-up study on vine conservation methods should be conducted to ensure fodder availability during dry and winter periods.

Chapter 5

The effect of feeding sweet potato vines on goat intake, growth parameters and gastro-intestinal nematode infestation

5.0 Abstract

The aim of this study was to measure the effects of feeding goats with sweet potato vines (from 1990 cultivar) on feed intake, growth attributes, and anthelminthic activities (haemonchus). Thirty-two yearling male Nguni goats, with a similar body weight of ±21.84kg were randomly allocated to four treatments with eight goats per treatment. Four levels of fresh sweet potato vine were included in diets (hay *ad libitium*) as follows: T1 (0%), T2 (1.5kg), T3 (2.0kg) and T4 (3.0kg). The feeding trial lasted for 8 weeks. The results revealed that feed intake increases ($p<0.04$) with increasing levels of SPV supplementation. Goats fed T3 had the highest ($p<0.05$) final weight (FW), total weight gain (TWG) and average daily gain of 26.05kg, 4.18kg and 74.56g/day, respectively. The egg per gram (EPG) was reduced in all groups of goats fed sweet potato vines, and vice versa to the control group. In conclusion, supplementing the diet of Nguni goats with sweet potato vines has the potential to improve goats' production and feed digestibility as well as reduce egg counts.

Keywords: anthelminthic, feed, goats, supplement, sweet potato vines

5.1 Introduction

Goats play a crucial role not only in food security but in clothing and other social and commercial aspects. They also significantly contribute towards socio-economic importance since they are used during traditional or cultural ceremonies such as paying of bride price and local trading if there is a special need (Megersa et al., 2013). Goats are also the kind of animals that are easier to work with or manage, which is why in other countries you will find women being responsible for goat keeping in households. Goats can adapt very easily to a certain routine e.g. if they are fed maize in the afternoon, they will easily adapt to feeding times and will always come around during that time to have some maize. Goats can be hand-held during the administration of medicine and other examination procedures such as FAMACHA, extraction of faeces for worm count, and body condition scoring. Although these small ruminants are easily manageable, there are still other challenges that makes their keeping a lot harder such as poor nutrition, internal parasites such as worms and theft (Malento et al., 2011).

Shortage of nutritious feed is a major challenged in goats' production system, especially in communal farming where supplementation is limited or not available (Tainton, 2000a). As a result, goats in communal farming do not produce as they are expected to, and that needs to be addressed. It must be remembered that goats need a good feed during lactation, breeding as well as in winter or dry seasons to meet production requirements but are often abandoned or neglected with limited resources. The worst part of it is that, the lactating period especially if it coincides with winter or dry periods, the quality of milk produced mostly relies on the nutritional diet of the livestock, and the quality of veld during that period especially in rural communities (Morand-Fehr et al., 2007). Hence there is no control breeding system in communal areas. These animals find themselves kidding in winter with limited feed resources to produce milk for lactating kids (Salem et al., 2008). In most rural poor communities, kid and lamb mortality is very high in winter or dry seasons because of the limited nutrients that are available, to sustain kids, lambs, ewes and dams. According to Luginbuhl (2015), goats have higher nutrient requirements than cattle. They require 14% of protein for growth, 13% during lactation and 11% protein for their maintenance (Hadgu et al., 2014). Most tropical grasses have lower protein content than the general minimum requirement for goats' and other ruminants' production (Megersa et al., 2013). It is even worse during winter since nutrients move to root, where they are stored for the production of new grass plants in spring. Feeds that have low nutrient status tend to have low feed intake and digestibility hence they do not provide enough protein for rumen microbes (Ali et al., 2015). Thus animal growth, reproduction, meat and milk production and immunity of goats may be compromised due to a shortage of protein (Luginbuhl, 2015). If the animal immunity is not strong, it tends to be easily affected by diseases and internal parasites like worms that are troublesome in goats' production system. However, worm infestation can be controlled, if livestock is fed nutritious feed. Some feeds contain low tannins that are said to increase protein availability if it is in amounts less than 50g/kg (Madibela et al., 2006) and may control worms. However, the use of crop residues from locally produced crops such as sweet potato can be an advantage to rural farmers if investigated in terms of their animal treatment since previous experimentation showed that it had relatively small amounts of tannin.

Sweet potatoes are a crucial staple human food in tropical and subtropical areas of Africa (Apata et al., 2012). The tubers are used for both consumption and income generation. However, sweet potato vines are less or not utilised as food for humans especially in Southern Africa, thus the competition for food between livestock and humans may be reduced (Apata et al., 2012). Ali et al. (2016) in a study conducted in Swaziland reported that sweet potato vines seem to be highly nutritious, fermentable and digestible by goats. The authors further reported that sweet potato leaves may have crude protein content that is comparable to legumes such as Alfalfa which are often expensive thus not available to farmers in communal areas. The results from Ali et al. (2016) are similar to the 8% crude protein observed in sweet potato vines in experimental chapter 4 above. Poor nutrition had been reported as the major factor affecting low productivity in goats and other livestock, especially in developing countries (Khalid et al., 2013; Megersa et al., 2013), which is not different to what is happening in rural communities of South Africa that are raising goats. According to Aregheore (2004), sweet potato vines also contain minimum amounts of tannins (that are less harmful to ruminants but may be enough to control gastrointestinal nematodes. However, they requested that studies must be done to confirm such allegations because containing tannins is not enough to predict control of helminths. Therefore, this study will be looking at the performance of goats fed sweet potato vines as a supplement and whether it will have any effect on worm control. It is, therefore, hypothesized that supplementing goats' diet with sweet potatoes vines will increase goats performance and reduce nematode infestation.

5.2 Materials and methods

5.2.1 Study area

The study was conducted at Owen Sithole College of Agriculture (OSCA) situated at KwaMthethwa area, under Umfolozi local Municipality, in KwaZulu-Natal, South Africa. The location is found at 28°45'S latitude and 31°53'E longitude and it receives rainfall of about 900mm per annum and has a 26°C mean temperature per annum (Kunene et al., 2015). Faecal egg count analysis was conducted at the Department of Agriculture laboratory in University of Zululand (28° 51' 06' S 31° 51' 08' E; altitude 102m), KwaDlangezwa, KwaZulu-Natal South Africa.

5.2.2 Ethics and consent

The procedures used in this study were approved by the Ethics Research Committee from the University of Zululand with ethical clearance number UZREC171110-030 PGM 2016/292.

5.2.3 Performance of goats

5.2.3.1 Animals, treatments, experimental design and feeding

Yearling male Nguni goats were allocated to four dietary treatments with each having eight per treatment in an eight weeks' experiment, hence 32 goats were used in this experiment. The experiment was conducted in a randomised complete block design and the factors were sweet potato vines at 0kg, 1.5kg, 2.0kg T4 3.0kg, following the method explained by Hussain (2010). Prior to the experiment goats were allowed to adapt to experimental feed and housing facilities for two weeks. Goats were placed in separate individual pens (150cm X 50cm X 60cm) for supplementation. The goats were first fed sweet potato vine supplements before introducing them to *Eragrostis* hay (as basic feed) *ad libitum* during the day. Each goat was fed with separate feeding bowls (to ensure each goat received the exact amount of feed allocated to minimise incidence of inconsistence during feeding), in the mornings around 8:00 am.

5.2.3.2 The composition of experimental diets

The 1990 cultivar was selected based on its nutritional quality, yield and relative abundance of vine as seen in previous studies (chapter 4). It was less affected by clipping and produced comparable yields of both tubers and vines though it was cultivated under dryland conditions. Table 5.1 below shows the nutrient composition of the diet for goats. The sweet potato vines were harvested from the sweet potato that was cultivated at OSCA specifically for feeding goats and vines were fed fresh. The hay used as a source of energy was collected from Dundee Research Centre (produced from *Eragrostis tef* grass). Hay was fed adlib. The nutrient composition of the diet used is presented in Table 5.1.

Table 5.1 The nutrient composition of diet (sweet potato vines and hay) fed to goats

Feed	DM%	NDF%	ADF%	ADL%	CP%	CT g/kg
SPV	17.80	48.52	33.06	14.93	17.02	35.98
Hay	80.00	75.10	45.53	8.16	5.66	--

SPV=sweet potato vines, DM=dry matter, NDF=nutrient detergent fibre, ADF=acid detergent fibre, ADL=acid detergent lignin, crude protein, condensed tannin

The biomass of sweet potato shown in Table 5.2 below was calculated from the yields of 1990 cultivar harvested 75 days after planting. The biomass was divided into i.e. biomass of vines and biomass of vines plus tubers. Biomass refers to the total yield of vines and tubers.

Table 5.2 Carrying capacity for sweet potato fed at different levels

Measurements	T1	T2	T3
Intake (kg/goat/day)	1,50	2,00	3,00
Forage yield, (kg/ha)	68330.00	68330.00	68330.00
Tuber yield, (kg/ha)	56910.00	56910,00	56910,00
Biomass yield, (kg/ha)	125240,00	125240,00	125240,00
Carrying capacity 1	316.17	237.13	158.08
Carrying capacity 2	695.78	521.8	347.89

T1 = 1.5kg spv/day, T2=2kg spv/day and T3=3.0kg spv/day fed as fresh. Biomass determined as forage +tuber yields as a fresh basis. Carrying capacity 1, calculated from daily intake per animal over 120 days. Carrying capacity 2 calculated from biomass yield and daily intake per animal over 120 days.

5.2.3.3 Growth performance

The feed was measured and recorded daily using a digital hanging scale and the feed intake was obtained by subtracting the feed refused from the feed offered. Goats were first measured at the beginning of the experiment and subsequently, weekly to be able to calculate the average daily weight gained. The feed conversion ratio (FCR) was obtained by dividing the average total feed intake by average total weight gain, as explained by Unigwe et al. (2014).

5.2.3.4 Digestibility Study

The digestibility study was conducted at the last two weeks towards the end of the trial. Goats were allocated as explained in 5.2.3.1. The total amount of feed given to the goats per replicated were recorded and the left overs were collected and weighed daily to calculate feed intake. Faeces were collected daily and oven dried, weighed and recorded to determine dry matter digestibility. Feed intake was expressed as the difference between feed offered and left overs. Dry matter digestibility was also expressed as the difference between the feed intake and dry faeces (Madzinga et al., 2017).

5.2.4 Anthelminthic effect of sweet potato vines and body condition of goats

The effect of feeding sweet potato vines on gastrointestinal nematodes was determined following the procedures described by Kunene et al. (2015).

5.2.4.1 Body Condition Score

Body condition score (BCS) was conducted following methods explained by Kunene et al. (2015). The BCS data were taken using a scale of 1 to 5 (scale 1 being too emaciated, 2 thin, 3 average conditions, 4 fat and 5 being obese). Body condition scoring was conducted at the initial day of the experiment and thereafter every two weeks on Monday morning during weighing period. It was performed by observing, touching and feeling the centre and sides of a goat's back bone towards the hind legs. The more piny and sharper the bone was the thinner the goats and the smoother and more rounded, it was then considered fat (4) to obese (5). The goats were body condition scored 6 times in total during this experiment.

5.2.4.2 Monitoring the anaemic levels in goats

The anaemic levels of goats were monitored using the FAMACHA© chart following the method described by Kunene et al. (2015). The FAMACHA© chart is an eye colour based stratification method, with five colour categories of the conjunctiva membrane from bright red to pale as an indicator of anaemia often caused by *Haemonchus contortus* infestation. The lower eyelid mucous membrane of each goat was examined and compared to a colour chart picture of an eye with five different levels of anaemia and assigned a score of 1 (showing red colour being non-anaemic and acceptable), 2 (red-pink colour illustrating non-anaemic and borderline), 3 (pink, meaning mild anaemic and dangerous), 4 (pink-white which is anaemic and fatal) and 5 (porcelain-white which stands for severity). FAMACHA recordings were first recorded at the beginning of the feeding experiment and thereafter every two weeks on Monday mornings during weighing. A total of 6 FAMACHA recordings were taken per treatment, during this experiment.

5.2.4.3 Determination of faecal egg count (FEC) in goats

The faecal egg count was done to investigate if sweet potato contains bioactive compounds that can be used to control nematodes. Faecal samples were first taken at the beginning of the feeding experiment and thereafter every two weeks on Monday morning during weighing. A total of 6 faecal samples were collected per treatment, during this experiment. The samples were then taken to the University of Zululand Agricultural Laboratory for analysis. One gram of faeces from 50 g of faeces collected from the rectum of each goat was dissolved in 40ml of sugar solution and allowed to stand for five minutes. Faecal egg count was counted using the modified McMaster Technique which estimates egg count per gram (EPG) of faeces (Kunene et al. (2015). The number of nematode eggs in both wells of the McMaster chamber multiplied by 133 [40 ml ÷ (0.15 ml x 2) = 133] to get EPG. Generally, 500 EPG had been suggested for treatment by many authors in order to lower pasture contamination and prevent the development of subclinical diseases. The FAMACHA© chart is often linked to wireworm (*Haemonchus contortus*) when relating faecal egg counts to FAMACHA scores. Since pathogenicity count is greatly influenced by species type and number, the total egg counts greater than 2000 will be considered as potential anaemic counts. The percentage reduction was calculated as followed:

$$\%Red = \left(\frac{IEPG - FEPG}{IEPG}\right) * 100$$

Where;

%Red = percentage reduction

IEPG = initial egg per gram

FEPG = final egg per gram

5.2.5 Statistical Analysis

All the data collected was subjected to the analysis of variance using the General Linear Models Procedure of SPSS (2015). Comparison of means was done using Turkeys t-test and means were different when p<0.05.

5.3 Results

5.3.1 The feed intake, dry matter digestibility, average daily gain of goats fed sweet potato vines

Hay intake, sweet potato vine and total feed intake increased (p<0.05) with the inclusion of sweet potato vines in the diet. The goats at T4 showed the highest (P<0.05) intake (Table 5.3). Furthermore, dry matter digestibility (DMD) was improved with the inclusion of sweet potato vines in diet and the highest (p<0.05) DMD% was seen in goats at T4. Supplementation with sweet potato vines increased (P< 0.05) AVDG of goats comparable to control treatment with the highest gain observed at T4. The FCR among supplemented goats decreased ($P < 0.05$) with increasing levels of sweet potato vine supplement. Goats in the control treatment had the highest ($p<0.05$) FCR compared to T4 with the list FCR.

Table 5.3 Effect of different feeding levels on feed intake, dry matter digestibility and average daily gain of goats

Parameters	T1	T2	T3	T4	SED	Sig
AVFI Hay kgDM/day	0.95^{a}	0.96^{b}	0.97^{c}	0.98^{d}	0.02	0.000
FI SPV kgDM/day	0.00^{a}	0.27^{b}	0.36^{c}	0.53^{d}	0.04	0.000
TFI kg/day	0.95^{a}	1.28^{b}	1.36^{c}	1.57^{d}	0.04	0.000
DMD%	63.68^{a}	69.91^{b}	70.60^{b}	73.75^{b}	0.96	0.001
AVDG g/day	14.51^{a}	23.81^{a}	45.09^{b}	74.56^{c}	0.00	0.000
FCR (g DM kg^{-1} BW gain)	70.93^{b}	62.72^{b}	30.82^{a}	21.28^{a}	4.85	0.000

Means with different ^{abcd} superscripts within a row had a significant difference at P< 0.05 and means with no superscripts are similar. AVFI Hay = hay feed intake, FI SPV = vines feed intake, TFI = total feed intake, DMD = goats dry matter digestibility, FCR = feed conversion ratio

5.3.2 The effect of feeding sweet potato vine on goat's live weights

The inclusion of sweet potato vine in the diet affected ($P < 0.05$) final weight, total weight gained and average daily gain (Table 5.4). The weights of goats improved ($P <0.05$) as inclusion level of sweet potato vines increased in the diet. Higher ($P <0.05$) final weight, total weight gained, and average daily gain were observed in goats supplemented at T4 when compared to T1, T2 and T3.

Table 5.4 Changes in goats' live weights with increasing portions of sweet potato vines as a supplement

Parameters	IW (kg)	FW (kg)	TWG (kg)	AVDG (g/day)
T1	21.84	22.62^{a}	0.75^{a}	13.40^{a}
T2	21.84	23.00^{a}	1.19^{a}	21.21^{a}
T3	21.84	24.49^{ab}	2.53^{b}	45.09^{b}
T4	21.84	26.05^{b}	4.18^{c}	74.56^{c}
SED	0.36	0.46	0.25	4.29
Sig	1.00	0.024	0.000	0.000

Means with different ^{abc} superscripts within a column had a significant difference at P< 0.05 and means with no superscripts are similar. IW= Initial weight, FW = final weight, TWG = total weight gained and AVDG = Average daily weight gained.

5.3.3 The anthelminthic properties of sweet potatoes vines fed to goats

Supplementation of sweet potato vines did not influence ($P > 0.05$) The final FAMACHA and final faecal egg per gram (FEPG) (Table 5.5) but affected ($p<0.05$) FBSC and %RED. Dietary effect ($P < 0.05$) was seen in FBSC and the highest ($p<0.05$) FBSC was observed in T3 and T4 goats while the least was in T1. The IEPG was statistically similar among goats supplemented but was different (P <0.05) from the control. The highest IEPG was observed in T4 goats and the least was in T1 goats but the reverse was true after feeding for FBSC.

Table 5.5 Comparison of goat body condition, anaemic level and haemonchus infestation on goats fed SPV as a supplement

Parameters	IBSC	FBSC	IFAM	FFAM	IEPG	FEPG	%RED
T1	3.25	3.19[a]	3.00	2.75	631.00[a]	1012.00	-60.38
T2	3.00	3.69[b]	2.88	2.38	3250.50[b]	1012.00	68.87
T3	2.88	4.00[c]	3.00	2.56	4187.50[b]	1337.00	68.07
T4	3.12	4.00[c]	3.00	2.38	4350.00[b]	925.00	78.74
SED	0.11	0.27	0.19	54.22	128.78	10.51	10.80
Sig	0.67	0.00	0.94	0.42	0.00	0.35	0.05

Means with different [abc] superscripts within a column a significant difference at P< 0.05 and means with no superscripts are similar. IBSC = initial body condition score, FBCS = =final body condition score, IFAM = initial FAMACHA, FFAM = Final FAMACHA, IEPG = Initial egg per gram, FEPG final egg per gram and %RED = percentage reduction on EPG. –ve meaning there was no reduction in gg count but an increase in egg.

5.4 Discussion

Hay feed intake increased as the feeding levels of SPV supplementation increased as seen at T4 with the highest total feed intake compared to other groups. This was associated with the nutritional value brought in by vine supplementation. From the chemical analysis of vines, it brought in relatively higher amounts of crude protein as well as moisture. The presence of moisture probably increased palatability and crude protein which might have increased the initial amount of proteins required for microbial growth increased digestibility hence intake. Increase in microbial growth also implies increase in feed breakdown since there will be many more microbes digesting the same quantity of feed. The similar trends in feed intake have been shown in the study conducted by Dom et al. (2009). However, intake was lower in goats fed T2 which was given a lower ration of sweet potato vines, such that there was no statistical difference when compared to T1 (control). This may be due to the fact that the number of nutrients (especially protein) in feed diets were low as a result feed acceptability was lowered. Similar results were reported by Katongole et al. (2009) in goats that were fed different levels of sweet potato rations. According to Mergesa (2013), an increase or no increase in feed intake may be influenced by the degree of supplementation as well as the amount of nitrogen available in the feed. Moreover, grass hay has a low amount of nitrogen and sweet potato vines that were given in small amounts had restricted amounts of proteins hence the possible explanation of lower intake in T1 and T2.

Feed convention ratio (FCR) was also decreasing with increasing feed levels, with treatment 4 having the lowest FCR, which may be attributed to the increasing nutrient value of the feed, like the sweet potato vine inclusion. This means that the animals were gaining more weight which implies that the weight will be increasing while the feed intake remains constant hence a decrease in FCR at T4. The FCR findings contradicted findings by Unigwe et al. (2014), who claimed that the inclusion of high levels of sweet potato resulted in increased FCR, due to anti-nutrients that are found in sweet potato vine. It may be presumed that the anti-nutrient effect in the feed that were given to goats in this experiment, was not high enough to affect goats' performance negatively. As a result, 3kg fresh sweet potato vines may be recommended as appropriate quantities for goats' supplementation.

Dry matter digestibility was highest in goats fed sweet potato vines when compared to the control feed. However, the digestibility was similar across all goats' groups that were supplemented with sweet potato vines, which is in line with the results reported by Megersa et al. (2013). This was due to the fact that sweet potato vines had relatively high protein content and were easily palatable (Katongole et al., 2009), thus can improve nutrient status and utilization (by goats) of tropical grasses. Therefore, feeding sweet potato vines can improve hay digestibility even when it is given at lower amounts. Supplementation with nutritious feeds may improve acceptability and encourage microbial growth, as a result, both feed intake and dry matter digestibility can increase hence resulting in improved goats' performances (Megersa et al., 2012). The research shows that sweet potato vines with 7.19% crude protein can improve digestibility of grass since the protein content can be enough to kick-start microbial activity. Thus, these findings can also be used to encourage farmers to utilise sweet potato vines as feed whenever they have access to them.

The live weights of goats improved with the inclusion level of sweet potatoes in the diet. This may be attributed to the increasing levels of crude protein available in the feed coming from increased utilisation of potato vine feed that may indirectly have a positive effect on growth rate and weight gain (Tamir et al., 2010). Goats in T1 and T2 had similar live weights which may be attributed to the fact that they were fed the least levels of sweet potato vines which might not have been able to provide enough crude protein to boost microbial activity that is enough to promote growth. Such feed may not have enough nutrients to improve goats' performance in terms of weight. According to Kalio et al., (2013) feed utilization efficiency depends on the nutrient value of the feed itself.

Goats that were fed 3kg fresh sweet potato vines (SPV) had the highest total weight gain (TWG) and average daily gain (Hadgu et al. 2014). Kebede et al., (2008), claimed as an acceptable live mass gain. This shows that sweet potato vines can be beneficial to rural livestock communities that cannot afford to purchase supplements. Feeding sweet potato vines can also result in production costs cutting in both commercial and emerging farm environments. A commercial farmer may as well decide to reduce a certain percentage of concentrates and replace with sweet potato vines as a strategy to manage resources as well.

The initial body condition score of goats ranged from 2.88 to 3.55 which shows that goats were in good body condition at the beginning of the trial. However, they initially had high worm infestation in treatment 2, 3 and 4 since they had higher EPG than 2000 which is regarded as high and goats may need to be treated against worm burden (Kunene et al., 2015). However, the goats used in this study were selected based on their weight only and not egg counts because the effect of the feed on egg count was also going to be monitored. Interestingly, the initial mean egg count for the control group of animals was very low but could not be changed as it would have affected the design of the experiment. Goats with high worm infestation tend to lose appetite and be emaciated but this was not the case as the initial body condition scores were normal. However, there was less incidence of sick goats at the beginning of the experiment. The final body condition score of goats increased with increasing levels of sweet potato vines. It was attributed to sweet potato vines' nutritive value. According to Filley et al. (2006) a good condition score is a function of nutritious feed, as a result, it is suggested that the body condition score may be used to draw the diet of goats, based on its production needs.

The initial FAMACHA results also showed that goats were mild anaemic, meaning goats were infested with worms and treatment was required. However, no treatment was being used on them as of that time in the farm hence their resistance against *Haemonchus contortus* worms. However, the final goat's anaemic levels were not affected by sweet potato vine feeding, though there were some positive reduction signs of anaemic levels in goats when compared to the initial levels. The FEG count revealed reduction of Haemonchus *contortus* worm burden in goats. Apart from the nutritional content of sweet potato vines, the reduction of *Haemonchus* may also play a vital role in influencing SPV feeding. The egg count reduction was attributed to the presence of condensed tannins in sweet potato vines. According to Mendez-Orttiz et al., (2012), the condensed tannins in feed results in the reduction of fecundity in *Haemonchus,* which then cease the reproduction or multiplication of *Haemonchus.* However, a negative percentage reduction was shown in FEG of the control which indicated that indeed inclusion of sweet potato vines in feed diets as a supplement, may reduce worms in livestock. Furthermore, Hoste et al. (2012), suggest that inclusion of tannins in diet may indirectly improve the immunity of goats against nematode infestation.

5.5 Conclusion

It was also observed that SPV improved dry matter digestibility of hay even when it was given at lower quantities to goats. Goats that were fed 3kg (T4) of fresh sweet potato vines (SPV) had the highest total weight gain (TWG) and average daily gain. The feed conversion ratio (FCR) was highest in T1 and lowest in T4. The results also revealed that supplementing at T4 reduced nematode egg counts. This indicates that sweet potato vines may be utilised as a substitute to concentrate and legumes in supplementary feeding which possesses anthelminthic potential. The anti-nutrient effect of sweet potato vines was not observed in this study but may be further investigated in subsequent studies by increasing the amount of sweet potato vines to 100% for goat feeding.

Chapter 6

6.1 General Summary

Lately in northern KwaZulu-Natal, the rainfall is not as high as before the 2015 drought (Enca, 2016). The drought that occurred in 2015 has been reported as the most severe when compared to the past 2 decades (Moraba, 2018; Xulu et al., 2018) which implies that natural vegetation which most of the rural farmers depend on is still a major limitation. Winters are often very harsh in northern KwaZulu-Natal with animals losing condition, dying or farmers being forced to sell animals to manage the situation (Moraba, 2018). Therefore, there is a great need to investigate alternative indigenous forages that can be exploited by the rural resource-limited farmers to remedy the situation, especially in winter. That is why this study was designed to investigate the feed potential of indigenous crop residues for goats.

In the local community, it was noticed that sweet potatoes were being planted by many people and the vines were not being used as feed but were left on the farm unattended as waste and burnt or used as mulch at times which is similar to the concerns by Tamir et al. (2010) that sweet potato vines are wasted, when they can be utilized as feed supplements to livestock. From this incomplete information, the first experimental chapter was designed to assess the knowledge and perception of small holding farmers, concerning indigenous crop residue supplementation especially feeding sweet potato vines to goats. The results from survey conducted in KwaMthethwa community area, showed that not only one cultivar of potatoes was planted in this region but many among which were 1990, A45, A49 BGRT, blesbok, Ndou, and other local indigenous cultivars. It was found that farmers were aware of supplementary feeding but the mission behind extra feeding was to ensure goats come back for kraaling without a header rather than gaining condition.

Most farmers were not feeding sweet potato vines since they believed sweet potato vines cause diarrhoea in goats and it is fatal, which may be due to the lack of knowledge concerning proper supplementary management. It may also be attributed to the fact that if goats or sheep are fed lush feed without proper adaptation, they tend to develop pulpy kidney disease (Alves et al., 2014). Pulpy kidney is caused by a bacterium called *Clostridium perfringens* that is normally found in the intestine of animals including humans and its effect is mostly triggered by a sudden change in diet (Uzal et al. 2008). This was an indication that more interventions are required to develop farmers' knowledge concerning supplementary feeding and the use of sweet potato vines as feed. The practical demonstration of goats fed sweet potato vines and change in goats' performance, as well as training and advice on supplementary feeding, may assist to remove the myth that sweet potato vines are fatal.

Elsewhere, there are a few studies that have demonstrated the use of sweet potato vines to feed animals and their results demonstrated positive influences on animal preferences such as carcass, milk and animal health control (Khalid et al., 2013; Megersa et al., 2013). This conclusion led to the investigation of the nutritional value of some of the potato cultivars that are available and most popularly used (1990, A40, A45 and Beauregard) by the majority of rural farmers in northern KwaZulu-Natal. The chemical constituents of these cultivars were the first nutritional value of the feed that was evaluated in experimental chapter 2 as well as their *in vitro* digestibility. The results clearly indicate that sweet potato vines have relatively higher crude protein and lower fibre which was less than 60% compared to most grass hays. *In vitro* digestibility also showed that it is very possible for these vines to be fermented in the rumen with potentially high yields of volatile fatty acids as seen in TD of vines harvested at 60 and 75 DAP.

Experimental chapter 3 did not investigate the chemical composition of the chosen cultivars but it looked at the effect of defoliation at different times of harvest on the chemical composition of sweet potato vines as well as tuber yield. The study was meant to give more information on when is best to harvest sweet potato vines without drastically affecting sweet potato yields which is the primary objective for planting them. The results from the chemical composition experiment revealed that sweet potato vines and vine components (leaves, petioles and stems), have protein content enough to meet the nutritional requirements for goats. This was because the Crude protein observed in SPV was higher than the minimum protein requirement (8%) in ruminant diets (Hadgu et al., 2014). Protein in feeds is also very crucial for the synthesis of microbial-protein as it is the major source for ruminants.

The dry matter content was very low due to high moisture content that was displayed in sweet potato vines. This is similar to what has been observed in many other studies especially vines with fresh leaves. The moisture content may be of advantage as a source of water for livestock especially during dry seasons where water sources are really scarce. When it comes to animal feeding, the required amounts can be estimated, and the farmers advised on the right quantities to be fed. For example, the study of

Peters (2008) showed that replacing hay (basal feed) with up to 50% quantities per animal of sweet potato vines (preferable varieties that produce large amounts of biomass from both vines and tuber) improved animal performances.

The *in vitro* dry matter digestibility seemed to be high, since they are more nutritious, they contain crude protein that is above minimum requirement for goats which concur with the report by Tamir et al. (2010). Cultivars with high *in vitro* degradability are reported to be the best protein supplements that can be used in winter, when the natural pasture has very low nutrient status and is unable to provide enough nitrogen required for microbial activity. For example, Ligwalagwala (sweet potato cultivar) vines, cassava leaves that was reported by Ali et al. (2016) in Swaziland and Siriat et al. 2010 in Indonesia, that they contain approximately 20% crude protein, which contain highly degradable N. Furthermore, sweet potato vines, cassava leaves and banana leaves, as well as other agricultural by-products from indigenous food crops can potentially be digested *in vivo* and compare to the findings from *in vitro* digestibility from this study for better understanding.

Sweet potato vines also displayed themselves to have low cell wall anti-nutritional content such as lignin and condensed tannins. Low condensed tannins in sweet potato vine were also reported by Ali et al. (2016). Smaller quantities of condensed tannins have been shown to have a positive effect in animal performance (such as feed intake, digestibility and weight gain), since they tend to increase the amount of undegradable protein and supply of essential amino acids to the digestive system of the animal (Kongmanila et al., 2012).

The yields of vines and tubers responded differently towards clipping, however the 1990 cultivar displayed itself to have good yield of both vines and tubers when harvested at 75 days after planting. It is crucial to remember that sweet potatoes form a staple food for human beings in African countries, and some make an income from it. It is, therefore, important to make sure that harvesting vines for livestock feeding, does not affect tuber yields to avoid a conflict of interest. Furthermore, sweet potato vines can make good supplement for low quality forages or grasses that are consumed by ruminants in the veld. However, harvesting sweet potato vines at 75 days after planting or at maturity (during tuber harvesting) may be recommended as well since they both do not affect tuber production.

Supplementing with sweet potato vines resulted in an increase in goats' feed intake and digestibility. This was seen by the varying amounts of SPV intake of the different cultivars. Goats seemed to gain weight with increasing SPV supplement levels. The performance of goats seemed to be improved when low-quality feed (grass hay) was supplemented with varying levels of sweet potato vine forage. The protein content in low quality forages is known to be a limiting factor in livestock performance; this implies that supplementation might have improved the protein richness of their feed. Studies by Madziga et al. (2017) and Megersa et al. (2013) also showed that supplementation increased animal performance. The body condition score was also increasing with increasing feed levels though there was no significant effect on anaemia levels (FAMACHA). The eggs per gram was also reduced in goats that were supplemented with sweet potato vines. To conclude, feeding sweet potato vines to goats as a supplement proved to enhance goats' performance in terms of growth, feed intake and digestibility and had a positive effect on haemonchus infestation in terms of egg count reduction.

6.2. General conclusion

Indigenous knowledge still plays a major role in livestock farming practices of rural communities especially in supplementary feeding and cure of diseases of their animals. Indigenous knowledge and experiences should be considered and somehow documented to avoid its extinction, and improved as well, since it is the most important tool that sustains small holding farmers. However, the indigenous knowledge may need to be tested since it may be based on beliefs and myths that could also mislead farmers. Hence, in this study it was discovered that most farmers were not feeding sweet potato vines since they believe sweet potato vines cause diarrhoea in goats and it is fatal. Farmers that were using drugs as a cure for helminths seemed to be using one active ingredient over and over, that may lead to resistance, thus more intervention is required to assist in developing animal health programmes.

Sweet potato vines presented as comparable nutritious feed for livestock especially during growing periods i.e. 60 to 75 days after planting. Though vines' nutrient content was reduced as they mature (120 days after planting), it still contained above 8% crude protein content which is a minimum requirement for goats and other ruminants. It is also advisable to grow cultivars that produce higher yields of tubers, higher aerial material (vines) and have less loss of leaves as the plant matures that may improve biomass. It is also advisable to utilise the whole vine as feed rather than separating it into its portion.

The 1990 cultivar was found suitable to be utilised as the dual purpose cultivar compared to other cultivars if clipped 75 DAP. Hence, no clipping effect was shown when harvested at 75 DAP, instead, its tuber yields were comparable to 120 ADP.

The feed intake, average daily gain and digestibility was improved in goats fed sweet potato vines as supplement, with increasing feeding levels in goats. It was also observed that SPV improved dry matter digestibility of hay even when it was given at lower quantities; goats and 3kg fresh vines (T4) was best with the highest total weight gain (TWG) and average daily gain. The worm infestation was reduced in all treatments fed sweet potato vines as supplement and negative reduction was realized in control (no vine fed). As a result, feeding sweet potato vines to goats seems to have an effect on nematodes control.

6.3 Recommendations

Findings from this study revealed that the reason behind farmers' supplementation is not for increasing production purposes but to ensure goats are kraaled every night. Therefore, there is need to educate farmers to understand the need for goats to still meet their daily nutritional requirements for survival, growth, maintenance and reproduction. Training about proper supplementary feeding is required by farmers. Most crop residues are available in autumn and they are fed immediately after harvesting, leaving goats and other livestock with less nutritious feed in winter to early spring, where nutritious supplements are needed the most. The indigenous food crop by-products, trees and shrubs that are used by communal farmers need to be investigated, documented and their potential as feed for livestock validated and when possible improved and conserved to increase the period of its availability for livestock. Furthermore, interventions to equip farmers with knowledge and skills on crop residue conservation (hay and silage making) practices, at a lesser cost, are also recommended. Moreover, this study revealed that sweet potato vines are nutritious and can improve goats' performance in terms of feed intake and growth, thus can be used as a feed supplement for goats and other livestock. However, there is also a need to conduct goat feed demonstration trials to show performance of goats and to eradicate the myth that sweet potato vines are fatal to goats in the rural communities. It is suggested that another study be conducted to determine whether there are other bioactive constituents of sweet potato vines that may have influence on the reduction of *Haemonchus contortus* worms.

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Appendix A (a)

Research Questionnaires

Faculty of Agricultural Science (University of Zululand, KwaDlangezwa, KwaZulu-Natal, South Africa)

Student number	: 201161197
Initials and surname	: C.F. Luthuli
Postal address	: P/Bag X 20013 Empangeni 3880
Contact numbers	: 0357951345/0823046778
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Dear respondent

I am an MSc Animal Science post-graduate student of the Department of Agriculture, University of Zululand. The purpose of this questionnaire is to help in my M. Sc. Research. My research is focused on the understanding of supplementary feeding and type of feed used as supplement to livestock by community farmers. What are the constraints of supplementary feeds utilisation? The information required from response is meant for the purpose of this research ONLY.

Please mark X in the appropriate box to answer the questions or answer yes or no where it is appropriate to do so.

Thanks

CF Luthuli

PERSONAL BIODATA/ EXPOSURE OF RESPONDENTS TO SUPPLEMENTARY FEEDING

Section A. bio data and background information of the farmer

1. Name of Respondent……………………………………………………………….. (optional)

2. Male or female

   Male Female

3. How old are you

18 – 25 25 - 35 35 - 40 40 - 45 45 - 55 55 - 65 Above 65

4. What is the level of you education

Never Grade 1 -7 Grade 8 - 12 Graduate Postgraduate

5. Are you a farmer or other?

Farmer Other

If other, please specify……………………………………………………………

Section B. Livestock information (type and quantity owned by a farmer)

1. Do you have cattle, sheep or goats?

Yes No

If yes, please indicate how many?

Cattle Sheep Goats

2. Who owns goats

Father Mother Son Daughter other

If other please specify……………………………………………………………

3. Why do you keep goats

Consumption Culture Source of income milk meat

Section C. Knowledge of a farmer concerning supplementary feeding

1. Have you ever heard about supplementary feeding?

Yes No

If yes, do you practice supplementary feeding? Yes or No

Yes No

Do you buy it or use harvesting waste or other?

Buy Use waste other

If other, please specify……………………………………………………………..

When do you feed supplements?

Breeding	Early gestation	Late gestation	Lactation	Drought or winter

2. Do you cultivate sweet potatoes?

Yes No

What do you specifically cultivate it for? …………………………………………

3. What do you do with sweet potato vines or waste after harvesting?

Feed to livestock	Leave as mulch or manure	Throw away as waste or burnt?

4. Have you heard that sweet potato vines or waste or surplus can be fed to livestock?

Yes No

5. What do you think about feeding sweet potato as supplementary feed?

Good Bad

Motivate your answer…………………………………………………………………

…………………………………………………………………………………………..

Section D. Causes of animal loses

1. Are there any goats' losses on your farm?

   Yes No

   If yes, what are the courses?

Malnutrition	Diseases	Theft	Other

If other please specify…………………………………………………………………………

2. If diseases contribute in animal losses what may be the causes or type?

Worms	Abortion	Foot rot	Lice/ticks	other

If other please specify…………………………………………………………………………

3. Are the worms treated

   Yes No

   If yes how often?

Never	Once a year	Twice a year	Thrice a year	More than thrice a year

4. What do you use to treat worms

   Drugs Traditional remedies

Please mention name of remedies use to treat worms …………………………………..
…………………………………………………………………………………………..

Thanking you in advance for participating in this survey. It is believed that the outcome of this research will be of fruitful to goats' farmers and South African livestock community.

Signature…………………………… Date………………………………....

Appendix A (b)

Imibuzo Yenhlolovo

Umkhakha wezesayensi nezolimo (eNyuvesi yasoNgoye, KwaDlangezwa, KwaZulu-Natal, EMzansi Afrika)

Inombolo yomfundi	: 201161197
Igama nesibongo	: C.F. Luthuli
Idilesi	: P/Bag X 20013 Empangeni 3880
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Ngiyakubingelela

Ngingumfundi wemfundo ephakeme eNyuvesi yasoNgoye ngaphansi komkhakha wezolimo. Inhloso yalenhlolovo ukusiza ocwaningweni olubheke kakhulu kulwazi lwabalimi abancane mayelana nokuphakela izimbuzi ukudla kokuchibiyela. Nokuthi iziphi zingqinamba ekuphakeleni ukudla kokuchibiyela. Lolulwazi ludingeka ukusiza lolucwaningo kuphela.

Uyacelwa ukuba ufake uX ebhokisini eliseduze nomubuzo, uchaze kuphela uma kunesidingo.

Ngiyabonga

CF Luthuli

IMININININGANE YOMLIMI KANYE NOLWAZI MAYELANA NOKUPHAKELA IZIMBUZI UKUDLA KOKUCHIBIYELA

Isigaba A. imininngwane yomlimi

1. Igama………………………………………………………….. (akuphoqekile)
2. Owesilisa noma Owesifazane

   Owesilisa Owesifazane

3. Uneminyaka emingaki?

18 – 25 25 - 35 35 - 40 40 - 45 45 - 55 55 - 65 Above 65

4. Ufunde wagcina kuliphi zinga?

Never　　Grade 1 -7　　Grade 8 - 12　　Graduate　　Postgraduate

5. Ungumlimi noma okunye?

Farmer　　Other

Uma ungasiye umlimi sicela uchaze…………………………………………………….

isigaba B. Ulwazi oluphathelene nemfuyo

1. Unazo izinkomo izimvu okanye izimbuzi?

Yebo　　Cha

Uma unazo zingaki?

Izimbuzi　　Izimvu　　Izimbuzi

2. Ubani umnikazi wezimbuzi

Ubaba　　Umama　　Indodana　　Indodakazi　　Omunye

Uma kungomunye siyacela umbalule………………………………………………

3. Nizigcinelani izimbuzi

Ukudla　　Isiko　　Zingenisa imali　　Ubisi　　Inyama

isigaba C. Ulwazi mayelana noudla kokuchibiyela

1. Ukewezwa ngokudla kwemfuyo kokuchibiyela?

Yebo　　Cha

Uma kungukuthi yebo, uyakuphakela kwemfuyo yini ukudla kokuchibiyela?

Yebo　　Cha

2. Uyakuthenga, usebenzisa izinsalela emasimini noma okunye?

Uyathenga	Usenzisa oksala emasimini	Okunye

Uma kungokunye sicela uchaze………………………………………………

3. Uphakela nini?

Ngesikhathi sokukhwelisa	Sezimithi ngasekuqaleni	Sezimithi ngasekugcineni	Ngesikhathi sokuncelisa	Ngesomiso/ ebusika

4. Uyawulima ubhata?

Yebo	Cha

Uwulimelani? …………………………………………………………………

5. Wenzani ngamakhasi kabhatata okanye izinsalela?

Uphakela imfuyo	Uwashiya abe umquba	Uyawalahla noma uyawashisa

6. Ukewezwa ukuthi amakhasi kabhatata ayaphakelwa imfuyo?

Yebo	Cha

7. Luthini uvo lwakho ngokuphakela amakhasi kabhatata?

Kuhle	Kubi

Sicela uchaze……………………………………………………………………….

………………………………………………………………………………………..

Isigaba D. Imbangela yokuncipha kwemfuyo

1. Kukhona yini ukuncipha kwezimbuzi emhlambini wakho?

Yebo	Cha

2. Kungabe yini imbangela yokuncipha kwemfuyo?

Indlala	Izifo	Amasela	Okunye	

Uma kungokunye sicela uchaze……………………………………………………………

3. Uma kuyizifo yini imbangela noma uhlobo luni lwesifo?

Izikelemu	Ukuphunza	Izinselo	Izintwala/ amakhizane	Okunye

Uma kungokunye sicela uchaze ……………………………………………………………

4. Niyaphuzisa niphuzisela izikelemu

Yebo	Cha

Uma uphuzisa, uphuzisa kangaki

Nhlobo	Kanye ngonyaka	Kabili ngonyaka	Kathathu ngonyaka	Ngaphezu kokuthathu

5. Usebenzisani ukulapha izikelemu

Imithi yesilungo	Imithi yesintu

Sicela uchaze uhlobo lomuthi owusebenzisayo …………………………………………..
……………………………………………………………………………………………..

Ngiyabonga kakhulu ekutheni ubambe iqhaza kulolucwaningo. Ngiyakholwaimiphumela yalolucwaningo izosiza abalimi bezimbuzi kanye nomphakathi wabalimi bemfuyo eMzansi Afrika

Isishicilelo……………………………   Usuku………………………………....