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DECLARATION

I, Lonita Amisi Manoa hereby declare that this thesis is my original work. It has not been presented for an award of a degree in any other University.

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This thesis has been submitted for examination with our approval as university supervisors

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DEDICATION

This work is dedicated to my dear parents, Mr. Amos Manoa and Mrs.Dorine Ominde for sacrificing so much to my education and their support for girl education, my brother Vincent Otsieka, sister Lillian Atieno and my husband Dr.Hillary Nyang'anga for their love, constant encouragement and support throughout the study period.

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LIST OF ABBREVIATION

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Varience
CIP	International Potato Center
CP	Crude Protein
DM	Dry Matter
FAO	Food and Agriculture Organisation
IVDMD	Invitro Dry Matter Determination
NDF	Neutral Detergent Fiber
ADF	Acid Detergent Fiber
ADL	Acid Detergent Ligni
SP	Sweetpotato
SPV	Sweetpotato Vines
SPVR	Sweetpotato Vines and Roots
ME	Metabolizable Energy
DM	Dry Matter
GDP	Gross Domestic Product
LAB	Lactic Acid Bacteria
MJ	Mega Joules
ML & FD	Ministry of Livestock and Fisheries Development
N	Nitrogen
NH_3-N	Ammonia Nitrogen
WSC	Water Soluble Carbohydrates

ABSTRACT

A study was conducted to evaluate the dry matter yields and silage qualities of six sweetpotato varieties (Gweri, Naspot-1, Wagabolige, Musinyamu, 103001.152 and Kemb-23) at the Faculty of Agriculture field station, University of Nairobi. The experiment was laid out in a split plot randomized block design with the six varieties as the main plots and two harvesting regimes (at 75 and 150 days) as the subplots. At the 75 day harvest, the vines were weighed prior to chopping and wilting for silage making and determination of DM yield and nutrient content. At 150 days, both subplots were harvested (vines and roots), freash weight taken, chopped and wilted prior to silage making and DM determinationCrude Protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) of fresh vines were determined.

The vines were ensiled alone, mixed with roots, with additives or no additives in silos (polythene bags) and stored for 90 days. Additives included salt, cassava meal, sun-dried layer manure, molasses and maize meal. , compacted and packed into mini. At opening the pH, ammonia nitrogen, DM, digestibility and CP content of the silage were determined.

Dry matter yields of vines harvested at 75d ranged from 1.13 (103001.152) to 2.07 (Kemb-23) t/ha and were similar between varieties. The mean DM yield of un-ratooned crop at 150d was 5.37 t/ha, higher than 4.07 t/ha for the ratooned crop with a significant difference between varieties. In both harvesting regimes, 103001.152 had the lowest vine yields (2.03 and 1.74), Gweri the (5.20 and 7.18) for the ratooned and unratooned vines respectively. The effect of variety on root dry matter yields was only significant among the unratooned crop where Gweri had the lowest root yields (1.37) tons dry matter per hectare (tDM/ha) than both Kemb-23 (4.78) and Naspot-1 (6.49). Root to vine ratios for the ratooned crop ranged between 0.20 (Gweri) to 1.30 (103001.152) and 0.20 (Gweri) to 2.21 (103001.152) for the unratooned crop respectively. Naspot-1 had highest CP content (17.97) while Wagabolige

(15.61) and Gweri (15.08) had the lowest. CP content of vines harvested after rattooning was not different among varieties. CP of vines harvested at 150 days continous growth were different among varieties Wagabolige had hogher CP (12.50) and 103001.152 (7.18) lowest. 103001.152 and Gweri were significantly different from Wagabolige and Musinyamu. The CP content decreased with age at harvest.

The pH of silages of vines alone or mixture of vines and roots was influenced by both variety and treatment. Among varieties, the highest pH (5.6 and 5.2) were observed for Naspot-1, the lowest values (4.7 and 4.5) for Gweri. Ammonia nitrogen (NH_3-N) content ranged between 2.2 to 2.7 % of total N in silages made from vines alone and 2.1 to 2.2 % in silages made from mixtures of vines and roots. Treatment and variety had no effects on ammonia nitrogen content. The CP content of silage was not affected by treatment for both types of silages, while the same was significantly affected by variety in silages made from vines alone, the CP content in 103001.152 (16.7%) was higher than that of Kemb-23 (13.5%). Dry matter content of silages ranged from 24.3 to 38.2 % and was affected by both variety and treatments for both types of silages. Addition of cassava meal and maize meal resulted in silages with the lowest pH values (4.93 and 4.84) for silages made from vines, and 4.66 and 4.68 for silages made from mixtures of vines and roots respectively. Silages treated with poultry manure and salt had the highest pH values of 5.32 (poultry manure) and 5.20 (salt) for vine silages and 4.91 (poultry manure) and 4.88 (salt) for vine and root silages. Ammonia nitrogen and crude protein content of the silages were not affected by treatments.

From this study, Gweri had the highest vine yields; Naspot-1 the highest root yield. . The ratooned crop at 150d had lower vine and root yields than the unratooned crop, while vines harvested at 75 days had higher CP content than those harvested at 150 days. The best quality (low pH and low NH_3-N) silage was obtained for treatments with cassava or maize meal as additive for both silages made from vines alone or mixtures of vines and roots.

1.0 INTRODUCTION

1.1 General Introduction

Agriculture supports 80% of Kenya's population and contributes 25% of Gross domestic product, playing a critical role in contributing towards national and social development objectives. Crops contribute 15%, while livestock contribute 10% of Agricultural Gross domestic product (ML and FD, 2004). Livestock feeds play a major role in the growth of livestock sub sector and directly influence the welfare, health, fertility and production of an animal (Crowder and Cheddar, 1982).

Animal feed resources in East Africa include Napier grass, crop residues, legumes, Rhodes grass, Kikuyu grass, Setaria and roadside grasses (Kariuki, 1998). Dairy production in Kenya is practiced under the zero grazing (type of dairy farming in which the cattle are fed with cut grass) , semi-zero grazing(form of grazing in which cattle are kept in enclosures some of the time and allowed outside to graze at other times) and extensive systems (Kariuki, 1998), where the type of system adopted and the main feed resource are usually determined by farm size and agro-ecological zones. The main constraint identified in all livestock production systems in Kenya is inadequate feeds, especially during the dry season, and the low nutritive value of the available forages (Abate and Abate, 1991).

Availability of fodder in most small scale farms is dependent on the rainfall pattern, being excessive during the rainy seasons and scarce during the dry spells. To even out the supply throughout the year, the solution lies in conserving the excess material during periods of excess (Crowder and Cheddar, 1982). Forage conservation thus solves two problems; it removes excess herbage that would otherwise be left to overgrow and provides quality feed during the dry season (Wilkinson, 1984). Conservation at the small-scale farm level can be achieved through hay making or small scale silage making, depending on the crop being ensiled and prevailing weather conditions.

Due to increased population and diminishing land sizes, the land available for forage is diminishing, as the little available is used for growing of food crops (FAO, 2006). There is need to identify multipurpose crops which can be used both as human food and livestock feeds. Recently, sweet potato (*Ipomoea batatas)* has attracted attention of various research organizations, governments, national and international developmental agencies and industries in the tropics and subtropics due to its adaptability to semi arid marginal conditions and the possibility of being used both as human food and livestock feed.

In 2007 the International Potato Centre (CIP) initiated a study to evaluate the role sweet potato can play in livestock production in East Africa (Peters, 1998). From the study, it was concluded that sweet potato can play a significant role as a partial replacement of Napier grass and other pastures in the nutrition of dairy cows, goats and pigs. Dual purpose varieties (those with high biomass yield from both tubers and vines) were particularly preferred because they gave farmers an opportunity to have enough fodder for livestock as well as tubers for human consumption. Dual-purpose varieties could be better utilized by continually or sporadically harvesting the vines throughout the growing season before finally harvesting the tubers at maturity (Woolfe, 1992).

The sweet potato has desirable characteristics as fodder due to the high levels of both energy and protein from the vines (Ruiz, 1981). Vines and tubers, used as feed resources, help meet the protein requirements of ruminants by providing rumen degradable protein for microbial protein synthesis plus protein that escapes ruminal degradation (Broderick, 1995). Sweet potato (*Ipomoea batatas*) is a valuable pig feed where both roots and leaves can be used fresh, dried or fermented to make silage (Woolfe, 1992).

The average national tuber production was estimated at 9.4 ton/ha in 2004 (FAOSTAT, 2008), which was low compared to yields of 50 ton/ha obtained under experimental conditions (Carey *et al.*, 1999). After harvesting tubers, sweet potato vines (SPV) are considered a waste as animals cannot consume the huge amounts produced within 2 or 3 days before the vines decay. Ensiling by-products like sweet potato vines is a simple and low-cost option, which can preserve feeds for long periods (Lien *et al.*, 1994). Ensiling renders some previously unpalatable products useful to livestock by changing the chemical nature of the feed (Kayouli and Lee 1998). Tinh *et al.*, (2000) reported that sweet potato vines ensiled with chicken manure resulted in highest high quality feed, high in crude protein and dry matter contents. The researchers also reported that rice bran and cassava leaf meal are good additives for fermenting sweet potato roots especially when used in combination with salt, where the fermented products could be stored on the farm for 4.5 months without any significant reduction in quality.

Currently, there are several sweetpotato varieties that have been been recomended from pre-breeding programs in various agro-ecological zones at Kenya Agricultural Research Institute (KARI) stations in Kenya. However, studies on their nutritional value for livestock are missing and this study is a step towards filling this knowledge gap.

The study was undertaken at an on-station field trial and fermentation trials to determine and compare the dry matter yields of vines and roots of six sweet potato varieties, under different harvesting regimes. Further, the silage quality and nutritional quality of ensiled sweetpotato vines tubers as well the mixtures of vines and roots ensiled with different additives will be evaluated. The six varieties to be evaluated are; two local and four imported namely, Wagabolige, Kemb-23, Gweri, Musinyamu, Naspot-1 and 103001.152.

1.2 Problem Statement

Increasing population and diminishing land sizes per family have reduced the area available for grazing and establishment of fodders and pastures. There is need for introduction of dual purpose crops that could be used both as livestock feeds and human food. The sweetpotato is a hardy and drought resistant crop whose roots can be used as human food and vines and roots used as animal feeds. Due to seasonality of rainfall, pasture growth is fast during rainy season resulting in surplus vegetation which can be conserved at its optimum stage of growth for use during the dry season.

1.3 Justification

Sweet potato is widely seen as a potential remedial crop for tropical smallholder farmers due to its high productivity and low input requirements, while its usefulness for both food and feed (dual-purpose) make it attractive in resource-poor areas where land availability is declining (Karachi and Dzowela, 1990; Woolfe, 1992; Leon-Velarde *et al.*, 1996; Leon-Velarde, 2000; Nyaata *et al.*, 2000; Larbi *et al.*, 2007). In addition, the high nutrient content of the vines can improve the nutritive quality of livestock feeds (Nyaata *et al.*, 2000). Dual-purpose sweet potato varieties allow a low number of toppings, which enables spreading of fodder availability over the year, without significantly affecting root yields (Tupus, 1983; Arteaga, 1997; Leon-Velarde, 2000).

The sweetpotato has favorable agronomic characteristics which include the potential for intercropping, ease of propagation, few crop pests and diseases, and good ground coverage for soil conservation (Woolfe, 1992). It also has favorable feeding characteristics due to the high contents of both energy and protein in its tubers and vines. The vines have high palatability and digestibility in both ruminants and monogastrics.

Though many studies have been done to evaluate the potential of sweet potatoes as animal feeds, there is need to evaluate the dry matter yields, nutritional and silage qualities of sweetpotato varieties that have been recently introduced by the Kenya Agricultural Research Institute and Intenational potato Center in various parts of the country. The purpose of such evaluation would be to identify the most appropriate varieties with the highest dry matter yields, nutrient contents and silage quality.

The harvesting regime ensures there is available fodder at the first harvest (75 days) thus the farmer can feed his/her animals before the final harvest(150 days) when both the vines and roots are ready.

1.4 Objectives of the Study

The main objective was to evaluate the dry matter yield and silage quality of six sweet potato varieties.

The specific objectives were to:

Determine the dry matter yield of six sweet potato varieties at two harvesting regimes.

Determine the nutritional quality of vines and roots of the six varieties harvested at two stages of growth.

Determine the silage quality of six sweet potato varieties combined with various additives.

Determine silage quality of sweet potato vines harvested at different stages of growth.

1.5 Hypothesis of the study

H_o: The six sweet potato varieties have the same dry matter yield, nutritional and silage quality.

2.0 LITERATURE REVIEW

Introduction

Livestock production systems occupy about 30% of the planet's ice-free terrestrial surface area (Steinfeld *et al.*, 2006) and are a significant global asset with a value of at least $1.4 trillion. The livestock sector is organized in long market chains that employ at least 1.3 billion people globally and directly support the livelihoods of 600 million poor smallholder farmers in the developing world (Thornton *et al.*, 2006). Livestock products contribute 17 per cent to per capita kilocalorie consumption and 33 per cent to protein consumption globally, but there are large differences in consumption patterns between rich and poor countries (Rosegrant *et al.*, 2009).

Livestock systems have both positive and negative effects on the natural resource base, public health, social equity and economic growth (World Bank, 2009). Currently, the livestock industry is one of the fastest growing agricultural sub-sectors in developing countries. Its share of agricultural GDP is already 33 per cent and is quickly increasing (Delgado, 2005). This growth is driven by a rapidly increasing demand for livestock products driven by population growth, urbanization and increasing incomes in developing countries (Delgado, 2005). In developed countries, on the other hand, production and consumption of livestock products are declining or stagnating. Despite this, livestock production and merchandizing in industrialized countries account for 53 per cent of agricultural GDP (World Bank, 2009).

The Kenya livestock population census figures are shown on Table 1 (Kenya Bureau of statistics, 2009).The livestock sector in Kenya contributes 10% of the total Gross Domestic Product (GDP) and includes the production of milk, meat, eggs, hides, skins and wool

(KBS, 2009). Red meat, comprising of beef, mutton, goat and camel meat accounts for over 80% of all the meat consumed locally (Export Processing Zone Authority, 2005). Approximately 67% of the red meat is produced in the arid and semi-arid lands (ASALs) under pastoral production systems. Pastoralists keep about 70% of the national livestock herd, estimated at about 9.7 million beef cattle, 9.6 million goats, 8.3 million sheep, and 0.8 million camels (Ministry of Livestock Development, 2009).

White meat, which includes poultry and pig meat accounts for about 19% of the the meat consumed in the country (Central Bureau of Statistics, 2004) and is mainly processed through Kenchick® and Farmers Choice® for poultry and pork respectively. The contribution of game meat, on the other hand, is negligible accounting for less than 1% of the total meat consumed in the country (Export Processing Zone, EPZ, 2004) .

Table 1: Kenya livestock population in (00'000)

Province	Cattle	Sheep	Goats	Camels	Donkeys	Pigs
Nairobi	5.5	3.5	4.7	0.002	1.3	3.0
Central	112.6	5.31	0.02	3.6	9.2	3,039
Coast	96.0	4.7	15.7	5.1	3.2	0.5
Eastern	226.0	18.9	47.3	2.5	3.0	4.3
North eastern	277.5	42.6	78.9	17.0	3.8	6.8
Nyanza	174.9	5.00	9.6	59	6.1	2.8
Rift valley	748.0	907.9	117.5	98.9	9.9	4.8
Western	106.4	2.3	2.6	0.02	0.2	0.9
Kenya (Total)	1174.7	1719.6	2774.0	297.1	183.3	3.3

Source: Kenya Bureau of Statistics (2009)

2.1 Roles of livestock

2.1.1 Food

Livestock produce a regular supply of products that provide critical food supplements and diversity to staple plant-based diets (Murphy and Allen, 2003). This is particularly true for milk and eggs, which can help mitigate the effects of large seasonal fluctuations in grain availability (Wilson *et al.,* 2005). In many systems, slaughtering animals for meat is infrequent, occurring only when animals become sick, unproductive, or for exceptional occasions such as religious ceremonies or hospitality (Scoones, 1992). An ideal protein is defined as one having a good balance of essential amino acids which are required for maintenance and production (Boisen *et al.,* 2000). Animal proteins are rich in lysine and have higher biological values than plant proteins, which are often low in lysine, tryptophan and sulfur amino acids. Maize protein can support adequate growth of pigs only after supplementation with both tryptophan, lysine and methionine, soybean is limiting in methionine, while fishmeal is high in both lysine and methionine (McDonald *et al.,* 1995).

2.1.2 Income

The household may own livestock for the express purpose of producing for the market while in other cases; sales may be occasional to meet an urgent need for cash such as paying school fees or medical costs (Kitalyi *et al.,* 2005).

2.1.3 Manure

Livestock waste is often an important input for maintaining soil fertility thus contributes to higher crop yields for food and income (Powell *et al.,* 1998). In some areas, dung is also used as a fuel, fertilizer, building material and as an energy source through production of biogas (Wilson *et al.,* 2005). Manure can also be used as animal feed, but this is only done to a limited extent because of health considerations. Moreover, most types of manures, with the exception of poultry manure have low nutritive value as ruminant feeds (Wit *et al.*, 1997).

2.1.4 Draught power

In many mixed crop-livestock systems, large animals function as farm equipment, providing traction power for transportation and crop production, and for hiring out (Powell *et al.*, 1998).

2.1.5 Financial instrument

The poor often do not have access to standard financial institutions, such as banks and other credit facilities. Livestock offer an opportunity for storing their savings or accumulated capital as a "living savings account" that, provides a reasonably robust hedge against inflation (Doran *et al.*, 1979; Bosman *et al.*, 1997; Moll, 2005). Moreover, they can be sold and transformed into cash as needed thereby providing an instrument of liquidity and consumption smoothing. Similarly, keeping livestock is considered an alternative form of insurance, providing the family with assets that can be sold in times of crisis (Hoddinott, 2006).

2.1.6 Social status

Cultural norms in many societies place considerable value on livestock as an indicator of social importance within the community. This social status is often based on the size of a family's livestock holdings, or in their sharing of livestock with others, to strengthen social bonds, including the use of livestock as dowry or bride price (Ferguson, 1994; Kitalyi *et al.*, 2005). Higher social status often translates into access to or authority over a broad base of resources in the community (Ferguson, 1994; Kitalyi *et al.*, 2005).

2.2 Constraints to livestock production

Livestock production in the tropics is constrained by many factors, the major ones being feed availability, diseases, genotype, limited manpower, market and infrastructure. The major feed resources are natural pastures or purposely grown forages and seasonal grasses . Fluctuations in feed quality and quantity compromise animal productivity, health and welfare (Owen *et al.*, 2005). The main limiting nutrient in roughages, particularly during the dry seasons is protein (Rufino *et al.*, 2006). Establishment of legumes, shrubs and fodder trees which are high in protein in agro-ecological zones that support livestock farming, would alleviate this constraint.

2.2.1 Quantity and quality of feed

Most developing countries in the tropics face critical shortage of animal feeds, particularly during the dry season (Seyoum and Zinash, 1995; Ørskov, 1998; Tolera, 2007). Climate and season greatly influence supply and quality of feeds. Unreliability of roughage production, especially during dry periods, is a major problem that limit livestock production (Baker and Gray, 2003). In smallholder systems, land for forage production is a limiting factor (Kosgey, 2004) and most farmers are increasingly switching to landless ruminant production systems where feed is mainly introduced from outside the farm system. The quality and quantity of many tropical grasses are often low and inadequate. Carles (1983); Gatenby (1986) and Charray *et al.*,(1992) proposed the use of livestock genotypes that are adapted to efficiently utilise poor quality feed resources, while Baker and Rege, (1994) observed that this trait was not conventionally included amongst those used to characterise suitable breeds.

Forage quality and quantity are affected by seasons and are major constraints to increased cattle productivity under most tropical livestock farming systems (De Leeuw *et al.*, 1999). Forage quality is generally high in the early part of the growing season but declines dramatically for the rest of the year (Mero and Udén, 1998), thereby increasing pressure on scarce supplemental feed resources (Shem *et al.*, 2001). Due to these problems, smallholder dairy farmers in the tropics tend to feed their cattle on a variety of forages, which often have unknown nutritive values.

2.2.2 Diseases

Animal diseases have a wide range of biophysical and socio-economic impacts on livestock welfare and productivity. These effects may be direct or indirect, and may vary from localized to global impacts (Perry and Sones, 2009). There have been relatively few changes in the distribution, prevalence and impact of many epidemic and endemic livestock diseases in Africa over the last two decades with a few exceptions such as the global eradication of rinderpest. East Coast fever (ECF) is the most important tick-borne disease of cattle in Eastern, Central and Southern Africa (Young *et al* ., 1989, Norval *et al.*, 1992). It is prevalent in large areas of East and Central Africa where it causes major economic losses through morbidity and mortality (Perry and Young, 1995). The disease is an important challenge to the improvement of the livestock industry in large areas of East, Central and Southern Africa (Norval *et al.*, 1992). Heartwater is a tick-borne disease of cattle, sheep, goats and wild ruminants, which is endemic in sub-Sahara Africa and is a major obstacle to the upgrading local breeds of livestock (Uilenberg and Camus, 1993).The disease is endemic in many parts of Kenya (Ngumi *et al.*, 1997).

Anaplasma marginale and *Anaplasma centrale* are the most important anaplasma parasites of cattle in Kenya (Ristic, 1968). *Boophilus decoloratus* ticks are the main vectors for anaplasmosis (Maloo, 1993). Tick borne diseases are a major challenge to livestock production in most agro-ecological zones in Kenya. This is mainly attributed to a break down in tick control services formerly supported by the government and which have been privatized over the last two decades (Keating, 1983). Maximum productivity in a given production system is only realized when disease control measures are optimal (Gatenby, 1986). Thus, healthcare is an important -problem to consider especially with the improved livestock breeds. Use of Community-based animal health care programmes (Njoro, 2001), and utilisation and upgrading of indigenous breeds tolerant to diseases are important factors to consider in development of the livestock sector, provision of health services is inadequate due to shortage of veterinary doctors and also the cost is high for farmers to afford thus the government is implementing the use of paraveterinary officers (Baker and Gray, 2003).

2.2.3 Climate

Acclimation is a phenotypic response developed by the animal to an individual source of stress within the environment (Fregley, 1996). The main climatic factor that has the greatest influence on animal productivity and health is temperature. High ambient temperatures cause a reduction in feed intake among endotherms, while low temperatures increase feed without a simultaneous increase in productivity as the extra energy is used in heat generating physiological processes. Adverse climatic conditions impose additional restrictions and requirements on cattle. Since cattle are homeotherms, energy must be expended to maintain body temperature within a defined range . This range is called the thermoneutral zone. As external temperature increase or decrease outside of this range, the metabolic machinery must expend energy to maintain body temperature. Consequently, more energy is needed for maintenance and less is available for productive purposed. For growing-finishing cattle, this translates into less gain. As environmental temperatures decrease below the thermoneutral zone, the animal must generate more body heat to survive. This is accomplished by increasing dry matter intake and cellular metabolism. However, extremely cold conditions may cause a cessation of intake. As temperatures elevate above the uppermost portion of the thermoneutral zone, an animal must dissipate excess body heat. Dry matter intake and cellular activity will decrease. Thermal stress lowers feed intake of animal which in turn reduces their productivity in terms of milk yield, body weight and reproductive performance. (Kimothi and Ghosh, 2005)

Animals kept outside their thermo-neutral zones have compromised health, low productivity and reduced reproductive efficiency (Beede and Collier, 1986; Lacetera *et al.*, 2003a). Acclimation to high environmental temperatures involves responses that lead to reduced heat load.the immediate responses are reduction of feed intake, increase in respiration rate and water intake (Collier and Zimbelman, 2007). The decreased energy caused by reduced feed intake, results in a negative energy balance (NEB), which partially explains why cows lose significant amounts of body weight and body score when subjected to heat stress (Lacetera *et al.*, 1996).

2.2.4 Genetics

Genetic variation within indigenous breeds is high and this is quite often the basis for local selection to increase production without losing desirable attributes of indigenous animals (Dan and Brown , 2003). Many small ruminants genetic improvement programmes have not been very successful in developing countries in the tropics (S¨olkner *et al.*, 1998; Rewe *et al.*, 2002; Wollny *et al.*, 2002; Kosgey *et al.*, 2006) mainly due to inadequate genetic characterization of local breeds.The disadvantageis that they have mostly been implemented without takinginto consideration all the needs of the farmers (Kosgey *et al.*, 2006). Further, the poor performance of imported breeds from the temperate developed world in the tropics has created a negative image for genetic improvement programmes (Turner, 1978; Rewe *et al.*, 2002; Ayalew *et al.*, 2003).

2.2.5 Marketing and infrastructure

Limited market infrustructure imposes a serious constraint on the marketing of livestock (Mahabile *et al.*, 2002). Most of the livestock farmers, especially cattle, sheep and goat, are located in areas remote from major markets, where there is a serious lack of both physical and institutional infrastructure (NDA, 2005). This partly explains the poor livestock supplies to formal market outlets by small-scale farmers (USAID, 2003). In communities that have marketing facilities, they are either in poor state or are non-functional because farmers do not have funds to maintain them (Frisch, 1999).

According to Sadoulet and de Janvry (1995) and Innes (2002), lack of markets, wide commodity price margins and limited access to working capital credit are major causes of poor performance of livestock markets in Africa.

2.2.6 Extension services

Inadequate provision of agricultural information is a key factor that has limited agricultural development in developing countries (Bailey *et al.*, 1999). Farmers need information that would enable them to make rational, informed and relevant decisions. This would strengthen their negotiating ability during transactions with buyers and consequently prevent possible exploitation by better informed buyers (Coetzee *et al.*, 2004).

Information needs for communal farmers range from information on prevailing production technologies, market conditions, type of product demanded, quality, quantity, price and market opportunities available (Bailey *et al.*, 1999). Lack reliable information is particularly severe in the ASALs where most of the beef meat production systems are prevalent

(Montshwe, 2006). The poor transfer of knowledge, skills and information is manifested by limited interaction of the farmers with extension officers (Coetzee *et al.*, 2004).

2.3 Common forage feed resources in Kenya

Forages which include natural pastures and purposely grown fodders are the most important feed resource for livestock in developed and developing countries (Jung and Allen, 1995). The major forages used in Kenya are described below.

2.3.1 Napier grass (*Pennisetum purpureum*)

Napier grass has become increasingly important among farmers who keep improved breeds of cattle in the semi-arid regions of eastern Kenya that receive between 500-800 mm of annual rainfall annually (Njarui and Wandera, 2000). Its the main forage fed to dairy cattle in the smallholder mixed zero and semi- zero grazing systems due to its high biomass productivity of 20-25 t/ha of DM (Anindo and Porter, 1994). Despite its high yield, Napier has a low DM content 170-260 g/kg, crude protein content of 85-111g/kg (young), 46-63g/kg (mature) and a metabolisable energy content of 8.6 MJ/kg DM (NRC, 1988; Anindo and Potter, 1994; Kariuki, 1998).

In some eastern and coastal regions of Kenya, the prolonged dry season can last up to 6 months (Jatzold and Schmidt, 1982) and during that period dairy cattle could be sustained on conserved Napier grass (Valk, 1990) from the high yields produced during the rainy season, when there is often an excess (Anindo and Potter 1994). Humphreys (1994) states that below a critical level of 6 - 8% CP in cattle diet, digestibility and voluntary intake of forage are likely to be reduced. Attempts have been made to make hay out of Napier grass (Brown and Chavulimu, 1985; Manyuchi *et al.*, 1996) but the succulent stems limit the rate of drying (Snijders *et al.*, 1992) and with excess drying the stems may become hard and brittle and less palatable to livestock. The alternative to hay making is to ensile the surplus (Cuhna and Silva, 1997) since leaving Napier grass to become too mature may compromise the quality. However, the proportion of farmers ensiling Napier grass is small (Valk, 1990).

Napier grass can be ensiled but the quality of silage obtained depends on the freshness of the ensiled material, the ensiling process and additives used in the process (Yokota and Ohshima, 1997; Ruiz *et al.,* 1992). Successful ensiling that maximizes nutrient preservation is achieved by harvesting the crop at the proper age, minimizing the activities of plant enzymes and undesirable epiphytic micro-organisms naturally present in the forage crop, and encouraging the dominance of lactic acid bacteria (Bolsen, 1995). Napier grass has low fermentable sugars (less than 50 grams/kg) (Mbuthia and Gachuiri, 2003), and energy sources such as bran and molasses have been found to enhance Napier silage quality (Yokota and Ohshima, 1997; Snijders and Wouters, 1990).

2.3.2 Calliandra *(Calliandra calothyrsus)*

Calliandra (*Calliandra calothyrsus Meissner*), a tropical multipurpose tree legume, native to the humid and sub humid regions of Central America and Mexico, was introduced to the Central Highlands of Kenya in the 1980s and since then has been widely promoted and adopted as a supplement to ruminants fed on low-quality forages (Wambugu *et al.* 2001; Franzel *et al.*, 2003).

Calliandra has desirable agronomic attributes, which include fast growth and high biomass production of foliage and wood (Tuwei *et al.*,2003). Although it has a high protein content (Lascano *et al.*, 2003; Tuwei *et al.*, 2003), research has shown that it has very high levels of condensed tannin, and low digestibility (Maasdorp *et al.*, 1999; Hess *et al.*, 2003; Lascano *et* *al.*, 2003). Tannins suppress ruminal degradation of nitrogenous compounds, because they form tannin-protein complexes which are hardly degraded by ruminal microbes (Broderick and Albrecht 1997).

2.3.3 Kikuyu grass (*Pennisetum Clandestinum)*

Kikuyu grass is a warm season perennial creeping grass which has an invisible inflorescence (Marais, 2001; Donaldson, 2001).The nutritive quality of the grass is low and cattle grazing on it have low milk yields (<11 Kg/cow/day) this is dictated by its unique morphology, physiology and chemical composition that vary according to the growth stage and environmental conditions (Reeves, 1997). One advantage of kikuyu grass as a feed is that it does not contain condensed tannins which reduce ammonia formation in the rumen (Jackson *et al.,* 1996). It has disadvantages such as the high levels of non protein nitrogen (NPN) (Marais, 2001), low levels of magnesium (Cheeke, 2005), and is deficient in phosphorus (Tainton, 2000).

Other factors that reduce the nutritive value of kikuyu grass are the low levels of readily available energy in the grass (Marais *et al*, 1990), low digestibility of structural components (Hacker, 1982), presence of oxalic acid in the plant (Marais, 1990), low sodium content (Smith, 1981) and high levels of nitrate when the grass fertilized with nitrogen fertilizers (Barnes *et al*., 2007). The total nitrogen concentration ranges from 13.6 to 41.1 g/Kg DM thus high levels of nitrogen result in poor protein metabolism and low milk yields (Marais *et al.*, 1990). Kikuyu grass yield ranges between 9 and 30 t DM/ha depending on N fertilization (Mears, 1992). In extreme conditions of water deficit irrigation (33% less water than optimal irrigation), kikuyu provides the highest yield significantly higher with 17 t DM / ha more than the 9 to 30 t DM /ha (Neal *et al.*, 2009).

2.3.4 Rhodes grass (*Chloris gayana)*

Rhodes grass (*Chloris gayana*) is a vigorous, perennial grass commonly grown in sub-tropical grazing systems which are characterised by dry and wet seasons (Mannetje, 1992). The cultivar is particularly useful because its growing season extends into autumn, when other grasses become less productive (Mannetje *et al.,* 1992). It has annual dry matter (DM) yields in excess of 24 t/ha (Colman, 1971), but not all of it is utilised by grazing animals due to the high stem:leaf ratio and the low digestibility of mature swards (Moss *et al.,* 1992).

Options for capitalising on the growth potential of Rhodes grass may be to conserve it as silage or make hay out of it. To date, conservation of tropical grasses has not been regularly practised due to the low digestibility of the conserved herbage (Kaiser *et al.,* 1993). The digestibility of vegetative Rhodes grass is limited by its high contents of neutral detergent fibre (NDF), cell wall polysaccharides, lignin and and phenolic acids (Akin and Hartley, 1992).

2.3.5 Leucaena (*Leucaena spp.)*

Leucaena leucocephala is a multipurpose tree species, with positive agronomic attributes such as fastgrowth, drought-tolerance, high palatability, high protein levels, high biomass yields and its ability to flourish on a wide range of soils (Gupta and Atreja, 1999). The leaves are a very good source of protein and can be used in both cut-and-carry and open grazing systems. Its feeding value, is however limited by the presence of the toxic amino acid, mimosine (Lukuyu *et al.,* 2007). In many tropical regions of the world, consumption of *L. leucocephala* by ruminants results in poor growth, alopecia, mouth and esophageal lesions, depressed thyroxine levels and goiter (Ram *et al.,* 1994).

2.4 Sweet potato

The Sweet potato (*Ipomoea batatas*) from the family Convolvulaceae is an important food crop, which is widely grown in tropical, subtropical and warm -temperate regions (Sihachakr *et al.*, 1995). It originated somewhere between the Yucatan Peninsula of Mexico and the mouth of the Orinoco River in Venezuela (Austin, 1988) and Portuguese explorers transferred it to Africa, India, South East Asia and the East Indies.

The Sweet potato is one of the 12 main plant species used as human food throughout the world (Woolfe, 1992) and it ranks as the world's seventh most important food crop, principally because of its versatility and adaptability (Cipotato, 2007). Dual-purpose sweet potato, which were recently introduced into Kenya, allows a limited number of toppings, which spreads fodder availability over the year, without significantly affecting root yields (Tupus, 1983; Arteaga, 1997; Leon-Velarde, 2000).

2.4.1 Occurence and distribution of sweet potato

Over 95% of the global sweet potato crop is produced in developing countries, where it is the fifth most important food crop in terms of fresh weight (FAOSTAT. PRODSTAT. Priorities, 2000). The United Nations Food and Agriculture Organization estimated that 110 million tons of sweetpotatoes were produced globally in 2008 (FAOstat, 2009). The majority of the world's sweetpotatoes are grown by China where an estimated 85 million tonnes or 77 % of total world production was produced in 2008 (FAOstat, 2009). Uganda and Nigeria are the second largest producers, with approximately 3 million tonnes produced per year in ecah country (FAOstat, 2009).

The Sweet potato has been cultivated in Kenya since the end of the 19^{th} century. It was mainly grown by poor farmers in an area covering 75,000 ha spread over various agro ecological zones in the country (Qaim, 1999). The ability of sweet potato to adapt to a wide range of growing conditions, in both fertile and marginal areas, makes it a versatile crop for Kenya's farming systems (Gibbons, 2000). The major challenge facing sweet potato farmers is the current low yields, which are the result of high losses due to pests and diseases and inadequate quantities of clean planting materials (KARI, 2000). According to KARI (2000) losses from viruses can be as high as 80 per cent of the harvest. Kenya's average sweet potato yields are 6 tDM/ha, which is less than half the world's average yields of 14 tDM/ha (Mungai, 2000).

2.4.2 Agronomic requirements

The sweet potato plant does not tolerate frost and grows best at an average temperature of 24 °C, abundant sunshine, and warm nights. Annual rainfall amounts of 750–1000 mm are considered most suitable, with a minimum of 500 mm in the growing season. The crop is sensitive to drought at the tuber initiation stage 50–60 days after planting and is not tolerant to water-logging which may cause tuber rot and reduce growth of storage roots (Ahn, 1993). It grows on a wide variety of soils, which should be well-drained, light to medium textured and with a pH range of 4.5-7.0 (Woolfe, 1992; Ahn, 1993). Sweet potatoes are very sensitive to aluminium toxicity and will die within 6 weeks after planting if lime is not applied at planting in this type of soil (Woolfe, 1992).

2.4.3 Utilization of sweet potato

Sweet potato is widely seen as a potential remedial crop for tropical smallholder farmers because of its high productivity and low input requirements. It can be used as both food and feed (dual-purpose) which makes it attractive in resource-poor areas where land availability is declining (Karachi and Dzowela, 1990; Woolfe, 1992; Leon-Velarde *et al.,* 1996; Leon-

Velarde, 2000; Nyaata *et al.*, 2000; Larbi *et al.*, 2007). It is a major starch staple in Africa and it is particularly important in East Africa where the crop is widely grown and provides household food security to many resource-poor farmers (Bashaasha *et al.*, 1995, Kapinga *et al.*, 1995).

Most small-scale farmers in Africa and Asia plant sweet potatoes for both tubers (for human consumption) and vines (as fodder). The tubers and vines are sources of energy, protein and vitamins for human beings and animals (Villarreall *et al.*, 1979) and livestock (Scott, 1992, Ali *et al.*, 1999 and Farrell *et al.*, 2000). The root has a high content of carbohydrates, and is an excellent source of vitamin A (in the form of beta-carotene). It also has high levels of vitamin C, manganese, copper, dietary fiber, vitamin B_6, potassium and iron (Cardenas *et al.*, 1993)). In some countries (Korea, Japan, Vietnam and China), the top of the sweet potato is also used as human food (Villareal *et al.*, 1985; Peter *et al.*, 2000).

Sweet potato is an important food crop to small scale farmers in several countries of Sub-Saharan Africa (Horton, 1988; Carey, 1999). It is a staple food for many people in Uganda, Rwanda, Burundi, Kenya and Eastern Zaire with a high per capita consumption (Carey, 1999). In the grain based food systems of Eastern and Southern Africa, sweet potato is a widely grown as a secondary crop, important for food security at certain times of the year or when other crops fail (Ndolo *et al.*, 2007).

2.4.4 Sweet potato as livestock feed

Sweet potato is commonly used as feed for pigs, cattle and chicken in Vietnam and many countries in Asia (Gohl, 1998; Peters *et al.*,2000 ; Ly *et al.*, 2003 ;, Duyet *et al.*, 2003). The dry matter yield of sweet potato vines can be as high as 4.3 to 6 tonnes DM/ha/crop

(Dominguez, 1992). Its foliage is high in protein containing between 16-20% crude protein content (Dung *et al.*,2001) with a high palatability for most livestock. It has a high nutrient content, which makes it a favourable feed for pigs in smallholder feeding systems. Despite their favourable nutritional quality, Dominguez and Ly, (1998) and Phuc *et. al.*, (2000) noted that inclusion of high level of sweet potato vines in pig diet tended to reduce feed intake and digestibility.

Sweet potatoes vines can be used fresh dried or ensiled (Lin *et al.*, 1988) and they are rich in highly digestible starch and sugars and constitute a valuable energy source for ruminant. The high dry matter degradability (85%) and the high content of soluble carbohydrates of roots may lead to high energy content in roots acidifies the rumen (Chanjula *et al.*, 2003) and should be introduced gradually and fed together with roughages to minimize the risk of digestive disturbances (Otieno *et al.*, 2008).

Carbohydrates make up between 80 to 90 % of the dry weight of sweet potato roots (FAO, 1991). The uncooked starch is very resistant to hydrolysis by amylases but cooking increases their susceptibility to the enzyme, thus increasing the hydrolysable starch fraction of sweet potato from 4% to 55% (FAO, 1991). The protein content of the tubers is low 4% DM of crude protein (Dominguez, 1992) with an unbalanced amino acid profile, which often necessitates addition of other protein sources in order to meet animal protein and amino acid requirements (Woolfe, 1992). This low protein content and the presence of a trypsin inhibitor have deleterious effects on the pig digestive process and often result in decreased performances in growing and finishing pigs (González *et al.*, 2002; Oyenuga *et al.*, 1975).

In studies by Woolfe, (1992), young pigs fed *ad libitum* on fresh sweet potato roots had low weight gains (109 g/day grazing and 136 g/day when pen-fed). The researcher attributed this to the bulkiness of the roots such that the young pigs could not take them in sufficient quantities to satisfy their energy and protein requirements. Roots used as animal feed are shredded before they are fed to cattle, pigs or poultry to reduce bulkiness (Woolfe,1992) while vines are can be fed fresh, dried or ensiled (Villareal *et al.*,1985; Mutuura *et al.*,1990; Semenye *et al.*,1992; Mok and Carey,1993).

Sweet potato leaves and roots contain high levels of minerals and vitamins A, B_2 and C suitable for pigs, poultry, rabbits and cattle (Mora *et al.*, 1992; Wethli and Paris, 1995; Ali *et al.*, 1999; Chen *et al.*, 1977).

Peters (2008), conducted some interviews in Rwanda and several Rwandan dairy cow farmers interviewed independently stated that regular feeding of sweet potato vines increases milk production by an amount that averages approximately 1.5 liters per day. Meanwhile, sporadic feeding of sweet potato vines is worse than not providing this high quality feed at all. Farmers should only feed it if they can afford on regular basis; otherwise, the productivity is even lower than not feeding it at all. The data collected for three instances where dairy cows were fed sweet potato vines regularly, never fed sweet potato vines and fed sweetpotato vines sporadically, the production was 16, 10-12, <10 liters/cow/day respectively. This is because Aonce the cows get used to high quality feed, they will not eat unless this quality feed is present. They will refuse to eat for a couple of days until they get too hungry to continue resisting inferior feeds and skipping two to three days of eating has a serious adverse effect on milk production. They may even stop lactating while waiting for the good feed.

2.4.5 Nutritive value of sweet potato vines and roots

Nutritive value is an indication of the contribution of a feed to the nutrient content of the diet. This value depends on the quantity of a feed which is digested and absorbed and the amounts of the essential nutrients (protein, fat, carbohydrate, minerals, vitamins) which it contains, it is determined by a number of factors, including composition, odor, texture and taste. This value can be affected by soil and growing conditions, handling and storage, and processing (Schneider & Flat, 1975).

The chemical compositions of leaves, stems and tubers vary depending on the time of harvesting and genotypic differences (NIAH *2001*; An *et al*., *2003*). The leaves have higher contents of DM and CP compared to the stems (An *et al*., 2003). The crude protein content of sweet potato vines range from 16 to 29% (Dung, 2001), while the levels of starch and sugars are 8 and 4 % respectively (Onwueme, 1978).

Sweet potato roots have high carbohydrate levels , low amounts of protein and minerals and low fat content (Manfredini *et al.*,1993). The root is rich in energy as it contains 80–90 % carbohydrate on DM basis (Dominguez, 1992). It is also a good source of vitamin A (in the form of beta-carotene), vitamin C, manganese, copper, dietary fiber, vitamin B6, potassium and iron (Cardenas *et al.,* 1993).

Predominant minerals in sweetpotato root are potassium, sodium, iron, phosphorus and calcium (Ali *et al.,* 1999) . Many sweetpotato cultivars are rich in carotenoids, especially the cultivars with yellow-orange flesh. It is also a good source of ascorbic acid and vitamins of the B complex (Onwueme, 1978; Woolfe, 1992).

The chemical compositions of sweet potato vines and roots as reported by various researchers are shown in Tables 2 and 3 below.

Table 2: Chemical composition of vines (%DM)

VINES						
DM	CP	ASH	NDF	ADF	ADL	REFERENCE
15.0	18.2	17.7	26.2	22.3	5.7	Godoy and Elliot, 1981
14.2	18.5	12.5	26.2	23.5	5.7	Dominguez, 1990
-	18.0	21.6	40.3	32.8	16.0	Dominguez and Ly, 1997
15	16.2	-	29.8	-	-	Hoang *et al.*, 2003
22.48	8.28	10.11	-	-	-	Serafettin *et al.*, 2010

Table 3:Chemical composition of roots(%DM)

ROOTS						
DM	CP	ASH	NDF	ADF	ADL	REFERENCE
-	4.4	3.1	6.7	4.2	0.7	Noblet *et al.*, 1990
29.2	6.4	5.3	-	5.5	-	Dominguez, 1990
-	0.95-2.5	-	-	-	-	Onwueme, 1978;Woolfe,1992
19.1	4	-	13.9	-	-	Hoang *et al.*,2003

2.4.6 Effects of harvest regime on yields and chemical composition of Sweet potato

Yield and quality of forage vary with the age of the plant. Dry matter accumulation usually increases with increasing age while the nutritive value declines (Crowder and Cheddar, 1982). Moat and Dryden (1993) reported an increase in dry matter yield, a decrease in protein content, and a fairly constant NDF content in sweet potato forage as the age of the plant increased. Cutting of forage at regular intervals maintains a balance between yield and quality in forage species (Crowder and Cheddar, 1982).

Removal of sweet potato vines during growth reduces the supply of photosynthates during the remainder of the plant's growth with an eventual reduction in root yield (Nwinyi 1992). Frequent defoliation of sweet potato plant disrupts photosynthetic process, leading to a reduced leaf, root and biomass production. Dahniya, (1979) observed that defoliation has a negative influence on root production in sweet potato. (An *et al.*, (2003); Kiozya *et al.*, (2001) and Ruiz *et al.*, (1980), in their studies, found out that forage yields increased with delayed cutting while root yields were depressed. Increasing the interval between cuttings gave the plant sufficient time to recover from the previous cutting (Uddin *et al.*, 1994).

Crude protein(CP) content of sweet potato forage increased as cutting interval became shorter while the fibre component reduced with increased cutting intervals (Ruiz *et al.*, (1980), Oyenuga (1968) and Moat and Dryden (1993). Ruiz, Oyenuga, Moat and Dryden also reported an increase in the CP content of sweet potato forage when the vine was cut frequently. In all the studies cited the gross energy contents of the forages remained constant across the cutting regime. The observations above show that frequent defoliation did not alter gross energy contents of sweet potato forages but stimulated dry matter partitioning to favor protein accumulation at the expense of the fibre component in the forage.

In studies by An *et al.*, (2003), it was observed that improved digestibility of the forage was associated with higher protein contents and reduced fibre in the forage as a results of frequency cuttings. Fibre content increases with age and decline in forage quality with maturity is directly related to the leaf/stem ratio. As a plant matures it becomes more "stemmy" (i.e., the leaf/stem ratio decreases). The decline in forage quality with maturity is primarily due to the increasing lignification of the stem and an increasing proportion of stem compared to leaf .

As a plant matures the cell wall content increases as a percent of the total plant cell. Plant cell walls are much less digestible than other parts of the cell (intracellular contents). Therefore, as the cell wall component of the cell increases with maturity, digestibility or quality of the forage decreases. Acid detergent fiber is associated with the digestibility of a feed, thus a feed with high ADF is less digestible than that of low ADF and a less digestible feed reduces the intake by animals.

Traditionally, in East Africa, women typically do the piecemeal harvesting, and they move around the field looking for cracks on the mounds or ridges, which they perceive as being indicative of a sizeable root. Mature roots are selected carefully during the harvesting and the earth is heaped up over the remaining ones to allow them to continue bulking, the heaping up of earth will also protect the roots from sun damage and reduce the chances of weevil access to them. Harvesting is usually done carefully with locally made sharp sticks, rods or machetes in order to avoid injuring the remaining roots. Other farmers harvest all the roots from one area of the field at once using a hand hoe. Some farmers use both methods. Farmers usually harvest enough sweetpotato for one or more meals for one or two days. Piecemeal harvesting can start as early as two/ three months after planting for some varieties. Farmers do not usually harvest large quantities at once, in order to avoid the roots rotting and being wasted. Harvesting a large field all at once is done when sweetpotato is destined for the market.

2.5 SILAGE

Ensiling is a process of fermentation of carbohydrates by acidification, and is a suitable method for preserving feeds that are seasonally abundant for later feeding during periods of feed shortage (Chedly and Lee, 1998). Primary factors affecting the fermentation process are the levels of water-soluble carbohydrates,buffering capacity, moisture content and type of bacteria which predominate and speed of fermentation (Bjorge, 1996).The purpose of making silage is to maximize the preservation of original nutrients in the forage crop through fermentation for feeding at a later date (Kung, 2005).

Lactic acid is the primary acid in good silage, and has to be at least 65 to 70% of the total silage acids (Kung and Shaver, 2001). It lowers the pH and inhibits the activity of undesirable microorganisms like *clostridia* species, which cause spoilage (McDonald *etal.*, 1991). Large volumes of effluent are produced when crops with a high moisture content are ensiled which causes loss of highly digestible nutrients (Zhang and Kumai, 2000), development of clostridial fermentation, dilution of plant sugar concentration slows down the decline in pH thus resulting into poor quality silage. (Yunus *et al.*, 2000).

2.5.1 Ensiling process

There are four phases involved in ensiling (Elferink *et al.*, 2000) as shown below:

Aerobic phase

Occurs in the presence of oxygen when microorganisms consume oxygen and break down the water-soluble carbohydrates (sugars), producing carbon dioxide and heat (Elferink *et al.*, 2000). The length of this phase is variable and depending on ensiling conditions, it can last for a few hours or several days (McDonald *et al.,* 1991).

Fermentation phase

This phase starts when the available oxygen is used up and aerobic bacteria cease to function. The microorganisms that predominate thereafter are lacto-bacilli species which produce lactic acid which lowers the pH of the silage (Bolsen *et al.*, 1996). Lactic acid bacteria (LAB) are active in the pH range of 4.0-6.8 (McDonald *et al.*, 1991). Clostridial spores produce some acetic acid, ethanol, and carbon dioxide when they convert sugars and organic acids to butyric acid . This leads to losses of DM and digestible energy (Bolsen *et al.*, 1996). They compete with LAB for fermentable carbohydrates (Henderson, 1993).

Stable phase

Proper sealing of silos ensures minimal oxygen entry and reduces biological activities due to decreased pH, which is reduced to 4.2 (Bolsen *et al.*, 1996). High levels of oxygen increase yeast and molds populations, resulting in losses of silage DM (McDonald *et al.*, 1991).

Good quality silage has a pH value of 4.2 or below and a butyric acid concentration of less than 0.2 % (Catchpoole and Henzell, 1971). Further, an ammonia nitrogen content of less than 11 % of the total nitrogen and a lactic acid level of between 3 to 13% of DM are also indicative of well preserved silage (Langston *et al.*, 1958; Carpintero *et al.*, 1969).

Feed out phase

Fermentation completely ceases after 3 or 4 weeks when the pH becomes so low that all microbial growth is inhibited (Bjorge, 1996). During this phase, sugars are broken to carbon dioxide and water, producing heat (Bolsen *et al.*, 1996, McDonald *et al.*, 1991). This leads to an increase in pH and proliferation of spoilage microorganisms such as Bacilli, Clostridia, enterobacteria and moulds (Elferink *et al.*, 2000). Aerobic spoilage occurs in almost all silages that are opened and exposed to air, however the spoilage rate is highly dependant on the numbers and activity of spoilage organisms. Losses of 1.5-4.5% DM loss per day can be observed in affected areas and these losses can be minimized by ensuring a high feed out rate, methods to optimize phases 2 and 3 are therefore based on the use of silage additives that is applied at the time of ensiling (O'kiely and Muck, 1998).

2.5.2 Silage additives

Silage additives are used to ensure that the lactic acid bacteria dominate the fermentation process resulting in well-preserved silage (McDonald *et al.,* 1991). They prevent excessive effluent production in low DM silages, improve the crude protein content of the silage and provide readily fermentable carbohydrates. The efficacy of any additive is judged by its effect on fermentation indicators such as ammonia-nitrogen, pH, lactic, acetic and butyric acids. Additives may be classified into fermentation stimulants, nutrients, fermentable substrates, and fermentation inhibitors like molasses, cereals and salt (Peters *et al.,* 1998).

2.5.3 Sweet potato silage making with and without additives

An (2004), did an experiment to determine the effects of adding cassava root meal, sweet potato meal, and sugarcane molasses as additives at rates of 0, 30, 60 and 90 gkg^{-1} (air-dry weight of additive) on leaves of fifteen varieties of sweet potatoes. The observations were; in all experiments the pre-wilted sweet potato leaves were successfully preserved as silage. However, in the absence of additives, the fermentation processes was slow, resulting in high pH values during the first and second weeks of ensiling compared to treatments with additives. This was explained by the low level of water soluble carbohydrates (WSC) in sweet potato leaves.

Hoang (2004), in a study using sweetpotato vine and sweet potato roots included 5 different ratios of sweet potato roots (SPR) and vines (SPV): 70, 60, 50, 40 and 30% of SPR with 30, 40, 50, 60 and 70% of SPV on a dry matter basis, respectively. Samples of SP silage were analysed at 0, 7, 14, 21, 28, 42, 70 and 84 days after ensiling to determine chemical composition and fermentation and physical characteristics. With increasing ensiling time, dry matter content increased and crude protein decreased in all treatments, but the changes were not significant. Ndf, calcium, and phosphorus did not change during the 84 days of ensiling in all treatments. The pH value in all treatments decreased rapidly in the first week (from around 6.4 to around 3.8) and continued to decrease up to day 14 (to around 3.6), then remained low until 84 days. The NH_3-N content in all treatments fluctuated at around 2-3% of total nitrogen and was not affected by ensiling duration or ratio of root to vine.No additives were used in this experiment.

Peters (2001) made silage using vines and maize meal, cassava meal and sun dried chicken manure as additives. The pH of chicken manure silage was significantly higher than of the silages without additives. The DM, CP, CF showed no significant differences over time. DM, CP and ash contents of treatments with chicken manure were all significantly higher than those of treatments without at 90 days. McDonald (1991) established that Cassava root meal, sweet potato root meal and sugar cane molasses can provide a source of potentially available energy for growth of the lactic acid bacteria. The CP content of the silage did not change during the first 2-3 weeks of ensiling, but there were significant decreases at day 56 in all treatments. Thus addition of poultry manure was advantageous.

Ruiz (1981) using chicken manure as additive observed that the pH of the treatments with chicken manure were significantly higher than those without, and the ones with chicken manure had already attained the required level of 3.7 pH after only 14 days of fermentation. In terms of pH, the treatments with chicken manure were regarded as of better quality than fresh vines or fermented vines without chicken manure. Dry matter (DM), crude protein (CP), ether extracts (EE), crude fiber (CF), and ash showed no significant difference over time (at 14, 30, 60, and 90 days of fermentation). DM, CP and ash contents of the treatments with chicken manure were all significantly higher than those without.

Peters *et al.*,2001 conducted a fermentation trial consisting of 12 treatments based on sweet potato vines with combinations of corn meal, cassava meal, rice bran, and sun-dried chicken manurewhere twelve different mixtures of sweetpotato vines, corn and cassava meals, rice bran, sun-dried chicken manure and salt were fermented, and the results were analysed for nutritional value. Nutritional analyses conducted 14, 30, 60, and 90 days after fermentation showed no significant differences over time. However, vines fermented with chicken manure had significantly higher crude protein, dry matter and ash contents than the other fermentation treatments. None of the preparations were found to contain aflatoxin or Salmonella. E. coli, although present in the original samples, disappeared after 14–21 days of fermentation.

3.0 MATERIALS AND METHODS

3.1 Study site

The research work was carried out at the Field Station, Kabete Campus, University of Nairobi. The station is located 15 km north of Nairobi, and lies at a latitude of $1^{0}15$"S longitude of $36^{0}44$"E and an altitude of about 1800 m asl. Rainfall is bimodal with long rains occuring in March to June and short rains in October to December. Annual rainfall is 1000 mm with mean monthly temperatures of 22°C. The soils are deep dark reddish brown to dark red clay with acidic humic top soil (humic nitisols), well drained with a pH of 5.0-5.5.

3.2 Plant materials

Six sweet potato varieties were used in this study. Cuttings were obtained from the University Field Station from germplasm that had been planted by the International Potato Centre in collaboration with the Department of Crop Science, University of Nairobi.The six varieties were chosen because they have shown the potential of being dual purpose through the pre-screening trial that had been done earlier by Inernational Potato Center(CIP),they are commonly grown in East Africa but their dry matter yield,nutritional and silage quality is not known.

Preliminary evaluation had been done to identify varieties with the following characteristics:

1. Low tuber, high vine yields
2. High tuber, low vine yields
3. High tuber, high vine yields

The varieties selected for their flesh colour as well as their root: vine ratios are shown in Table 4. For the colour, the orange type (deep or intermediate) shows that particular variety is rich in beta-carotene which provides vitamin-A that prevents night blindness.

Table 4: Selected sweet potato varieties

Name	Root/Vine ratio	Flesh colour
103001.152	2.53	Deep orange
Gweri	0.18	Intermediate orange
NASPOT-1	2.84	Yellow/cream
Wagabolige	2.73	Yellow/cream
Kemb 23 (local)	0.80	Cream
Musinyamu (local)	0.60	Cream

3.3 Agronomic field trial

3.3.1 Land preparation

The experimental field was cleared using slashers and dug with hoes prior to the onset of the rains. To attain a uniform tilth and leveled seedbed, large clods of soil were broken into a finer tilth using hoes and rakes.

3.3.2 Experimental design

A randomized block with a split plot design was used. The six varieties were grown in a split plot design with each replicated three times. The varieties constituted the main plot and days to harvest (75 and 150 days) constituted the subplot.

3.3.3 Planting

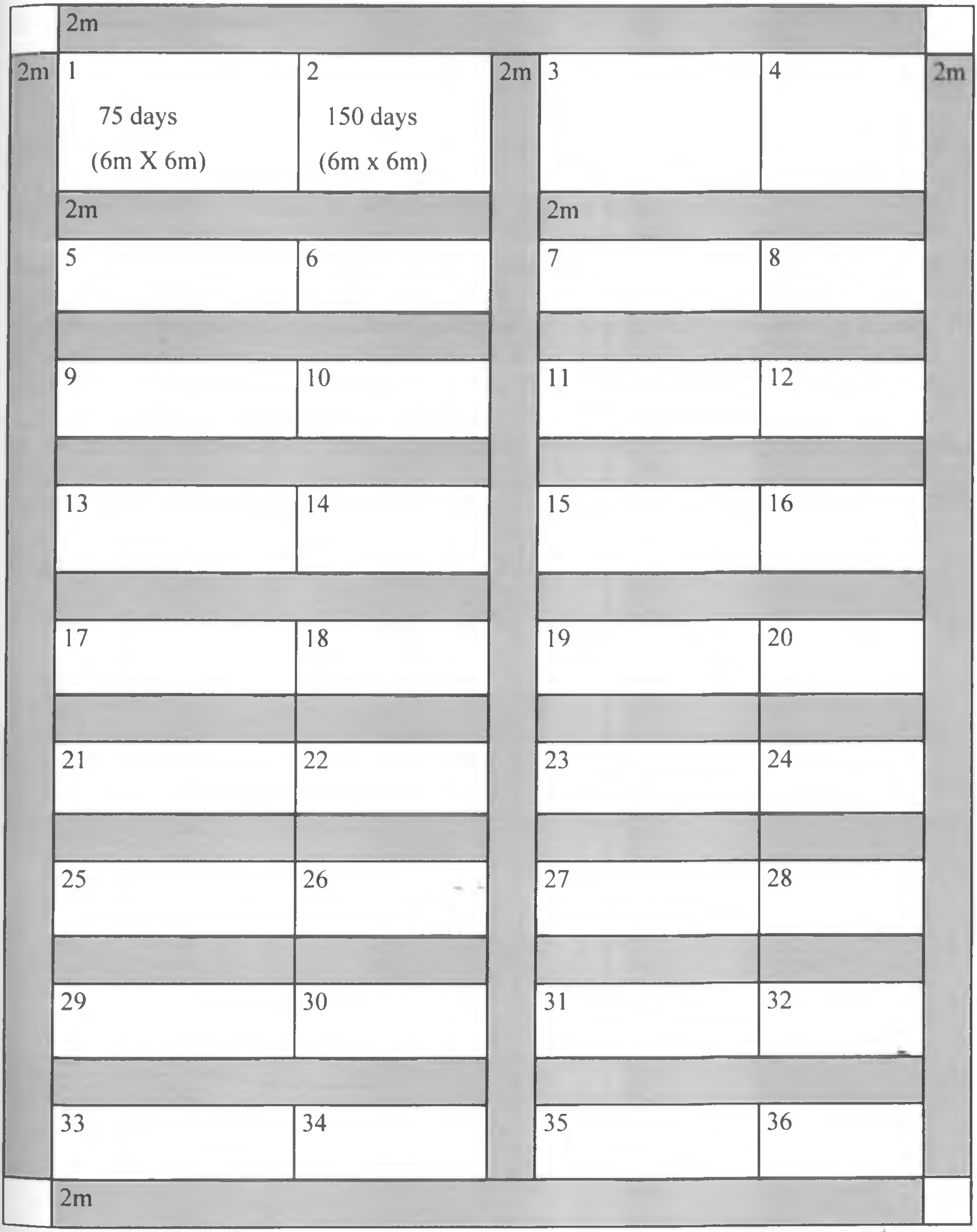
The planting was done on a field measuring 30 m wide by 74 m long laid out in 3 blocks, each constituting the main plots of the 6 varieties each measuring 12 m wide by 6 m long. The space between the two main plots was 2 m with a buffer zone of 2m on both outer sides. Each main plot was subdivided into sub-plots measuring 6 m by 6 m. Each subplot consisted of six rows of seedlings (1 m apart), each row had 30 seedlings (20 cm apart), thus a total of 180 seedlings in each sub-plot. The seedlings were planted on moulds (30 cm high) and weeding done at appropriate time.The layout is shown in Fig.1.

3.3.4 Harvesting

The first harvesting was done after 75days, where only vines from 18 sub-plots were harvested by hand using knives ensuring a stubble measuring 20 cm was left to re grow. The second harvest was done after 150days, where the whole vine was harvested and roots uprooted from all the 18-subplots (i.e those harvested at 75days and those with 150days continuos growth). Fresh weights were taken during both harvests. The vines were chopped using a chuff cutter into appropriate length and tubers were sliced into irregular pieces of about 5cm in size using a panga for, Dry matter determination, chemical analysis and silage making.

3.4 Silage preparation

All materials were prepared (vines and roots chopped at 2cm and 5cm rspectively, vines pre-wilted to a moisture content of 55-60%, weighed, mixed with the additives) and put into labeled polythene bags. Additives used were, feed-grade molasses, cassava meal, maize meal, chicken manure and salt added in proportions shown in Table 5 and Table 6.The mentioned additives were used because of their availability in most areas and also for easy comparison of the results obtained in my study and those done by other scientiests who mostly used the same additives. Poultry manure used in this study was collected from layers reared in cages, the moisture content was 40% and sundried to 15%. Poultry waste has been shown to have a high buffering capacity due to high NPN, ash contents and hydrolysis of uric acid to ammonia with ensiling thus requires high levels of lactic acid to bring the down compared to silages without poultry manure (Bolsen, 1999).



Plots 1-12 make one block, One variety planted in two plots (1-2), plot 1 harvested at 75days and allowed to regrow, both plots 1 and 2 harvested at 150 days.

Fig 1: Layout of the Experimental Plot

3.4.1 Ensiling procedure

The harvested vines were chopped using a chuff cutter whereas the roots were sliced using a panga. The vines were wilted to reduce the moisture content to by spreading out the vines on polythene sheets for two days, 40-45% moisture was lost by pre-wilting.

The chopped vines or combinations of vines and roots were weighed and manually mixed with the appropriate amount of different additives on a plastic sheet spread on the ground. The mixture was packed in quantities of 3 kg (wilted weight) in polythene silo bags measuring 12 by 18cm and a thickness of 1000g. Compaction was done manually by hand and the bags tightly sealed using a cellotape after expelling as much air as physically possible. In all the silages common salt (NaCl) was added at 0.5% to help in drainage, because during the pre-wilting period,there was a lot of rain. All the bags were stored in a cool shaded area. Treatments are shown in Table 5 below.

Table 5: Ingredients used in combination with sweet potato vines (SPV) in the fermentation trial

Harvested material: Six varieties (3 replicates per variety)	Proportion (per cent by weight) wt/wt				
	SPV + 0.5 % Common salt	SPV + 5% Cassava Meal + Common salt	SPV + 10% Sun-dried Layer Chicken Manure +0.5% Common salt	SPV + 2% Molasses (diluted with 2 parts water) +0.5% Common salt	SPV+5% Maize Meal +0.5% Common salt
1	√	√	√	√	√
2	√	√	√	√	√
3	√	√	√	√	√
4	√	√	√	√	√
5	√	√	√	√	√
6	√	√	√	√	√
7	√	√	√	√	√
8	√	√	√	√	√
9	√	√	√	√	√
10	√	√	√	√	√
11	√	√	√	√	√
12	√	√	√	√	√
13	√	√	√	√	√
14	√	√	√	√	√
15	√	√	√	√	√
16	√	√	√	√	√
17	√	√	√	√	√
18	√	√	√	√	√

Table 6: Ingredients used in combination with sweet potato vines and roots (SPVR) in the fermentation trial

Harvested material: Six varieties (3 replicates per variety)		Proportion (per cent by weight) wt/wt			
	SPVR + 0.5% Common salt	SPVR + 5% Cassava Meal + 0.5% Common salt	SPVR + 10% Sun-dried Layer Chicken Manure +0.5% Common salt	SPVR + 2% Molasses (diluted with 2 parts water) +0.5% Common salt	SPVR+5% Maize Meal +0.5% Common salt
1	√	√	√	√	√
2	√	√	√	√	√
3	√	√	√	√	√
4	√	√	√	√	√
5	√	√	√	√	√
6	√	√	√	√	√
7	√	√	√	√	√
8	√	√	√	√	√
9	√	√	√	√	√
10	√	√	√	√	√
11	√	√	√	√	√
12	√	√	√	√	√
13	√	√	√	√	√
14	√	√	√	√	√
15	√	√	√	√	√
16	√	√	√	√	√
17	√	√	√	√	√
18	√	√	√	√	√

For tables 5 and 6, they show that silage was made from vines alone harvested at 150 days and mixture of vines and roots harvested at 150 days continuous growth from the 18-subplots.

All the silos were opened after 90 days. Any visibly spoiled material was separated. A 200 g sample was collected for DM analysis and another sample dried at 60^0C for one week then ground in a willey mill (2 mm) and stored for chemical and Near infrared spectrophotometry (NIRS) analysis.100 g sample was collected and immediately blended with 1 liter of distilled water for determination of pH and ammonia nitrogen.

3.5 Characterisation of fresh yield and silage

Dry matter content, ash, crude protein, neutral detergent fiber, acid detergent fiber and acid detergent lignin were all determined using standard methods (AOAC, 1998).

3.5.1 Determination of dry matter content

Dry matter content of fresh samples (vines and roots) and silage samples was determined by sun drying a known amount and moisture loss determined, and then ground in Wiley mill (2mm sieve). A sub sample was taken, weighed and dried at 105^o C overnight, using standard methods (AOAC 1998). Dry matter was calculated as the residue expressed as a percentage of the initial weight.

3.5.2 Chemical analysis

Crude protein and ash were determined in accordance with the standard procedures (AOAC 1998). Ash was determined by igniting the sample at 600°C to burn off all organic material. Crude protein of samples was determined in a 0.5g sample digested with H_2SO_4 and alkalinized with 40% sodium hydroxide by Kjeldahl steam distillation and titration method. NDF, ADF and ADL were determined according to Van Soest *et al.* (1991).

3.5.3 Near infrared spectrometry (NIRS)

This method was used to analyse for DM, Ash, CP, *In vitro* Dry Matter digestibility (IVDMD), Metabolizable Energy, NDF, ADF and ADL in silages.This method was used to save on time since the samples being analysed were many (270 samples).

3.5.4 pH

A 100 g sample of silage was mixed with 1 liter of distilled water and blended for 45 seconds. The mixture was left to stand for two hours in 1.5-liter glass jars covered with aluminum foil (Mbuthia *et al.*,2003). The pH of the silage extracts were determined using a glass electrode pH meter, standardized with buffers of pH 4 and pH 7. The blended material was squeezed through two layers of cheese cloth and centrifuged at 2500 rpm for 30 minutes

(^{g} = relative centrifugal force; to convert to RPM use the following formula:

$g = (11.7 \times 10^{-7)}\ RN^2$ where

R = radius in mm from centrifuge spindle to extreme point on the tube, and

N = speed of centrifuge spindle in RPM.

$=(11.7 \times 10^{-7})*150*2500*2500$

=1097 rpm

1g=1097 rpm

= (2500*30 rpm*1)/1097

=68.4g

A 20 ml aliquot was treated with 10 ml of 20 % sulphuric acid and frozen awaiting ammonia-N analysis (4 ml acid to 20 ml).

3.5.5 Ammonia nitrogen

Ammonia nitrogen was determined on a 5 ml sample aliquot alkalized with 40% sodium hydroxide by Kjeldahl steam distillation and titration (AOAC, 1990). Five millilitres of the sample were measured into a kjeldahl flask and 10 mls of 40% sodium hydroxide were added and mixture distilled. The distillate was collected in 1 % boric acid and titrated against 0.01 M hydrochloric acid. The results were given as mg ammonia nitrogen/100ml acidified silage extract and then converted to grams of ammonia nitrogen/ kg total N in the original dry matter.

3.6 Statistical analysis

Statistical analysis was done using Genstat, 13th Edition and significant treatment means compared using the Bonferroni Mean Test, with the level of significance set at $p<0.05$.

4.0 RESULTS AND DISCUSSION

4.1 Dry matter yields

4.1.1 Vine dry matter yields

The effect of variety and harvest regime on vines DM matter yields (t DM/ha) is shown in Table 7. The dry matter yields of vines harvested at 75 days were not different among varieties ($P>0.05$), although Kemb-23 tended to have a higher vine dry matter yield (2.07 tDm/ha) compared to 103001.152 (1.13 tDM/ha) which had the lowest.

Table 7: Effect of variety and harvest regime on dry matter yield of sweetpotato vines (t DM/ha)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	**SED**	**F.probability**
75 days	1.13	1.99	1.81	2.07	1.32	1.48	**0.40**	**0.207**
Ratooned at 150 days	0.89^{a}	3.20^{b}	2.60^{b}	2.58^{b}	2.16^{ab}	3.18^{b}	**0.34**	**0.001**
75d + Ratooned Total	2.03^{a}	5.20^{c}	4.41^{bc}	4.65^{bc}	3.48^{b}	4.67^{bc}	**0.33**	**0.001**
150 days unratooned	1.74^{a}	7.18^{b}	5.42^{b}	6.82^{b}	4.16^{ab}	6.89^{b}	**0.82**	**0.001**

^{abc} row means with different superscripts are significantly different ($p\leq0.05$) .SED-Standard Error of Difference of the Means

The DM yield of vines harvested at 150 days after rattooning were significantly different between varieties ($p<0.05$). The varieties Gweri, Wagabolige, Kemb-23, Naspot-1 and Musinyamu were significantly different from 103001.152. Gweri had the highest vine DM yields (3.20 tDM/ha) while 103001.152 had the lowest (0.89 tDM/ha).

The total dry matter yields of vines harvested at 75 days and 150 days after ratooning (addition of both harvests) were different among varieties ($p<0.05$). The variety Gweri had the highest yield (5.20 tDM/ha) while 103001.152 had the lowest (2.03 tDM/ha). There was no significant diferrence between Wagabolige, Kemb-23 and Musinyamu.

Dry matter yields of vines harvested at 150 days of continuos growth were different among varieties (*$p<0.05$*).The varieties Gweri, Wagabolige, Kemb-23 and Musinyamu had similar yields which was significantly different from that of variety 103001.152. The variety Gweri had the highest vines dry matter yields (7.18 tDM/ha) while 103001.152 had the lowest (1.74 tDM/ha) compared to other varieties. There was an increase of 38, 46, 20, 48 and 18% in vine DM yield for Gweri, Kemb-23, Naspot-1, Musinyamu and Wagabolige respectively when harvesting was done after 150 days of continuous growth thus increase of forage yield with delayed harvesting, while for 103001.152 there was a 15% decrease since the initial value of ratooned vines was 2.03 and for 150 unratooned crop was 1.74.

The dry matter yield of vines decreased when harvesting was done at 75 days could be attributed to the reduced number of leaves thus reduced surface area affecting the rate of photosynthesis. Dry matter yields of vines harvested after 150 days of continous growth were higher due to the higher leaves percentage, thus increased leaf surface area increasing the rate of photosynthesis. Sweet potato vine dry matter yields increases with age due to reduction in moisture content and increased cell wall contents (Crowder and Cheddar, 1982; Moat and Dryden, 1993). Uddin *et al.,* (1994) reported that forage yield increased with delayed cutting. Peters *et al.,* (1998) reported vines dry matter yield of 103001.152, Gweri, Naspot-1, Wagabolige, Kemb-23 and Musinyamu as 1.58, 5.05, 0.69, 1.54, 2.67 and 2.18 respectively. These were similar to those of 103001.152 and Gweri observed in this study but lower than those observed for Naspot-1, Wagabolige, Kemb 23 and Musinyamu. The differences could be attributed to the difference in genotype*environment interactions.

Orodho *et al.*, (1990) and Karachi (1982) reported DM yield of vines to be 2.7t/ha and 24.8t/ha respectively for Musinyamu, which may be due to difference in the agroecological zone and the genotype-envoironmet interaction. Onim *et al.*, (1985) reported 8.5t/ha DM vines yields for Musinyamu which was much higher than the values observed in this study, the harvesting was done after 8 months whereas in this study it was done at 5 months thus DM increased with age (Crowder and Cheddar, 1982). Results from this study show that Gweri and Musinyamu was the highest vine yielding varieties.

4.1.2 Root dry matter yields

Table 8 shows the effect of variety and harvest regime on roots DM matter yields (t DM/ha). The dry matter yields of roots harvested after re-growth at 150 days were not different among varieties ($P \geq 0.05$).

Table 8: Effect of variety and harvest regime on roots dry matter yields (t DM/ha)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	**SED**	**F.probabilit**
Ratooned at 150 days	2.26^{a}	1.02^{b}	1.89^{a}	2.41^{a}	3.64^{a}	2.40^{a}	**0.76**	**0.100**
150 days unratooned	3.44^{ab}	1.37^{a}	3.65^{b}	4.78^{bc}	6.49^{c}	2.78^{ab}	**0.78**	**0.01**

^{abc} *row means with different superscripts are significantly different ($p \leq 0.05$) .SED-Standard Error of Difference of the Means*

Root yields of the unratooned crop were different among varieties ($p<0.05$), yields of Naspot-1 being significantly higher than Gweri, Musinyamu, 103001.152 and Wagabolige. Among the ratooned varieties, Gweri had the lowest root yield, which was significantly lower than of Wagabolige, Musinyamu, Kemb-23 and Naspot-1 ($p < 0.05$). Dry matter yields of roots harvested after 150 days continuos growth were different among varieties ($p<0.05$). Naspot-1 had a significantly higher yield (6.49) than the other varities while Gweri had the lowest (1.37 tDM/ha).

Root yields of the ratooned crop were different among varieties ($p<0.05$), with the yield of Naspot-1 being higher than that of Gweri, Musinyamu, 103001.152 and Wagabolige ($p< 0.05$). Again Gweri had the lowest root yield, which was lower ($p<0.05$) than that of Wagabolige, Kemb-23 and Naspot-1 ($p< 0.05$). Yields from 103001.152, Wagabolige, Kemb-23 and Musinyamu were not different ($p> 0.05$). The unratooned crop yielded more roots at 150 days than the ratooned crop.

Harvesting of vines at 75 days reduced the dry matter yield of roots due to disruption of the photosynthesis process leading to reduced root production whereas dry matter yields of roots harvested after 150 days continous growth were higher due to the presence of adequate leaves that enhanced photosynthesis thus increased root production. Dahniya (1979) observed that frequent cutting of vines caused significant reductions in root yields and also depressed total biomass production. In his study he reported that cutting sweet potato vines at intervals of 4, 6 and 8 weeks compared to not cutting reduced root yields by 50, 41, and 31% respectively. Similar observations were made by An *et al*., (2003), Kiozya *et al* ., (2001) and Ruiz *et al* (1980) who also noted that defoliation had a negative influence on root production in sweet potatoes. At longer cutting intervals (6-8 weeks) yield of sweet potato forage increased significantly ($P < 0.05$) when compared to the unratooned vines while the root yield was significantly ($P<0.05$) depressed. This disagrees with the findings of,Uddin *et al.*, (1994) who reported that forage yield increased with delayed cutting while root yield was depressed.

Age at harvest has been shown to be an important management factor that affects the fodder and tuber yields and their quality (An *et al.,* 2003). Several studies have been reported on the relationship between plant parts and sweet potato tuber yield (Amarchandra *et al.,*1987). Bourke (1984) showed a dependence of tuber yield on total plant dry matter. Earlier studies indicated that distribution of assimilate to the tuber is more important than total photosynthate production in determining the final tuber yield (Austin *et al.,* 1973). Austin *et al.,* (1970) observed that the formation of storage roots of sweet potato in the field did not retard the vine growth but proceeded concurrently with the growth of the tops and variation in yield occurred in sweet potato due to the influence of season, planting material and tuber development. From this study, it can be concluded that Naspot-1 and Kemb-23 were the highest root yielders.

Harvesting of roots at 150 days resulted in higher root dry matter yields compared to 150 days after re-growth. There was an increase of 52, 34, 93, 98, 78 and 15% for 103001.152, Gweri, Wagabolige, Kemb-23, Naspot-1 and Musinyamu respectively. Peters *et al.*, (1998) reported root dry matter yield of 4.00 (103001.152), (0.89) Gweri, (1.93) Naspot-1, (4.21) Wagabolige, (4.27) Kemb-23 and (2.62) Musinyamu t DM/ha. These values agree for Musinyamu whereas Naspot-1, Wagabolige, Kemb-23 and Gweri values were lower than those observed in this study, this was due to the difference in genotype*environment interactions. Sweet potato varieties have been categorised as forage, tuber or dual purpose (León-Velarde *et al.,* 1997), which could have contributed to the variations in root yields. Dry matter content of roots has been reported to increase with age (Crowder and Cheddar, 1982) which could explain the increase in DM yield at 150 days,i do concurr with this statement since when there is a high leaf percentage there is an increase in leaf surface area which increases photosynthesis thus there is enough photosynthate to be transported to the tubers enhancing their growth thus high DM. The reduction in dry matter yield of roots harvested at 150 days after re-growth could be attributed to reduction in the leaf area after 75 days harvest thus affecting the photosynthesis process leading to reduction in root production.

Frequent cutting at 4 week intervals did not improve forage yield of sweet potato when compared to control, but the root and total biomass yield were depressed (Dahniya 1979). Cutting sweetpotato vines at 4, 6, 8 weeks interval reduced the root yield by 50, 41, and 31% respectively. The frequent defoliation of the sweet potato plant disrupts the photosynthetic process, leading to a reduced leaf, root and biomass production.

Table 9 :Total DM yield of the varieties (t DM/ha)

VARIETY	TOTAL DM YIELD (75 DAYS)	TOTAL DM YIELD (150 DAYS)
103001.152	4.29	5.18
Gweri	6.22	8.55
Wagabolige	6.30	9.07
Kemb-23	7.06	11.60
Naspot-1	7.12	10.65
Musinyamu	7.07	9.67

Table 9 above shows the total biomass yield for the different varieties. Kemb-23 and Naspot-1 had the highest DM yield. The above values were obtained by adding the total dry matter yields of vines and roots for a particular regime. For example to get the total dry matter yield of 75 days harvest for 103001.152 ,the total vine yield of ratooned crop (2.03) was added to the dry matter yield of unratooned crop (2.26) giving a total of 4.29.

4.1.3 Root to vine ratio

The effect of variety and harvest regime on root to vine ratio is shown in Table 10. The root to vine ratio after re-growth at 150 days were different among varieties ($p<0.05$).

Table 10: Effect of variety and harvest regime on root to vine ratio (t Dm/ha)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	SED	F. probability
Ratooned at 150 days	1.30^{b}	0.20^{a}	0.44^{ab}	0.53^{ab}	1.21^{b}	0.48^{ab}	**6.55**	**0.004**
150 days unratooned	2.21^{c}	0.20^{a}	0.67^{ab}	0.67^{ab}	1.57^{bc}	0.44^{b}	**6.85**	**0.001**

^{abc} *row means with different superscripts are significantly different ($p\leq0.05$) .SED-Standard Error of Difference of the Means*

The variety 103001.152 had the highest root to vine ratio (1.30) while Gweri had lowest (0.20). The root to vine ratio of Gweri was significantly different from Naspot-1 and 103001.152. Root to vine ratios at 150 days continous growth were different among varieties ($p\leq0.05$). The variety 103001.152 had highest root to vine ratio while Gweri had the lowest. 103001.152, Gweri and Musinyamu were significantly different. There was an increase of root to vine ratio by 70%, 52%, 26%, 29% for 103001.152, Wagabolige, Kemb-23, Naspot-1 respectively while there was a decrease of 9% for Musinyamu but no change for Gweri. Root to vine ratio was obtained by dividing the root yields and total vine yield od that particular regime,for example for Naspot-1 harvested after 150 days of continous growth=Root DM of unratooned/Vine DM of unratooned=6.49/4.16=1.57.

These ratios could probably be differing since the varieties fall into different categories namely; forage, root and dual purpose types. (León-Velarde *et al.*, 1997) reported five classifications of sweet potato according to the root to vine ratio: forage (R/F of 0–1), low dual purpose (R/F >1–1.5), high dual purpose (R/F >1.5–2.0), low root production (R/F>2.0–3.0), and high root production (R/F >3.0). In this study, for roots harvested after ratooning 103001.152 and Naspot-1 can be classified as low dual purpose varieties, Gweri, Kemb-23,Wagabolige and Musinyamu are forage varieties. At 150 days continous growth, 103001.152 was classified as a low root production, Gweri, Kemb-23, Wagabolige and Musinyamu were forage varieties, whereas Naspot-1 was a high dual purpose variety. Harvesting regime from this study, can change thus the classification of a variety depending on the genotype*environment interaction (Leon,1997). Peters *et al.*, (2001) reported that when a variety contains a high amount of total dry matter in both roots and vines, it is recommended as a dual-purpose variety.

Peters *et al.*, (1998) reported ratios of 2.53 (103001.152) 0.18 (Gweri), 2.84 (Naspot-1) and 2.73 (Wagabolige). From the current study 103001.152 and Gweri fall within these ratios for both ratooned and unratooned and Naspot-1 for the ratooned, whereas Wagabolige falls within the forage variety.

4.1.4 Crude protein content

Table 11 shows the effect of variety and harvest regime on CP content (% DM) of vines harvested at 75 and 150 days (ratooned and unratooned crops). The CP content of vines harvested at 75 days were not different among varieties ($p>0.05$). The CP content ranged from Gweri (15.08) to (17.97) for Naspot-1.

Table 11: Effect of variety and harvest regime on crude protein (%)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	**SED**	**F.value**
75 days	16.56	15.08	15.61	15.96	17.97	16.67[a]	**0.83**	**0.067**
Ratooned at 150 days	11.82	13.86	12.75	10.27	12.86	14.04	**2.36**	**0.634**
150 days unratooned	7.18[a]	9.26[a]	12.50[b]	10.05[ab]	11.26[ab]	11.69[b]	**1.11**	**0.008**

[abc] *row means with different superscripts are significantly different ($p \leq 0.05$) .SED-Standard Error of Difference of the Means*

Crude protein content of vines harvested after rattooning was not different among varieties ($p>0.05$). The CP ranged from 10.27 (Kemb-23) to 14.04 (Musinyamu). The CP content of vines harvested at 150 days continous growth were differed between varieties ($p<0.05$). Wagabolige had the highest (12.50) and was significantly different from 103001.152(7.18) which had the lowewst.103001.152 and Gweri were significantly different from Wagabolige and Musinyamu.

The CP content for all the varieties decreased with age at harvest, this was mainly due to lignification that increased the cell wall contents (NDF) with maturity in agreement with (Etela and Oji, 2009). Oyenuga (1968) and Moat and Dryden (1993) also reported high protein content in young sweet potato vines and a decrease in protein content with age. Vines harvested at 75 days had higher CP content than those harvested at 150days (both ratooned and unratooned). Ondabu *et al.,(*2005) harvested vines at 90 days and reported the CP content of 18.4 for Wagabolige and 16.5 for Musinyamu. This value was higher compared to the results obtained in this study for Wagabolinge (15.6) but agreed with those observed for

Musinyamu. The observed values were lower than those obtained by Vo Lam (2004) (22.7) for Hshinchu variety and Olorunnisomo (2007) (21.8 for TIS-Ex-Igbariam variety) harvested at 8 weeks. The differences could be attributed to varietal and environmental differences. In the current study the CP content of vines for all varieties decreased with age, in agreeement with Olorunnisomo (2007) who reported the CP content of TIS-Ex-Igbariam variety harvested at 4, 6 and 8 weeks as 26.7, 25.0 and 21.8 respectively.

4.1.5 Fiber

The effect of variety and harvesting regime on the NDF, ADF and ADL content of vines is shown on Tables 12, 13 and 14.

Table 12: Effect of variety and harvest regime on neutral detergent fiber (%DM)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	**SED**	**F.probability**
75 days	42.10^{b}	43.78^{b}	39.51^{ab}	36.90^{a}	39.91^{ab}	39.40^{ab}	**1.21**	**0.003**
150 days unratooned	45.52	44.88	46.41	46.22	46.97	46.11	**1.12**	**0.550**

^{ab}row means with different superscripts are significantly different (p<0.05).SED-Standard Error of Difference of the Means

Table 13: Effect of variety and harvest regime on acid detergent fiber (%)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	**SED**	**F.proba**
75 days	41.30	38.16	38.69	38.91	38.06	39.28	**1.27**	**0.152**
150 days unratooned	32.78[a]	31.56[a]	35.55[b]	28.59[a]	33.60[ab]	35.67[b]	**1.54**	**0.090**

[abc] *row means with different superscripts are significantly different ($p \leq 0.05$) .SED-Standard Error of Difference of the Means*

Table 14: Effect of variety and harvest regime on acid detergent lignin (%)

DAYS TO HARVEST	VARIETY							
	103001.152	Gweri	Wagabolige	Kemb-23	Naspot-1	Musinyamu	**SED**	**F.probabili**
75 days	14.66	12.58	12.81	13.28	14.37	13.23	**0.91**	**0216**
150 days unratooned	8.69	8.44	10.50	9.38	10.27	10.71	**0.81**	**0.061**

[abc] *row means with different superscripts are significantly different ($p \leq 0.05$) .SED-Standard Error of Difference of the Means*

The NDF content was significantly different among varieties for vines harvested at 75 days (Table 12).The variety Gweri had the highest NDF content (43.78) while Kemb-23 had the lowest. 103001.132 and Gweri were significantly different from Kemb-23 interms of NDF. There were no significant differences in NDF content between varieties at the 150 days harvest, the range being 44.88 (Gweri) to 46.97 (Naspot-1).

There was no significant difference in ADF content among varieties for vines harvested at 75 days (Table 13), the range being 41.30 (103001.152) to 38.06 (Naspot-1). ADF content was significantly different ($P<0.05$) among varieties for vines harvested at 150 days . Musinyamu had the highest content (35.67) which differed significantly from Gweri (28.59) and Musinyamu (26.70) .

There was no significant difference in ADL content among varieties for vines harvested at 75 days (Table 14), the range being 14.66 (103001.152) to 12.58 (Gweri). ADL content at 150 days was not significantly different among varieties though Musinyamu gave the highest value of 10.71 while Gweri gave a lowest of 8.44.

Vo Lam (2004), reported NDF and ADF content of 35.6 and 26.5 respectively for for Hshinchu variety. In the current study, Kemb-23, Naspot-1, Wagabolige and Musinyamu harvested at 75 days for NDF were similar to what Vo reported but the ADF values were lower were than what was obtained in our study except for Kemb-23 for 150 days unratooned Olorunnisomo (2007), reported an NDF, ADF and ADL content of 48.0, 29.0, 7.50 respectively with TIS-Ex-Igbariam variety, the NDF values were much higher, whereas ADF and ADL were lower than what was obtained in our study.

The fibre content increased with age for NDF and the decline in forage quality with maturity is directly related to the leaf/stem ratio. As a plant matures it becomes more "stemmy" (i.e., the leaf/stem ratio decreases) the decline in forage quality with maturity is primarily due to the increasing lignification of the stem and an increasing proportion of stem compared to leaf (Pinkerton *et al.*,1992).

NDF is a chemical estimate of the plant cell wall content of a forage, and ADF is the cell wall content minus a cell wall component called hemicellulose. As a plant matures the cellwall content increases as a percent of the total plantcell. Plant cell walls are much less digestible than other parts of the cell (intracellular contents). Therefore, as the cell wall component of the cell increases with maturity, digestibility or quality of the forage decreases. Fibre content changed in all the varieties (Pinkerton *et al.*,1992).

The role of fiber in monogastrics animal species such as the pig is very important, due to the fact that digestion of fiber may influence performance traits of economic importance (Siers, 1975; Frank *et al.*, 1983). In this respect fiber utilization in growing pigs largely depends on the level of fiber fed, source of fiber, stage of forage maturity, and levels of other nutrients in the diet (Farrell and Jørgensen, 1973; Close, 1993). Feeding diets with high fiber content will increase the time needed to consume the daily allowances (Morz *et al.*, 1986). A high level of fiber might also be involved in inducing satiety through increasing gut distension. According to Fernandez and Jørgensen (1986), Dierick *et al.*, (1989) and Bach Knudsen and Jørgensen (2001), 94-99% of all carbohydrates are digested by the time they reach the terminal ileum in pigs. However, digestion of hemicelluloses and cellulose up to the terminal ileum is very limited (Keys and DeBarthe, 1974), and the amount of carbohydrates and other nutrients transferred from the small intestine into the large intestine is highly dependent on diet composition. Digestibility of lignin by the large intestinal microbes is very limited, and lignin is not degraded in noticeable amounts (Fernandez and Jørgensen, 1986; Dierick *et al.*, 1989).

From this study, Kemb-23 variety cut at 75 days had Low NDF, ADF and ADL, making it the most suitable of the varieties tested. NDF is closely associated with total potential intake of the forage by an animal while ADF is more closely related to digestibility of the forage and as such both values are used in predicting forage quality (Pinkerton *et al.*,1992).

4.2.Effects of variety and treatment on silage quality

Table 15 shows the effect of variety on silage quality.

Table 15. Effects of variety on silage quality

	Vines alone								Mixture of vines & roots							
Parameter	N	W	G	M	K	C	SED	F prob.	N	W	G	M	K	C	SED	F prob
pH	5.15^{b}	4.84^{ab}	4.51^{a}	4.75^{a}	4.64^{a}	4.67^{a}	0.11	0.001	5.61^{b}	5.05^{a}	4.69^{a}	5.05^{a}	5.06^{a}	5.04^{a}	0.14	0.001
NH_4.N %	2.50^{ab}	2.29^{ab}	2.29^{ab}	2.24^{ab}	2.16^{a}	2.68^{b}	0.17	0.03	2.13^{a}	2.24^{a}	2.06^{ab}	2.24^{ab}	2.05^{a}	2.14^{b}	0.29	0.77
CP %	15.60^{ab}	14.33^{ab}	14.32^{ab}	14.01^{ab}	13.48^{a}	16.73^{b}	1.04	0.03	13.32	13.97	12.85	12.87	12.81	13.38	0.90	0.77
DM %	24.28^{a}	29.32^{b}	36.00^{c}	32.30^{bc}	25.66^{a}	38.16^{c}	2.07	0.001	25.17^{a}	24.67^{a}	35.49^{b}	30.11^{ab}	25.83^{a}	32.91^{c}	2.99	0.001

N = Naspot-1 W = Wagabolige G = Gweri K= Kemb-1 C = 103001.15 M=Musinyamu

^{abc} *row means with different superscripts are significantly different ($p \leq 0.05$) .SED-Standard Error of Difference of the Means*

Table 16: Comparison of significance level between SPV and SPVR among Varieties (T-test)

Variety	pH	NH_3-N	DM	CP
Naspot-1	0.001*	0.004*	0.731	0.004*
103001.152	0.001*	0.001*	0.054	0.001*
Gweri	0.028*	0.235	0.911	0.235
Kemb-23	0.001*	0.558	0.192	0.558
Musinyamu	0.001*	0.127	0.229	0.127
Wagabolige	0.439	0.736	0.164	0.736

**$P\leq 0.05$-Significantly different*

4.2.1 Effect of variety and treatment on dry matter content of silage

The dry matter content of silage made from 150 days unratooned vines were significantly different among varieties. 103001.152 had a higher DM content (38.16) which was significantly different from Naspot-1(24.28), Kemb-23(25.66), Wagabolige (29.32) but not Musinyamu (32.30) and Gweri (36.00). The dry matter content of silage made from 150 days unratooned vines and roots was significantly different among varieties. Gweri had a higher DM content(35.49) which was significantly different from Naspot-1,Wagabolige,Kemb-23 but not Musinyamu and 103001.152 as shown on Table 15.

The DM values were not significantly different for vines alone and a mixture of vines and roots as shown by the T-test (Table 16). Factors such as type of forage to be ensiled, and maturity, DM content and WSC content of that forage, all influence the ease of ensiling and ultimately the quality of silage that is produced. Consequently, the largest losses in silage dry matter (DM) can occur during the feed-out phase (Rotz *et al.,* 1992).

It is desirable to increase the DM content of forage. High moisture silages (20 to 27% DM) promote a very active fermentation and they are often associated with increased in seepage losses from the silo. Furthermore, intake of high moisture silages also tends to be reduced relative to intake of forage ensiled at optimal (27 to 38%) DM (Demarquilly *et al.*, 1970; Thomas *et al.*, 1961).

From the above, DM content of forage tends to increase with advancing maturity of the crop, but silage DM can also be increased by wilting a less mature forage in the field prior to ensiling. In this case, the higher DM was achieved without the increased lignification associated with more mature plant cell walls. Thus, wilting can be used as an effective tool to elevate forage DM into an acceptable range for ensiling. Over wilting the forage, however, can reduce silage quality. Loss of DM from forage during wilting can be as high as 4% per day (McDonald *et al.*, 1991) and prolonged plant respiration can further reduce WSC levels. Reducing available WSC reduces the amount of lactic acid produced. Consequently, the pH of wilted silage is often higher than silage that is chopped directly . Lower WSC levels may also account for the lower rate of digestion and effective degradability observed with wilted silage as compared to direct-cut silage. Wilting, therefore, can also affect ruminal digestive characteristics as well as nutrient value of silages, although not to as great an extent as forage maturity.

In general, wetter silages have higher concentrations of ammonia. Extremely wet silages (< 30% DM) have even higher ammonia concentrations because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations. In this study the varieties (Naspot-1, Wagabolige, Kemb-23 and 103001.152) with less than 30% DM, had high ammonia-N values. Ruiz (1982) showed that the dry matter content of sweet potato foliage silages did not change by adding roots.

4.2.2 Effect of variety and treatment on crude protein content

The CP content of silage made from 150 days unratooned vines was significantly different among varieties.103001.152 had a higher CP content (16.73) which was significantly different from Kemb-23(13.48) but not Gweri, Wagabolige, Musinyamu and Naspot-1. The CP content of silage made from 150 days unratooned vines and roots was similar among varieties.The CP content ranged from 13.97(Wagabolige) to 12.81(Kemb-23) as shown on Table 14. CP values of Naspot-1 and 1003.152 made from vines alone were significantly different from those of vines and root mixture though there was a significant difference among Gweri,Musinyamu,Kemb-23 and Wagabolige as shown by the T-test (Table 16).

There was an increase of the CP content when the vines were ensiled because the CP content of fresh material was 7.18, 9.62, 12.50, 10.05, 11.26, 11.69 for 103001.152, Gweri, Wagabolige, Kemb 23, Naspot-1 and Musinyamu respectively for 150 days unratooned crop. Thus the quality of the fresh material was improved signifying there was no deamination of amino acid during fermentation caused by clostridial action.These results are different from what was reported by (McDonald *et al.*,1995) where there was a slight decrease in CP content due to some deamination of amino acids that occurs during fermentation

High concentrations of ammonia (>12 to 15% of CP) are a result of excessive protein breakdown in the silo caused by a slow drop in pH or clostridial action. In general, wetter silages have higher concentrations of ammonia. Extremely wet silages (< 30% DM) have even higher ammonia concentrations because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations but in this study the ammonia levels were low within the acceptable range of

<5%. Addition of roots reduced the CP content due to low CP content in roots, 0.95-2.4%, (Woolfe,1992).

4.2.3 Effects of variety and treatment on pH

The pH of silage made from the 150 days unratooned mixture of vines and roots only was significantly different among varieties.Naspot-1 had a higher pH value(5.61) which was significantly different from wagabolige(5.05), Gweri(4.69), Musinyamu(5.05), Kemb-23(5.06) and 103001.152(5.04). There was a significant difference in pH among varieties of silage made from the 150 days unratooned vines only. Naspot gave a higher pH value (5.15) which was significantly different from Gweri(4.51), Musinyamu(4.75), Kemb-23(4.64), 103001.152(4.67) but not Wagabolige(4.84) as shown on Table 15.

The pH of an ensiled material is a measure of its acidity, and is affected by the buffering capacity of the crop. Buffering capacity measures to what degree a forage sample will resist a change in pH, with all forages having different buffering capacities. Fresh forage with a high buffering capacity will require more acid to reduce its pH than forage with a low buffering capacity (Kung and Shaver, 2001).

In principle, good silage should have a high lactic acid content, which is dominant to other acids such as acetic, propionic and butyric acids. The lactic acid is usually responsible for most of the drop in silage pH (Kung and Shaver, 2001). The classification of silage based on pH value is: pH below 4.0(excellent), between 4.1 and 4.3(good) pH between 4.4 - 5.0(average) and above 5.0(bad). From the resuilts of this study, Naspot-1 had high pH values of 5.61 and 5.51 and can be classified as bad silages. Silage made from Gweri had pH values of 4.69 and 4.51, resulting in average quality silages, with the other varieties resulting in average-bad silages as their pH ranged from 4.64 to 5.06.

The pH values obtained in this study could be classified as bad according to McDonald *et al.*, (1995), who concluded that good silages are characterized by having low pH values, usually between pH 3.7 and 4.2. Nguyen *et al.*, (2000) reported pH of SPV silages (values ranged from 3.52 to 4.20) . The pH values of silage of Naspot-1, 1003.152, Kemb-23, Wagabolige made from vines alone were significantly different from those of vines and root mixture though there was no significant difference among Gweri and Wagabolige as shown by the T-test(Table 16).

Reasons for a high silage pH are; dry silage (> 50% DM), silage not fully fermented due to early sampling time relative to harvest, cold weather during harvest, and slow or poor packing, legume silages with extremely high ash contents (> 15% of DM) and (or) high protein content (> 23-24% CP), silage with excess ammonia or urea, clostridial silages,spoiled or moldy silages,silages containing manure (Kung, 2010). The two latter reasons applied in this study.

Hoang (2004), in a study using SPV and SPR included 5 different ratios of sweet potato roots (SPR) and vines (SPV): 70, 60, 50, 40 and 30% of SPR with 30, 40, 50, 60 and 70% of SPV on a dry matter basis, respectively. Samples of SP silage were analysed at 0, 7, 14, 21, 28, 42, 70 and 84 days after ensiling to determine chemical composition, fermentation and physical characteristics. The silage on all treatments had a good smell at all times up to 84 days. The pH value in all treatments decreased rapidly in the first week (from around 6.4 to around 3.8) and continued to decrease up to day 14 (to around 3.6), then remained low until 84 days.

The roots increased the pH values of silage in this study, this could have been mainly due to the ratio of vines to roots that was used which was 3:1 respectively, increasing the root percentage would have increased the water soluble carbohydrates thus increasing the lactic acid leading to a decrease in the pH values,this explanation is observed in an experiment done by(Hong *et al.*,2003) where he did 5 mixtures of different ratios of SPR and SPV, namely 70, 60, 50, 40 and 30 % of SPR with 30, 40, 50, 60 and 70% of SPV, respectively, on dry matter basis, were successfully ensiled without any additives, resulting in good quality silage that could be stored for at least 3 months, thus when SPR levels increased from 30% to 70%, there was an increase in lactic acid leading to low values and he attributed it to the increased level of water soluble carbohydrates. Varieties have different pH values since different additives were used,they have different DM content and buffering capacity (Kung and Shaver, 2001).

With increasing ensiling time, dry matter content increased and crude protein decreased in all treatments, but the changes were not significant. Other chemical components such as NDF, calcium, and phosphorus did not change during the 84 days of ensiling in all treatments. The NH3-N content in all treatments fluctuated at around 2-3% of total nitrogen and was not affected by ensiling duration or ratio of root to vine.

4.2.4 Effect of variety and treatment on Ammonia- N content.

The ammonia N content of silages for the unratooned vines harvested at 150 days was significantly different among varieties. 103001.152 had a higher Ammonia-N content (2.68) which was significantly different from Kemb-23 (2.16). Gweri, Wagabolige, Musinyamu and Naspot-1 were not significantly different from the two.There was significant difference in the ammonia N content of silages from the 150 days unratooned vines and roots among the varieties,103001.152 was significanty different from Kemb-23,Wagabolige and Naspot-1. The ammonia-N content ranged from 2.24 (Wagabolige) to 2.05 (Kemb-23).

Ammonia-N is an indicator of fermentation quality, an indicator of the degree of protein degradation in preserved silages (Wilkinson, 2005). Well-preserved silages contain less than 100 g NH_3-N/kg (10%) of total Nitrogen (McDonald *et al.*, 1991), higher values are associated with butyric fermentation caused by clostridia. The silages in the present study had ammonia-N concentrations of less than 100 g NH_3-N/kg TN as the range was 2.05-2.68% of the total N (Table 15).

The ammonia-N values of Naspot-1 and 103001.152 silages made from vines alone were significantly different from those of vines and root mixture though they were no similar among Gweri, Musinyamu, Kemb-23 and Wagabolige as shown by the T-test (Table 16).
High concentrations of ammonia-N (>10 of Total Protein) is a result of excessive protein breakdown in the silo caused by a slow drop in pH or clostridial action. In general, wetter silages have higher concentrations of ammonia. Extremely wet silages (< 30% DM) have even higher ammonia concentrations because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations (Kung, 2010).

Hoang (2004), in a study using SPV and SPR included 5 different ratios of sweet potato roots (SPR) and vines (SPV). The NH3-N content in all treatments fluctuated at around 2-3% of total nitrogen and was not affected by ensiling duration or ratio of root to vine. The ratio of ammonia-N to total N (NH_3-N/TN) in silage provides information on the stage of protein degradation and it undeniably constitutes a test of the state of conservation of the ensiled proteins. The higher the ratio, the more protein has been degraded, and the poor the quality. In the system proposed, a maximum of 50 points is given for a ratio lower than 5 percent classifying the silage as good quality whereas those >10-15 as poor quality silage, thus the values in this study are less than 5% giving good silage quality.

Table 17.Effect of additives on silage quality

	Vines alone							Mixtures of vines & roots						
Parameters	MM	CM	PM	Molasses	Salt	SED	F prob.	MM	CM	PM	Molasses	Salt	SED	F prob
pH	4.93^{a}	4.84^{a}	5.32^{b}	5.13^{ab}	5.20^{ab}	0.13	0.003	4.66^{a}	4.86^{a}	4.91^{b}	4.69^{a}	4.88^{a}	0.10	0.04
NH_4.N %	2.25	2.51	2.25	2.47	2.32	0.15	0.23	2.13	2.19	1.97	2.06	2.21	0.13	0.35
CP %	14.06	15.66	14.04	15.46	14.50	0.95	0.27	13.28	13.71	12.31	12.89	13.81	0.82	0.35
DM %	32.18^{ab}	30.99^{ab}	36.03^{b}	27.80^{a}	27.77^{a}	1.89	0.001	28.89^{ab}	28.88^{ab}	34.49^{b}	26.10^{a}	26.80^{ab}	2.73	0.03

MM = Maize Meal   CM = Cassava Meal   PM = Poultry Manure

^{abc} *row means with different superscripts are significantly different ($p \leq 0.05$) .SED-Standard Error of Difference of the Means*

Table 18:Comparison of significance level between SPV and SPVR among additives(T-test)

Additives	pH	NH_3-N	DM	CP
CM	0.083	0.027*	0.468	0.027*
PM	0.038*	0.087	0.499	0.087
MM	0.020*	0.367	0.398	0.367
Molases	0.002*	0.004*	0.483	0.004*
Salt	0.029*	0.457	0.725	0.457

**P≤0.05-Significantly different*

4.2.5 Effect of additive on DM content of silage

The DM content of silage made from unratooned vines harvested at 150 days was significantly different among the additives used. Addition of poultry manure resulted in silages of higher DM content (36.03) which were significantly different from molasses (27.80) , salt (27.77) but not maize meal (32.18) and cassava meal (30.99).

The DM content of silage made from unratooned vines and roots harvested at 150 days was significantly different among the additives used. Poultry manure gave silages of higher DM content (34.49) which were significantly different from molasses (26.10), but not maize meal (28.89), cassava meal (28.88) and salt (26.80) as shown on Table 17. The high dry matter content especially in silages where maize meal, cassava meal and poultry manure, can be explained by the higher DM content of cassava meal, maize meal and poultry manure. There was a significant difference among the DM values obtained from adding the additives in both vines and mixture of vines and roots silages as potrayed by T-test (Table 18).

Peters *et al.*,(2001) conducted a fermentation trial consisting of 12 treatments based on sweetpotato vines with combinations of corn meal, cassava meal, rice bran, and sun-dried chicken manure where twelve different mixtures of sweetpotato vines, corn and cassava meals, rice bran, sun-dried chicken manure and salt were fermented, and the results were analysed for nutritional value. Nutritional analyses conducted 14, 30, 60, and 90 days after fermentation showed no significant differences over time. However, vines fermented with chicken manure had significantly higher crude protein, dry matter and ash contents than the other fermentation treatments. None of the preparations were found to contain aflatoxin or Salmonella. E. coli, although present in the original samples, disappeared after 14–21 days of fermentation.this results are similar to our findings.

Molasses and salt gave the poorest silage quality in terms of DM content when they were used as additives whereas poultry manure gave the best silage in terms of quality since in both silages where vines only and a mix of vines and roots were used, it gave DM values above 30% that is recommended for good quality silage (Wieringa 1960; Catchpoole & Henzell 1971; Jones et al., 1971).

Molasses is expected to result in silage with a high DM content because it contains DM content of 70-75% and a soluble carbohydrate content of about 65%DM. This is because it was used at 2% (w/w). In order to obtain maximum benefit, it should be used at 4% (w/w) for grass silage and 6% (w/w) for legume silage (FAO, 2002).

4.2.6 Effect of treatments on CP

The CP of silage made from unratooned vines harvested at 150 days was not significantly different among the additives used. The CP values ranged from 15.66 (cassava meal) to 14.04 (poultry manure). The CP of silage made from unratooned vines and roots harvested at 150 days was not significantly different among the additives used. The CP ranged from 13.81 (salt) to 12.31 (poultry manure) as shown on Table 17. There was a significant difference among the CP values obtained from adding CM and molasses in both vines and mixture of vines and roots silages except for PM, Salt and MM as shown by T-test (Table 18).

There was no significant difference in the CP content for vines only and mix of vine and roots silages between the silages without additives and those with additives, the expectation was that in silages where poultry manure was added could achieve highest CP content due to the addition of N, the reason behind this could be excessive breakdown of proteins caused by clostridia,since during the aerobic phase of ensiling,there is breakdown of crude protein and this has an effect on the final CP content in silage,in this study the low CP content can be attributed to excessive breakdown of proteins to ammonia and amides thus resulting in poor silages made from poultry manure.

Addition of roots decreased the CP content which was significantly different between silages made from vines only and mix of vines and roots. Where cassava meal and molasses were used, this was due to low CP content in sweetpotato roots of about 0.95-2.4%, (Woolfe,1992), however Cassava meal and molasses too are sources of carbohydrates not proteins.

4.2.7 Effect of additives on pH of silage

The pH of silage made from unratooned vines harvested at 150 days was significantly different among the additives used. Poultry manure addition resulted in silage with higher pH value (5.32) which was significantly different from silages with maize meal (4.93), cassava meal (4.84) but not silage with molasses (5.13) and salt (5.20). The pH of silage made from un-ratooned vines and roots harvested at 150 days was significantly different among the additives used where silages with poultry manure was significantly different from silages with other additives. The pH values ranged from 4.91 (poultry manure) to 4.66 (maize meal) as shown on Table 17,the poultry manure value could have been due to low water soluble carbohydrates content that are essential in fermentation process. Silages with salt only and poutry manure were classified as bad since they fell within the range of bad/poor silage , whereas the ones with molasses were average and for maize meal and cassava meal were the best due to presence of adequate water soluble carbohydrates that enhance the fermentation process.

McDonald *et al.*,(1991) reported that Cassava root meal, sweet potato root meal and sugar cane molasses as sources of potentially available energy for growth of the lactic acid bacteria. Higher pH values indicate butyric fermentation which is an indicator of poorly fermented silage. This could be due to low water soluble carbohydrates leading to slow rate of fermentation. There was a significant difference among the pH values obtained from adding PM, Salt, MM and molasses in both vines and mixture of vines and roots silages except for CM as potrayed by T-test (Table 18).

An *et al.*, (2004) investigated the effects of adding cassava root meal, sweet potato meal, and sugarcane molasses as additives at rates of 0, 30, 60 and 90 gkg^{-1} (air-dry weight of additive) on leaves of fifteen varieties of sweet potatoes. He observed that in all experiments the pre-wilted sweet potato leaves were successfully preserved as silage. However, in the absence of additives, the fermentation processes was slow, resulting in high pH values during the first and second weeks of ensiling compared to treatments with additives. This was explained by the low level of water soluble carbohydrates (WSC) in sweet potato leaves. This is similar to what was observed in this study where we had salt added (control) had high pH values of 5.20 and 4.88 for silages with vines alone and mixture of vines and roots.

Ruiz (1981) using chicken manure as additive observed that the pH of the treatments with chicken manure were significantly higher than the ones without, and the ones with chicken manure had already attained the required level of 3.7 pH after only 14 days of fermentation. In terms of pH, the treatments with chicken manure were regarded as of better quality than fresh vines or fermented vines without chicken manure.This findings are in agreement with of our study because silages where poultry manure was added were significantly higher than the control(salt) and of better quality when we look at the % DM of which is higher. Dry matter (DM), crude protein (CP), ether extracts (EE), crude fiber (CF), and ash showed no significant difference over time (at 14, 30, 60, and 90 days of fermentation). DM, CP and ash contents of the treatments with chicken manure were all significantly higher than those without. Peters (2001) made silage using vines and additives like corn meal, cassava meal and sun dried chicken manure. The pH of chicken manure silage was significantly higher than of the silages without additives. The DM, CP, CF showed no significant differences over time. DM, CP and ash contents of treatments with chicken manure were all significantly higher than those of treatments without at 90 days. Poultry waste has been shown to have a high buffering capacity due to high NPN,ash contents and hydrolysis of uric acid to ammonia with ensiling thus requires high levels of lactic acid to bring the down compared to silages without poultry manure (Bolsen, 1999).

Lin *et al.*, (1988) also concluded that the general nutrient values (including metabolizable energy), fatty acid composition and amino acid contents (including the proportion of essential amino acids) in silages of mixtures of sweet potato roots and maize meal did not change during ensiling.

4.2.8 Effect of treatments on Ammonia-N

The Ammonia-N of silage made from unratooned vines harvested at 150 days was not significantly different among the additives used. The Ammonia-N values ranged from 2.51 (cassava meal) to 2.25 (maize meal and poultry manure). The Ammonia-N of silage made from unratooned vines and roots harvested at 150 days was not significantly different among the additives used. The Ammonia-N values ranged from 2.21 (salt) to 2.06 (molasses) as shown on Table 17.There was a significant difference among the Ammonia-N values obtained from adding CM and molasses in both vines and mixture of vines and roots silages except for PM, Salt and MM as potrayed by T-test (Table 18).

In this study a high ammonia-N content was expeted where poultry manure was used due to high levels of NPN but this was not the case since there was no significant difference among silages.Though the results were similar to what was observed by Hoang (2004) where the NH_3-N content in all treatments fluctuated around 2-3% of total nitrogen and was not affected by ensiling duration or ratio of root to vine.

High concentrations of ammonia (>12 % of CP) are a result of excessive protein breakdown in the silo caused by a slow drop in pH or clostridial action. In general, wetter silages have higher concentrations of ammonia. Extremely wet silages (< 30% DM) have even higher ammonia concentrations because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations. In this study the ammonia levels were low and within the acceptable range of <5%.Therefore poultry manure did not increase the ammonia N,since the silage had a high DM content of over 30%.

5.0 CONCLUSIONS

Variety Naspot-1 had the highest DM yield at 75 days harvest regime, whereas Kemb-23 had the highest DM yield at 150 days of continous growth harvest regime.Harvesting of vines at 75 days depressed the root production.

Vines from variety Musinyamu had the best nutrient quality with a CP content of, 16.67 and 11.69 at 75 days and 150 days of continous growth respectively, and the lowest NDF making it most suitablke for feeding non ruminants.

The best silage quality was one made from Gweri variety and of mixture of vines and roots by using maize meal as an additive.

The best silage quality was from vines made from 150 days of continous growth due to high DM, CP and low pH values.

6.0 RECOMMENDATION

Forage varieties such as Wagabolige, Gweri, Musinyamu and Kemb-23, should be planted for fodder production and excess preserved in form of silage to feed livestock during dry spells. Non marketable roots from 103001.152 can be mixed with vines during silage making.

Naspot-1 is a duwal purpose variety which may be grown to help solve the problem of feed competition between human and livestock since the vines and unmarketable roots can be fed to livestock while the marketable roots can be consumed by human.

Sweet potato vines and roots can be preserved in form of silage to give silages of high dry matter content increasing the dry matter intake by livestock and also high CP content for microbial protein synthesis. The silage provides high quality feed for livestock during the dry periods.

Additives such as cassava meal, maize meal and molasses can be used during silage making to improve the silage quality interms of dry matter and use of poultry manure to improve the crude protein content, thus a study on the econimic part of use of maize meal and cassava meal should be analysed since they are mainly used as food for human.

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