CONSERVATION OF NAPIER GRASS AS SILAGE BY SMALL HOLDER DAIRY FARMERS IN TANZANIA

BY

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ABSTRACT

A 2^3 factorial experiment was conducted to investigate the best method of conserving napier grass as silage under small scale dairy farmers situation. Four treatments (methods) were imposed on the forage before it was ensiled in either earth pits or concrete silos, namely; T1 - 5cm chopped grass with 3% molasses, T2 - 5cm chopped grass without molasses, T3 - unchopped grass with 3% molasses and T4 - unchopped grass without molasses. The silage was sampled after 3 months, and analyzed for percentage DM losses, chemical composition, fermentation and sensoric qualities. *In vitro* DM and OM digestibilities and DM degradability. The rate of silage intake in gDM/ minute was determined using six dairy heifers. Additionally, cost of producing the silage under each method were estimated in Tsh./kgDM of useful silage.

Both chopped and 3% molasses treated napier silage showed lower ($P < 0.01$ and $P < 0.05$, respectively) percentage DM losses as compared to unchopped and unmolassed silage. However, the DM losses did not differ significantly between the silo designs used. Chopped silage had more ($P < 0.001$ and $P < 0.01$) CP and WSC contents than unchopped silage. Also addition of 3% molasses significantly increased ($P < 0.01$ and $P < 0.001$) the CP and WSC composition of napier silage. The CP content however, was more reserved in napier silage produced in the earth pits than the concrete silos.

The preservative quality of napier silage was highly ($P< 0.001$) improved by chopping and/ or addition of 3% molasses at ensiling. Lower pH (3.99 vs 4.64), NH_3 - N (4.03 vs 6.37) and butyric acid concentration (2.6 vs 7.5 gkg^{-1} DM) and higher content of lactic

acid (37.3 vs 14.2 gkg^{-1} DM) and acetic acid (38.5 vs 21.8 gkg^{-1} DM) were observed in chopped than unchopped silage. Lower pH, NH_3 - N and butyric acid (4.21 vs 4.43, 4.09 vs 6.31% and 3.8 vs 6.4 gkg^{-1} DM, respectively) were also observed in molasses treated compared to untreated silage, while lactic and acetic acid concentrations were significantly higher (36.8 vs 14.7 gkg^{-1} DM and 40.3 vs 20.1 gkg^{-1} DM, respectively). Additionally the sensoric scores were significantly (P< 0.001) better for chopped and/ or molasses treated napier silage. The condition which was more observed on silage made in the earth pit silos.

Chopped silage had significantly higher (P < 0.001 and P < 0.01) *In vitro* DM and OM digestibility and *In sacco* DM degradability than unchopped silage. Also molassed silage showed significantly higher (P < 0.001) *In vitro* DM and OM digestibility. There was a significant (P< 0.01 and P< 0.001) improvement in rate of silage intake when the animals were fed on pre - chopped and/ or molasses treated napier silage, however minor differences were observed for the silage made in either type of the silo.

Economically, chopping and addition of molasses at ensiling produced napier silage at a least cost especially from the earth pit silos compared with other ensiling methods.

It is concluded that, pre - chopping and addition of at least 3% molasses to napier grass at ensiling produced good quality silage. Also the technique can be more economical and technically feasible in short terms when plastic sheet covered earth pit silos are used rather than the concrete silos which have higher initial construction costs.

DECLARATION

I, FLORENCE ELIZABETH HENRY MAEDA, do hereby declare to the Senate of Sokoine University of Agriculture that the work presented in this dissertation is my own and has not been submitted for higher degree in any other university.

Signature......FMaeda......

date...11/11/1996...

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES AND PLATES

Figures **page**

Plates

LIST OF APPENDICES

ABBREVIATIONS

ADF = Acid detergent fibre

ADL = Acid detergent lignin

AOAC = Associations of Official Agricultural Chemists

CF = Crude fibre

cm = Centimetre (s)

CP = Crude protein

cv = Cultivar

DM = Dry matter

DMD = Dry matter digestibility

DML = Dry matter loss

EE = Ether extract

FAO = Food and Agriculture Organization of the United Nations

FC = Fixed costs

FCM = Fat corrected milk

FYM = Farm yard manure

g = Gram (s)

g/min = Gram (s) per minute

GLM = General linear model

h = Hour (s)

ha = Hectare (s)

IVDMD = *In vitro* dry matter digestibility

IVOMD = *In vitro* organic matter digestibility

kg = Kilogram (s)

LSD = Least significance differences

LSM = Least square means

m = Metre (s)

m^3 = Cubic metre (s)

ME = Metabolizable energy

MJ = Mega joule (s)

ml = Millilitre (s)

mm = Millimetre (s)

n = Number of observations per treatment

NB - 21 = Napier bajra hybrid No.21

NDF = Neutral detergent fibre

NFE = Nitrogen free extractives

NH_3 - N = Ammonia - Nitrogen

NPK = Nitrogen, phosphorus and potassium fertilizer

NPN = Non Protein Nitrogen

NS = Non significant

OM = Organic matter

OMD = Organic matter digestibility

PDIFF = Probability of difference

SAS = Statistical Analysis System

SEM = Standard error of the means

SS1 = Sum of squares type 1

T1 - CM = Treatment 1. (5cm chopped, 3% molasses treated napier grass)

T2 - CW = Treatment 2. (5cm chopped napier grass without molasses treatment)

T3 - UM = Treatment 3. (unchopped napier grass treated with 3% molasses)

T4 - UW = Treatment 4. (unchopped napier grass without molasses treatment)

TC = Total costs

Tsh. = Tanzanian shilling (s)

VC = Variable costs

VFA = Volatile fatty acid

$W^{0.75}$ = Metabolic body weight

WSC = Water soluble carbohydrate

1. INTRODUCTION

Availability of feed resources is one of the main constraints towards livestock production in most tropical countries. In many places. there is inadequate and inconsistent supply of good quality pasture and fodder crops. This problem is more evident during the dry season which in most places has been recorded to last for about 6 to 7 months per year (Mbwile and Madata, 1984). During this period both the quality and quantity of tropical pastures decline sharply. Consequently, the amount of essential nutrients found in pastures might fail to meet both maintenance and production requirements of the animals and sometimes the amount of crude protein may decline below the critical 7% of total dry matter. This level is insufficient to supply even the maintenance protein requirement of farm animals (Crowder and Chheda, 1982); as a result the overall performance of the animals may be greatly reduced.

This situation seems to be more serious among the small holder dairy farmers, particularly those who practice zero grazing systems (Sarwatt and Njau, 1990; Kimambo *et al.*, 1990). Under this livestock rearing system most of the land is utilized for cultivation of food and cash crops leaving aside small areas usually not more than 1 hectare of land for pastures and fodder production. These small plots cannot produce sufficient and good quality pastures for feeding dairy animals especially during the dry seasons. During the rainy season, however there is a flush growth of both natural and established pastures such as *Panicum maximum, Setaria spp,* Guatemala (*Tripsacum laxum*) grass and napier (*Pennisetum purpureum)* grass (Mbwile and Madata, 1984;

Urio *et al.*, 1988). If left to grow and mature in the fields these forages tend to loose their nutritive value, thereby resulting into wastage of valuable feed resources. In order to avoid such losses and to maintain higher productivity of dairy animals even during the dry season, there is a need to develop the most efficient methods of conserving the surplus pastures available during the wet season. Silage making is one of the methods that could be used to achieve this objective.

Among the forages mentioned above, napier grass has been found to flourish extensively in many tropical humid and sub humid regions as well as in highland areas of East Africa. Napier grass is most commonly harvested and utilized as green fodder for feeding dairy animals under the cut and carry zero grazing system. During the rainy season, the productivity of napier grass may be very high even within the small established pasture plots of small holder farmers (Mtengeti *et al.*, 1989; Otieno *et al.*, 1990). Napier grass is also established between contours and along water courses as a means of controlling soil erosion and some grow wildly along river banks (Musangi, 1969; Crowder and Chheda, 1982). With application of nitrogenous fertilizer and other forage management practices, napier grass can offer sufficient and good quality feed material, and the excess material can possibly be conserved in the form of silage, thereby ensuring availability of good quality feed for feeding dairy animals through out the year.

Silage making and utilization has been practised for a long period by dairy farmers in temperate countries (Woodard *et al.*, 1992) and in a few tropical countries such as Cuba (Ojeda *et al.*, 1992). In sub saharan Africa, the technology of making grass silage is still new, and it has been reported to be practised by only few farmers in Nigeria.

Kenya and Malawi (Aken óva, 1975; Otieno *et al.*, 1990; Urio personal communication, 1994), where napier silage of good quality comparable with that of maize and sorghum has been produced and utilized.

In Tanzania, however the technique of conserving forages in form of silage appears to be confined only within the research stations and in few medium and large private and parastatal farms where maize and sorghum are mainly used. At Sokoine University of Agriculture, Sarwatt (1995) carried out conservation studies involving maize, sorghum and Rhodes grass. No studies have been carried out using napier grass, which appears to be the most abundant material utilised by small scale dairy farmers.

The main objective of this study was therefore to investigate the possibility of conserving napier grass as silage. The specific objectives of the study were:

(a) To study the effect of ensiling long or chopped forage material on the quality of napier silage produced.

(b) To study the effect of addition of molasses on quality of napier silage.

(c) To study the effect of two different types of silos (Concrete and earth pits) on the quality of napier silage.

(d) To compare the costs of ensiling napier grass under different ensiling techniques applied above.

LITERATURE REVIEW

2.1 Napier grass as a livestock feed

Napier (*Pennisetum purpureum)* grass is a widely grown perennial fodder flourishing within latitude limits between 10° North and 20° South, and at an altitude range of 0 - 2000m above sea level (Bogdan, 1977; Gŏhl, 1981; Skerman and Riveros, 1990). The temperature required for it's growth range between 15°C - 40°C with a minimum of 11.5°C ± 5.4°C during the coldest months of the year (Russel and Webb, 1976; Skerman and Riveros, 1990). The grass grow well in fertile moist soils and in areas receiving rainfall in excess of 1500mm /annum, with a mean value of 1483mm ± 620. However, it has a capability to tolerate considerable periods of droughts. Therefore, ensuring it's availability throughout the year (Stephens, 1967; Russel and Webb, 1976: Skerman and Riveros, 1990).

In Africa, napier grass originated in Zimbabwe, then spread to other countries such as Nigeria, Malawi, Uganda, Kenya and Tanzania (Aken óva, 1975; Savory and Thomas, 1977; Mugerwa and Ogwang, 1979; Mathuva *et al.*, 1985; Mtengeti *et al.*, 1989; Skerman and Riveros, 1990). The fodder grows in a wide range of varieties, from local to improved cultivars such as bana (*P.purpureum* * *P. typhoides*) grass. It's moisture content, nutrients composition and feeding value vary greatly depending on cultivar adaptation in a certain location, variety, frequency of cut. harvesting stage and intensity of management. But when utilized either as green fodder or as a silage it's ability to improve milk production has been realized where the animals are supplemented with a minimum levels of proteins and energy concentrates (Ojala *et al.*, 1988; Muinga *et al.*, 1995).

2.2 Potential of napier grass for silage making

The potential of any forage material for ensilage is determined by it's dry matter yield and nutrients composition at harvest (Raymond *et al.*, 1982; Crowder and Chheda, 1982; Wilkinson, 1983a). Napier grass has been found to fulfil some of these qualities when harvested at the correct stage of growth and when produced under intensive forage management systems.

2.2.1 Dry matter yield of napier grass

Studies made from various places revealed significant high variation in productivity of different cultivars and hybrids of napier grass ranging between 6.3 to 56.9 Tons DM/ha/year (Aken óva, 1975; Mugerwa and Ogwang, 1979; Mathuva *et al.*, 1985; Mtengeti *et al.*, 1989). An average yields of about 31.6Tons DM/ha/year is still a good indication of high productivity level of napier grass to provide large quantities of silage. A study made by Liumba (1989) revealed production of about 6.04Tons DM/ ha for the first cut of napier grass from an established plot applied farm yard manure at a rate of 12 Tons/ ha. Further increase in dry matter yield of napier grass may be observed when a combination of NPK fertilizer is applied to the sward. According to findings of Munegowda *et al.* (1987) application of a combination of 120-180 kg N, 80-120 kg $P_2 0_5$ and 40-80 kg K_2O/ ha to hybrid napier (*P. purpureum* * *P. americanum* cv. NB-21) in 1979-1981 gave total fresh fodder yields of 224.2 - 237.2 Tons/ ha in 10 cuts compared with 162.98 Tons/ ha without application of NPK. Similar trend was reported by Skåra (1994).

Dry matter yields of napier has also been found to increase with advanced stage of growth. Mtengeti *et al.* (1989), reported significantly ($P< 0.01$) higher dry matter yields ranging between 29 - 57 Tons DM/ha from grass harvested after 8 - 10 weeks compared with yields of 8 - 17 TonsDM/ha obtained from forage harvested between 4 - 6 weeks of growth.

2.2.2 Chemical composition of napier grass

The most important nutrient components which determine the suitability of forage material for ensilage, hence overall quality of the silage product include the dry matter, crude protein and water soluble carbohydrates (Raymond *et al.*, 1982; Wilkinson, 1983a). The performance of dairy cows has been explained to depend largely on energy and protein value of a feed (McDonald *et al.*, 1988). Therefore, fresh herbage containing higher concentrations of energy and proteins are more preferred for ensilage, because these are subjected to a lesser degree of nutrients loss during ensilage (McDonald, 1973).

Experimental results obtained by various workers on chemical composition of different varieties of napier grass has proved it's potentiality for silage making. Several researchers have reported dry matter and crude protein contents ranging between 16 - 25% and 7 - 13.5%, respectively from different cultivars of napier grass harvested between 8 - 10 weeks intervals from Tanzania, Kenya, Uganda, and Zimbabwe (Mugerwa and Ogwang, 1979; Göhl, 1981; Boddorf and Ocumpaugh, 1986; Otieno *et al.*, 1990; Skerman and Riveros, 1990; Mwakajumba, 1991; Tisian, 1994). Mtengeti *et al.* (1989) reported dry matter yields of about 17.4 and 56.9 Tons /ha and crude protein contents of about 16.82% and 12.85% from napier grass harvested at 6 and 10 weeks of growth respectively, on a field applied fertilizer at a rate of about 200 kgN/ha. According to the author, the protein value of napier when cut at a younger age was considerable high in comparison with the total amount of dry matter harvested.

Ojala *et al.* (1988), was able to produce napier silage with an average percentage dry matter, crude protein and crude fibre of 24.5, 6.6 and 33.5, respectively, from fresh napier sprayed with 5% molasses with 21.5, 8.9 and 27.7 average percentages of dry matter, crude protein and crude fibre cut between 10 - 12 weeks, respectively. To conclude, inspite of napier grass harvested from various places to possess lower dry matter content (less than optimum 25 - 35%), still the fodder promise production of large quantity of silage with sufficient level of protein and energy when a well managed stand is harvested between 8 - 12 weeks of growth. Provided an additive such as molasses is used which raise the total DM and increase the amount of water soluble carbohydrates. This is obvious from observations made by Andrade and Gomide (1971) that, *Pennisetum purpureum* contain relatively low levels of WSC (< 3%) when freshly cut at an age below 12 weeks.

With more frequencies of cut however, amounts of WSC in napier grass might increase to as high as 8.37%, giving napier silage a pH ranging between 3.8 and 4.3 as observed from the results of an experiment conducted at the University of Florida (Woodard *et al.*, 1992). Also as cited from Bogdan (1977) bana grass have about 25% and 12% more proteins and soluble sugars, respectively than other varieties of napier, therefore this variety might increase suitability of napier grass for silage making. Hence napier grass can substitute ensilage of maize and sorghum as these are mainly grown for production of grains for human consumption and formulation of concentrates for monogastric animals .

2.3 Basic Principles of silage making

Production of good quality silage needs a thorough knowledge on the basic principles of silage making. These principles should be followed step by step, starting with management of the forage pre ensiling up to utilization of the silage product. These principles are always the same irrespective of the type of forage used; although methods of their application and facilities to be used might differ depending on the amount of silage to be produced, type of forage and financial position of the farmer.

Proper management of the forage pre ensiling determines the quality and quantity of silage to be produced (McCullough, 1983). The forage stand managed well during establishment in the field is expected to give good quality silage so long as other steps will be followed properly. Skåra (1994) reported higher crude protein in rye grass silage (217 vs 96 g kg^{-1} DM) from herbage applied with 300kg N/ha than unfertilized stand.

Harvesting at optimum stage should be done so as to maintain the quality of silage. Since the quality of forage do decline with age above maturity, it is recommended that forage for silage making should be harvested at their vegetative stage and not later than the early blooming stage which vary depending on the type of forage specie (Göhl. 1981). Researches done by several workers in the tropics recommended cutting of napier grass at about 1 - 1.2m high as optimum for production of good quality silage (Bogdan, 1977; Göhl, 1981; Otieno *et al.*, 1990; Skerman and Riveros, 1990). Good harvesting operations should also be established to avoid contaminating the forage with soil and residues which can spoil the quality of silage.

Harvesting should be followed by establishment of proper conditions for ensiling which aims at maintaining purely anaerobic condition inside the silo and enhances production of sufficient acidity which secures low pH to stabilize the silage (Ekern and Vik-Mo, 1979; Urio *et al.*, 1988; McDonald *et al.*, 1988). This can be facilitated by careful preparation of the silo, chopping and sometimes wilting of forage and addition of preservatives depending on nature of the forage to be ensiled. Chopping of forage facilitate better compaction of ensiled material thereby restricting carbohydrates losses and rise in temperature due to aerobic respiration (McCullough, 1976). Wilting of high moisture forage to a DM between 25 -35% have been recommended by different authors as appropriate range for production of good quality lactate silage (Dixon, 1982; McCullough, 1983). Further addition of a reasonable amount of silage preservatives might assist to improve silage fermentation, detailed information on influences of some of these are reviewed under sections 2.7.

Creation of anaerobic condition inside the silo is very necessary, this inhibits the wasteful activities of aerobic fungi and bacteria as well as the oxidative enzymes present in fresh herbage (McDonald *et al.*, 1988; Skerman and Riveros, 1990). Instead anaerobic condition favours multiplication of anaerobes and facultative anaerobes including yeasts which according to McDonald *et al.* (1966), their active multiplication period lasts between 2 to 3 days only, within a temperature range of 20 - 40°C followed by a period of declining count. Apart from chopping and selection of a good silo design, protection of the silo from entrance of water and air will ensure maintenance of anaerobic condition. This is achieved by rapid filling, even distribution of the forage material, efficient compaction and proper sealing through provision of mechanical support mainly soil, heavy stones and /or unuseful tyres (McCullough.

1976; Urio *et al.*, 1988).

2.4 The silage fermentation process

"Silage" is a conserved ruminants diet obtained as a by - product of controlled fermentation of fresh forage materials inside the silo (McDonald *et al.*, 1988; Skerman and Riveros, 1990). As quoted by Crowder and Chheda (1982), the fermentation process is initiated by plants enzymatic activities together with the presence of yeasts, mould and aerobic bacteria. These breakdown structural carbohydrates and sugars into short chain organic acids, heat and Co_2. When all oxygen is used up within a period of 1 to 4 hours (Skerman and Riveros, 1990), aerobic microbes rapidly die, and anaerobic condition develop. This together with heat and available soluble sugars activate rapid multiplication of anaerobic bacteria and increase the acidity causing cessation of growth of mould and yeasts and further stimulation of production of short chain organic acids (McDonald *et al.*, 1973). The fermentation process is also accompanied with degradation of substantial amount of plant proteins into non protein nitrogenous compounds by proteolytic enzymes and microbes (Bergen *et al.*, 1974).

Therefore the pattern of silage fermentation is influenced by several interrelated factors, such as the dry matter content, water soluble carbohydrates, proteins and buffering capacity of the ensiled material (Weissbach *et al.*, 1974; Bergen *et al.*, 1974; Wilkinson *et al.*, 1982; Wilson and Bridgestocke, 1981; Lu, 1990), together with the presence of anaerobic condition which create specific microbial environment for silage fermentation inside the silo.

2.4.1 Roles of micro organisms on silage fermentation

Since silage is obtained as a by - product of natural lactic acid fermentation brought about by activities of several species of anaerobic microbes, it is very important to understand clearly the various roles played by micro organisms in the process of silage fermentation. The source of micro organisms involved in the process of silage fermentation comes from the fresh herbage. According to Moon and Henk (1980) their total number vary between 10^6 to 10^9 g^{-1} DM. These include aerobic bacteria and some few anaerobic bacteria, mainly *Enterobacteriaceae, Bacillus* species and *Clostridial* spores; and lactic acid bacteria such as *Lactobacillus, Pediococcus, Streptococcus* and *Leuconostoc* species, which are facultative anaerobes (McDonald *et al.*, 1988).

When the silo is completely sealed and anaerobic condition persist, growth and activities of aerobic microbes cease as these are replaced by the microbes capable of growing under anaerobic condition. Lactic acid producing bacteria have been reported to be the most important anaerobes responsible for good preservation of silage (Cai *et al.*, 1990). However, at the beginning they are usually found in small number than their competitors, fungi and enterobacteria. At ensiling, lactic acid bacteria multiply rapidly, and within few days, they become completely dominant especially if the forage has adequate level of soluble sugars and in addition if it's either lacerated or chopped (Gibson *et al.*, 1961; McDonald *et al.*, 1988). Wieringa (1966) suggested that an average of about 6% soluble sugars in forage is enough for successful lactate fermentation.

As anaerobic condition persists and temperature maintained below 40°C lactic acid bacteria continue to multiply, fermenting WSC in forage into organic acids, mainly lactic acid and small amounts of acetic, propionic, formic and succinic acids (Skerman and Riveros, 1990). Consequently, osmotic pressure increases as the pH declines such that at certain critical range of pH 3.5 to 4.2, microbial activities cease and silage become stable inhibiting further breakdown of carbohydrates and proteins as long as anaerobiosis is maintained (Crowder and Chheda, 1982). There is considerable variation in the actual species of lactic acid bacteria dominating a particular silage fermentation. However some workers have identified several genera of lactic acid bacteria at certain stages during fermentation, with *Lactobacillus plantarum* being the most dominant specie (Moon *et al.*, 1981; Lindgren *et al.*, 1983; Tjandraatmadja *et al.*, 1990).

If anaerobic condition is not achieved inside the silo, then the undesirable micro organisms mainly Clostridia, Enterobacteria and yeasts will proliferate (McDonald *et al.*, 1988). These may cause secondary fermentation of lactic acid to butyric acid, proteolysis of amino acids to ammonia-N and amine as well as mould growth (McDonald *et al.*, 1988).

2.4.2 Roles of forage dry matter content in silage fermentation

The activities of microbes during fermentation are highly affected by the moisture content of materials ensiled. Forages with low contents of dry matter (high moisture) were found to have lower contents of WSC (Raymond *et al.*, 1982). Consequently these were reported to be susceptible to secondary fermentation (Flynn, 1981; Wilkinson, 1983a; Lu, 1990) and high nutrients losses in effluent (McCullough, 1983; Lu, 1990). On the other hand, it is not easy to compact forage with high DM content sufficiently. As a result, such forages are subjected to heat damage, ending up into production of mouldy silage of low digestibility (Yu and Thomas, 1976). Therefore, researchers have suggested the range of 25 - 35% DM to be optimum for ensilage of tropical forages (Dixon, 1982; McCullough, 1983).

Silage with higher pH (4.6) was reported by Ojala *et al.* (1988) from napier grass ensiled at 21.5% DM. Lu (1990) recorded slightly lower pH values, 4.45 and 4.21 from pangola (*Digitaria decumbens*) grass ensiled at 22% and 38% DM, respectively. Therefore field wilting was observed to improve the dry matter content of high moistured crops thereby reducing nutrients losses and improving the fermentation quality of silage. However, under tropical environments field wilting is difficult because of high humidity and abrupt changes in temperatures and rainfall (Crowder and Chheda, 1982). In addition, inefficiency in compaction of wilted tropical forages, might lead into production of heat damaged moulded silage.

2.4.3 Contribution of carbohydrates present in forages during silage fermentation

Carbohydrates occupy greater part of the total dry matter contained in forages. These are mainly classified as structural and non structural carbohydrates. As stated by Bailey (1973), the main components of structural carbohydrates found in plants include hemicellulose, pectin and cellulose, whereas the water soluble carbohydrates form the main component of non structural carbohydrates. Among the carbohydrates components of plants, however hemicellulose and water soluble carbohydrates constitute the main substrate for lactic acid bacteria during silage fermentation (McDonald *et al.*, 1960; Soares *et al.*, 1980; Wilkinson *et al.*, 1982). This was clarified by McDonald *et al.* (1960) in Table 2.1 which summarizes some changes occurring on the forage carbohydrates components during silage fermentation.

Hemicellulose which occurs mostly in the lignified walls of forages was observed to assist the process of silage fermentation (McDonald *et al.*, 1960). This process is facilitated by the release of sugar molecules mainly xylose, arabinose. glucose, galactose and mannose found within the complex structure of hemicellulose. These sugars are fermented after being hydrolysed either by plant enzymes or by addition of acids to the crop at the time of ensiling (Van Soest, 1982).

Table 2.1 Changes in some carbohydrates components of forages during fermentation

Carbohydrate component	Grass %DM	Silage %DM
Sugar	9.5	1.5 - 2.0
Fructosan	5.6	0.2 - 0.3
Hemicellulose	15.9	7.8 - 13.7
Cellulose	24.9	26.6 - 27.1

Source: McDonald *et al.*(1960)

Water soluble carbohydrates play significant role in silage fermentation as they are usually fermented into short chain organic acids by action of lactic acid bacteria present in ensiled forage (Tjandraatmadja *et al.*, 1990). However, their concentration in plants vary depending on several factors such as plant specie, variety, climate, weather conditions prior to harvest and soil fertility (Smith, 1973).

Main water soluble carbohydrates occurring in temperate grasses include glucose, fructose, sucrose and fructans (Smith, 1973). Glucose and fructose form the most important monosaccharide occurring as free sugars at a concentration ranging between 10 - 30 g kg^{-1} DM (Smith, 1973). The disaccharide, sucrose was reported to occur in larger amounts, ranging between 20 to 80 g kg^{-1} DM. Whereby, fructans form the most abundant of the water soluble carbohydrate, being present at a concentration of about 50 to 90 g kg^{-1} DM (Smith, 1973; Van Soest, 1982).

On the other hand, tropical pastures have been reported to have lower contents of WSC's when compared with temperate species (Noble and Lowe, 1974; Van Soest, 1982). Catchpoole and Henzell (1971) and Tosi *et al.* (1975) reported WSC content in tropical forages varying from 2.5 to 9.9 percent of the dry matter. Reasons creating such a variation were explained to be either caused by high ambient temperatures at which tropical forages are grown or the C4 configuration of the carbohydrates present in tropical species which allow plants to accumulate more cellwalls than soluble carbohydrates. Further, grasses of tropical and sub tropical origin, have been reported to accumulate polysaccharides inform of starches, rather than fructans in their vegetative parts (Smith, 1973). According to Van Soest (1982), starches unlike fructans, are partially soluble in hot water. Therefore, starches present in tropical grasses are not readily available for fermentation by lactic acid bacteria, because it's solubility depend largely on the temperature created inside the silo and the presence of weak acids to assist breakdown of hydrogen bonding (Van Soest, 1982).

Very low concentration of water soluble carbohydrates, below 2% were observed in unwilted fresh crops and in early harvested tropical forages with high moisture content

(Andrade and Gomide, 1971; Wilkinson, 1983a). These increase chances of secondary fermentation of lactic acid to butyric acid leading into production of high pH silage with high concentration of butyric acid and free NH_3 - N (McDonald *et al.*, 1988). Several researchers suggested that, a minimum of 3% water soluble carbohydrates content in tropical as well as temperate forages was enough for fermentation to a stable, low pH, low ammonia, lactic acid dominant silage (Tosi, 1973; Hamilton *et al.*, 1978; Soares *et al.*, 1980; Wilkinson *et al.*, 1982). This was proved by results of Tosi (1973) working on napier grass whereby the forage with DM and WSC contents of 29.1 and 3.67% respectively, was able to ferment into silage with a pH of 3.7, and 5.0, 2.0, 0.0 and 8.6% of lactic, acetic and butyric acids and ammonia - N respectively.

2.4.4 Roles of nitrogenous constituents in silage fermentation

Nitrogenous components in forages are divided into proteins and non protein nitrogenous compounds. According to McDonald *et al.* (1988), proteins constitute about 75 - 90% of the total nitrogen leaving aside about 10 - 25% as non protein nitrogen.

Immediately after harvesting, plant protease (enzymes) hydrolyses proteins to amino acids, and within 12 to 24 hours, about 20 to 25 percent of the total N in protein is converted into non protein nitrogenous compounds (McDonald *et al.*, 1988). These include amino acids, amides, glutamine, asparagine, peptide, amine, ureide, nucleotide, chlorophyll and nitrates. Plant protease activity has been reported to continue at an optimal pH range between 4 and 8 (McKersie, 1983), and at high moisture content (Muck, 1987). Enzymatic degradation of proteins may continue even after ensilage in high moisture forages until acidity increases. In uncontrolled fermentation of high moisture crops, a reduction of true protein content as high as 50 - 60% might occur (McDonald, 1976; Searle *et al.*, 1986; Fairbairn *et al.*, 1988).

In the silo containing young forages with high moisture and low concentration of soluble carbohydrates, achievement of high acidity capable of inhibiting activities of undesirable proteolytic bacteria seems to be very difficult. Under such conditions McDonald *et al.* (1991) reported a slight decline in pH from 6.1 in original crop to 5.3 on reaching the 3rd day of storage. There after the pH continued to rise until it reaches 7.3 after 147 days in store, and about 560g kg^{-1} of total N was found to be in form of ammonia by 57th day of storage, indicating extensive degradation of amino acids and direct relationship between pH and ammonia - N production. However, in properly ensiled N fertilized young herbage containing nitrates between 1 to 2 percent clostridial fermentation could be inhibited by reduction of nitrate to nitrite (Skerman and Riveros, 1990).

As reviewed by Wilkinson (1983a) the extent of protein degradation in tropical silage is higher than those originating from temperate pastures. This might be caused by heat damaging effects, created by prevailing high ambient temperature coupled with the production of respiration heat in the initial period of ensiling. Since no study has been done to investigate the extent of proteolysis in tropical silage, this argument can be supported by the recorded higher values of *in vivo* N digestibility from fresh napier and setaria grasses of 43 and 57 percent, respectively, compared with their corresponding value for both silages which was only 23 percent (Hamilton *et al.*, 1978; Vilela, 1981). Therefore, the extent of proteolysis in silage vary depending on the rate and extent of pH changes, moisture content of ensiled material, microbes and prevailing temperature.

2.5 Silage quality

Quality of silage made from tropical pastures is poorer in comparison with those obtained from the temperate species. This being due to a combination of forage properties influenced by the soil and high temperature conditions prevailing in the tropics which induce rapid physical maturation of the plant tissues. As a result, tropical pastures were reported to be coarse and stemmy, high in crude fibre and low in proteins and water soluble carbohydrates (Catchpoole and Henzell, 1971; Holm, 1974).

Several techniques have been employed to evaluate the quality of silage. These include assessment of physical properties in terms of appearance, smell and texture, biochemical analysis of the fermentation products and determination of its nutritive value.

2.5.1 Physical examination of silage quality

Physical assessment of sensoric parameters of silage in terms of appearance, smell and texture is very important. As reported by McCullough (1976) these parameters assist to identify the extent through which heat has been produced inside the silo and finally determine whether the preservation method has been successful or not. Basing on silage temperature, appearance, smell, texture and taste, McCullough (1976) identified three distinct types of silage. Good silage was described as the one which maintained temperature between 26.7 - 37.8°C, this silage had a light green to yellow colour, with a pleasant aroma like vinegar, firm tissues and sharp acid taste. Poor silage was the one which maintained temperature below 26.7°C, with a dirty greenish colour, strong odour, slimy tissues, insipid taste and with a pH of 5 and above. On the other hand, an over heated silage was described as the one with high temperature above 40°C and maintained a brown to blackish colour.

Otieno *et al.* (1990) classified silage basing on appearance and smell. Zimmer (1959) went further by arbitrary categorizing a variety of silages on the basis of smell, texture and colour and graded them as very good, good to satisfactory, medium to hard and spoiled.

2.5.2 Classification of silage in terms of the fermentation products

Several measures have been used and accepted to classify silage according to its fermentation qualities. These include the pH values (Virtanen, 1952), concentration of VFA's (Flieg, 1938) and concentration of ammonia - N (Nilson *et al.*, 1956). These fermentation criteria are normally combined together in making judgement on the quality of silage under study (Breirem and Saue, 1973). These parameters might also give a clear indication of the overall nutrients utilization by animals (Ekern *et al.*, 1975).

2.5.2.1 pH value

pH of the silage has been widely used as an easy measure of the success of the ensiling process. It's use however, was observed to offer little assistance in evaluating the silage quality if the preservation is not due to lactic acid fermentation (McLean, 1941; Catchpoole and Henzell, 1971; McCullough, 1976). This is caused by lack of perfect information on the correlation between the pH content and the specific acid constituent present in the silage (McCullough, 1976). In general however, as the pH decreases, it reflects an increase in lactic acid, total acidity and amino acids while denoting a decrease in volatile acids content (McCullough, 1976). Djikstra (1957) suggested a pH not exceeding 4.2 to be optimum for well preserved high moisture grass silage and less than 5.0 for high dry matter grass silage. This variation in pH has been caused by differences in the buffering capacity between high moisture and high dry matter containing ensiled material.

2.5.2.2 Fermentation acids

Flieg (1938) developed an index based on the proportion of lactic, acetic and butyric acids (expressed in milliequivalents). According to author, the higher the proportion of lactic and acetic acids to butyric acid the higher the scores and the better is the quality of silage. Later on this index was modified by Zimmer (1966) who, recorded the concentrations of the acids basing on percent proportion of the acids and categorized the silage as very bad (0 - 20), bad (21 - 40), medium (41 - 60), good (61 - 80) and very good (81-100).

2.5.2.3. Concentration of ammonia Nitrogen

The concentration of ammonia - N (as percent of total N) in silage has been used for a long time as a criterion of assessing silage quality. Ammonia - N level indicates the extent by which protein is degraded or lost during fermentation. Nilson *et al.* (1956) reported a threshold level of 8.0 percent ammonia N (as a percent of total N) as a measure of well preserved silage.

However for accurate assessment of silage quality, all the above fermentative properties (pH values, ammonia - N and concentration of lactic acetic and butyric acids) should be used and studied together since no single criterion appears to be satisfactory by itself (Langston *et al.*, 1958). Catchpoole and Henzell (1971), summarized observations made by several workers on fermentation products of tropical silage, and came out with the following standards as indication of good quality unwilted tropical silage:

pH value	≤ 4.2
Lactic acid	3 - 13%
Butyric acid	< 0.2%
NH_3 - N (as % of total N)	< 11%

Apart from setting the above standards, Breirem and Saue (1973) made an arbitrary classification of the silage quality basing on some important fermentation products as seen in Table 2.2.

Table 2.2 Silage quality based on some important fermentation products

silage quality	Butyric acid concentration %	NH_3 - N as % of total N
Good	max 0.1	max 8
Acceptable	0.1 - 0.3	8.1 - 12
Poor	0.3 - 0.6	12.1 - 18
Not acceptable	above 0.6	above 18

Source: Breirem and Saue (1973)

2.6 Nutritive value of silage

Nutritive value of silage as in all other ruminants diets is reflected by its chemical composition, palatability and feeding value to the animals (McDonald *et al.*, 1988). These are influenced by type of forage specie used, nature of the crop at the time of harvesting and the changes which might occur as a result of the activities of plant and microbial enzymes during harvesting and storage.

2.6.1 Chemical composition of silage

In a well preserved silage, the amount of nutrients retained may be almost similar as those found in the fresh herbage from which the silage was made (Woolford, 1984). However, results of several experiments have revealed great variations in chemical composition of silage, particularly for the energy and protein fractions (Catchpoole and Henzell, 1971; McDolnald, 1973; Holm, 1974; Waldo *et al.*, 1975; Woolford, 1984). Reasons for this were explained to be due to breakdown of soluble carbohydrates in the ensiled forage material followed by a simultaneous increase in concentration of organic acids and structural carbohydrates together with transformation of nitrogenous components.

Therefore, the most important chemical composition parameters which can be used to assess nutritive value of silage include it's dry matter, crude protein, water soluble carbohydrate contents and the structural carbohydrates found in the fibrous fractions of silage.

2.6.1.1 Dry matter content of silage

Dry matter content of silage provides clear indication of the total amount of nutrients retained that can be utilized by the animals. It also combines the volatile acids resulting from the fermentation process. Hence determination of dry matter content of silage through oven drying methods has been discouraged, as these may cause significantly higher losses of volatile substances as well as chemical changes which might lead into under estimation of the dry matter content and misinterpretation of both *in vivo* and *in vitro* parameters (Brahmakshatriya and Donker, 1971; Danley and Vetter, 1971; Larsen and Jones, 1975). More reliable data on dry matter, chemical composition and digestibility of silage can be obtained using results from either toluene distillation or freeze dried samples (Larsen and Jones, 1975). In places where such facilities are not available prolonged air drying, as applied by Otieno *et al.* (1990) can save the purpose so long as the drying place receives maximum air circulation and samples are protected from impacts of rain and dust. The amount of DM in forage ensiled together with the extent of nutrients lost in effluent and biochemical changes taking place during fermentation determine the overall dry matter retained in silage. Forages low in DM contents were observed to be highly prone to clostridial fermentation and increased effluent losses ending up with production of low DM containing silages (McCullough, 1983; Woolford, 1984). To obtain silages with slight higher DM from high moisture forages, a short period of wilting or addition of silage preservatives is a prerequisite (Machado and Muhlbach, 1986). Vilela and Wilkinson (1987) reported the silage DM contents of 22.8, 36.9, 46.8, and 71.5% from unwilted, 6, 30 and 54 hours wilted *Pennisetum purpureum schum*, respectively. According to them, higher DM content in pre wilted silage is attributed to increased concentration of water soluble carbohydrates and minimum degradation of proteins to ammonia nitrogen during fermentation. However, too high DM contents in herbage might cause poor compaction of the ensiled mass, hence increasing the probability of producing mould silage with low contents of digestible nutrients (Watson and Nash. 1960; Wojahn, 1977). In Kenya, Otieno *et al.* (1990) reported higher dry matter content in molasses treated bana silage (19.8 vs 16.9%)) compared with untreated silage from ensiling fresh forage with 15.9% dry matter. From their findings the lower dry matter content in untreated bana silage was mainly attributed by low DM content of ensiled material which increased chances of clostridial fermentation.

2.6.1.2 Crude protein content of silage

The protein content of silage like that of other forages, is estimated by multiplying Kjeldahl total nitrogen by 6.25 (AOAC, 1980). This does not give the real estimate of true protein content in silage since determination of total N also includes other non protein nitrogenous compounds. Since rumen microorganisms are able to assimilate any simple nitrogenous compounds, it's use as an indicator of protein value of silage in ruminants nutrition is still valuable.

The amount of protein contained in silage vary depending on the protein content of the ensiled forage, which vary with maturity and amount of N in the soil. Randhawa and Gill (1992) reported a decrease in crude protein content of hybrid napier (*P. purpureum X P. americanum)* silage from 10.9 to 7.12% when the 3rd year regrowth were cut at 75 and 125 cm height, respectively. Secondly, the extent at which protein is degraded during fermentation plays great role in determination of the amount of protein recovered in the silage product. The true protein N content may fall from about 800 to 600 g kg^{-1} N within the first 24 hours of fermentation, by the end of fermentation the total amount of true protein in silage might decrease to about 300 g kg^{-1} N and below (Bergen *et al.*, 1974; Kuhbauch and Kleeberger, 1975; Ohshma *et al.*, 1979). The above changes in protein fraction due to ensiling has been proved by observations made on protein contents on a variety of temperate and tropical forages and silage. Otieno *et al.* (1990) reported a slight difference in crude protein contents varying from 12.5, 10.38 and 11.94% in bana grass, bana silage without additive and bana silage with 5% molasses, respectively. Messman *et al.* (1994) recorded the crude protein content of 23.1% from fresh rye grass containing NPN compounds amounting 8.7% of crude protein, while it's respective silage had 25.3% crude protein out of which 63.1% constitute the NPN compounds, leaving aside little proportion as true proteins.

Overheating during fermentation has been reported to damage and lower the protein content of the silage product (Wilkinson, 1983a; Fechner, 1990; Tjandraatmadja *et al.*, 1991). This occur as a result of maximum protein degradation and maillard reactions which bound the amino acids into insoluble complexes (Fechner, 1990). Sarwatt *et al.* (1989) observed a sharp decline in crude protein content on guinea grass silage averaging 1.9% units due to overheating compared with only 0.2 % units observed in a well fermented maize silage.

2.6.1.3 Carbohydrates content of silage

Several workers have reported significant reduction in concentration of WSC in both tropical and temperate forages as a result of ensilage (McDonald *et al.*, 1960; Sarwatt *et al.*, 1992). In temperate grasses, soluble sugars were observed to decline from about

9.5% of DM to a range of 1.5 - 2.0% of DM in their respective silage (McDonald *et al.* 1960). Sarwatt *et al.* (1992) working on tropical silage reported lower contents of WSC averaging 28.5, 29.3 and 16.7g kg^{-1} DM from maize, sorghum and rhodes grass silage, respectively compared with 103.3, 95.1 and 18.6g kg^{-1} DM from their respective forages.

Cell wall constituents as categorized by Van Soest (1982) into NDF, ADF and ADL have sometimes been used to express fermentation of structural carbohydrates. Observations made by Sarwatt *et al.* (1992), indicated higher concentration of NDF, ADF and ADL averaging 653.2, 382.4 and 84.7 g kg^{-1} DM in rhodes grass silage, respectively compared with 647.9, 355.5 and 76.6 g kg^{-1} DM, respectively found in it's corresponding ensiled grass. Similar trend was obtained by Singh and Pandit (1978) while working on sorghum ensiled with urea and molasses. The increases are likely to be created by losses of cell contents in gaseous form or effluent leaving aside higher content of cell wall which occupy the largest part of the total silage dry matter.

However in some cases, the NDF fraction which is mostly occupied by hemicelluloses may be lower in silage than in the original ensiled forage. This is supported by results obtained by Sarwatt *et al.* (1992) indicating average NDF contents of 647.9 and 631.6 g kg^{-1} DM in maize crop and molasses added maize silage, respectively. Reasons for this was explained to be created by increased hydrolysis of the linked sugar molecules in the cell wall of forages, resulting from increased acidity caused by addition of molasses (Van Soest, 1982).

2.6.2 Digestibility of silage

Chemical composition data can only give the quantitative estimation of the various nutrients supplied by the forage. But its actual nutritive value to the animals can only be arrived through determination of its biological value when fed to the animal through digestibility and intake studies.

Ruminants are advantageous over non ruminants due to their high ability to extract various nutrients from fibrous forages which first, undergo microbial degradation in the rumen followed by it's digestion and absorption in the small intestines. Results of experiments done by several workers on digestibility of well fermented silages by ruminants revealed small variations from that of their respective forages prior to ensiling (Wilkins, 1974; McDonald and Edwards, 1976; Flynn, 1981; McDonald *et al.*, 1991). McDonald and Edwards (1976) working with sheep observed non significant difference in digestibility between 36 different temperate grasses and silage which were reported to give an average *in vivo* DM digestibility of 0.768 and 0.767 g kg^{-1} DM, respectively. In contrast, Sarwatt *et al.* (1992) working on tropical fodders reported slightly higher *in vitro* DM digestibilities in fresh forages ranging between 59.7 - 70.4% compared with 56.4 to 64.1% in their respective silage.

In some instances, ensiling of tropical pastures has been observed to cause a considerable reduction in digestibility of forages. As reported by Holder and McBarror (1964) whereby ensiling of *Pennisetum clandestinum* reduced forage *in vivo* DMD of dairy cows from 64% to 46%. The above reductions are apparently larger than would be expected with the temperate silages, which according to Flynn (1981), their *in vivo* DM digestibility by cattle ranged between 70 - 75 percent. This is caused by characteristic nature of tropical forages which are higher in crude fibres and lower in proteins and minerals contents compared to temperate species (Crowder and Chheda. 1982).

Bad preservation was also reported to reduce the digestibility of grass silage. as a consequence of high concentrations of butyric acid and ammonia nitrogen in the resulting silage (Givens *et al.*, 1993). According to the authors, *in vivo* digestibility of the badly preserved lolium perenne silage (with butyric acid and ammonia - N averaging 35g kg^{-1} DM and 36.4% of total N, respectively) was found to be lower. averaging 64.5% of DM compared with the expected temperate standards of 70 - 75% of DM.

Therefore among other factors, digestibility of silage vary depending on the growing environments and climatic conditions existing at the time of harvesting, the fibre fractions of forage as influenced by herbage maturity during harvesting and the fermentation quality of silage product.

2.6.3 Degradability of silage

Degradability studies are very important in evaluation of nutritive value of ruminants diets. These assist in the determination of the potential extent and rate through which various nutrients can be digested by the rumen microbes before passing into the hind gut (Ørskov, and Ryle, 1990). They also provide good estimates of the apparent digestibility of forages, when relying on the 48 hours *in succo* DM and or OM degradability coefficients, as this period is closer to the mean retention time of the feed in the rumen (Tuah *et al.*, 1986; Ørskov, and Ryle, 1990). Hence data on *in sacco* degradability at this period were found to be positively correlated with *in vivo* DM and OM digestibility of a feedstuff.

Reduced concentrations of soluble sugars and proteins of forage with a subsequent production of organic acids and soluble NPN compounds in silage limits microbial protein degradation of the silage fed animals (Van Soest, 1982). This is because multiplication and activities of cellulolitic microbes in the rumen depend on the available energy from the carbohydrates and protein content of the diet (Van Soest. 1982). Extensive conversion of sugars into VFA's in a badly preserved silage. may offer very little energy for the rumen microbes. This reduce ability of rumen microbes to degrade nutrients available in the cellwall components of the silage diet ending into lowered effective degradability of the silage dry matter.

Studies on *in sacco* degradability of silage has recently drawn attention of a number of researchers on feed evaluation. Keady *et al.* (1995) working with male calves reported slightly improvement of *in sacco* N degradation from 0.702 to 0.729 g/kg in a well preserved untreated and lactic acid inoculated grass silage, respectively, while their mean DM degradability was maintained at 0.5 g kg^{-1}. Thus addition of commercial prepared lactic acid improved the fermentation of grass silage thereby enhance retention of extra energy for microbial protein degradation. Also, Hristov (1995) reported improved *in sacco* degradation of lucerne silage when the grasses were treated with enzyme complex and sodium metabisulfite as these additives inhibited production of ammonia in silage.

2.6.4 Silage intake and rate of intake

Overall performance of farm animals depend mostly upon the amount of food they consume. In several studies, feed consumption has been measured through feeding trials, in which voluntary food intake is determined by measuring the amount of food eaten by an animal or group of animals given free access to the food for a specific period of time, often one day (Forbes, 1986). In some instances however, the rate at which food is eaten (g/min) has been used to predict voluntary food intake as confirmed by McLeod and Smith (1989) who observed significant ($P < 0.01$) high relationship between voluntary intake and intake rate with a correlation of 0.89.

There are several animal and feed related factors affecting the rate at which a forage can be eaten. These also influence the rate of intake of grass silage, hence it's overall voluntary DM intake by an animal. Some of the most important ones include:

- The physical characteristics of the feed, such as size of particles in the diet (Kenney and Black, 1984; Minson, 1990), moisture content (Kenney *et al.*, 1984; John and Ulyatt, 1987) and cell wall content (McLeod and Smith, 1989).
- Acceptability of the feed by animals which depend upon taste, smell and texture (Arnold *et al.*, 1980; Grovum, 1984) as well as the protein content of the feed (Forbes, 1986). In case of silage, concentration of various by - products of fermentation mainly ammonia - N and organic acids (lactic and volatile fatty acids) influences silage acceptance and consequently it's voluntary intake by ruminants (Rogers *et al.*, 1979; Forbes, 1986).
- The individual animal and it's degree of satiation, and physiological and psychological state (Weston, 1982; Grovum, 1988).

Generally, silage intake has been recognized to be lower than that of fresh or dried forages made from the similar forage species (Demarquilly, 1973; Wilkins, 1974; Rogers *et al.*, 1979). From a series of 87 experiments with sheep Demarquilly (1973) noted decline in silage DM intake varying between 1 - 64% lower than that of their corresponding forage expressing great variation in the extent through which silage intake can be depressed. According to Forbes (1986) a reduction in silage intake compared with fresh forage is obvious even if the ensiling method applied abide to all the precautions for making good silage. From this argument, it's clear that the inhibitory effects on silage intake was affected by the method of conservation, together with the acceptance and palatability of silage as influenced by forage species or additive used in it's preservation.

Fine chopping before ensiling has been found to improve intake of silage. Panditharatne (1985) working with sheep, reported increased DM intake of *Panicum maximum* silage by 17% units when grasses harvested after 2 - 3 weeks of growth were chopped to a length of about 15 cm prior to ensiling. According to the author, chopping was believed to have improved fermentation, minimize nutrients losses and increased the rate of passage of feed particles through the gut of the respective animals.

Voluntary intake of silage was observed to be positively correlated with it's DM content (Wilkins *et al.*, 1971). This was confirmed by Olubanjo *et al.* (1989) working on small ruminants in which an average daily DM intake of 62.7 and 54.9 g/ $KgW^{0.75}$ were observed when animals were fed napier silage with about 19.2% DM and a ration consisting of 50% napier + 50% cocoa pod silage with 16.9% DM, respectively.

Silage containing crude protein less than 9 g kg^{-1} DM was found to offer insufficient amount of nitrogen for effective microbial fermentation in the rumen of farm animals (Thomas *et al.*, 1975). Therefore, since most tropical grass silage are believed to have lower contents of protein due to low protein values of their respective forages. protein and energy supplementation to grass silage fed dairy animals in the tropics is very crucial. This will increase voluntary intake and maintain high productivity from dairy animals. Alternatively, incorporation of urea or legumes with high protein value was found to improve the N content of grass silage, thereby improving silage intake (Chandler *et al.*, 1975; Sarwatt, 1995).

A negative correlation between intake and total organic acids and ammonia - N concentrations in silage has been reported by Thomas and Chamberlain (1983). From their findings however, silage with higher proportion of lactic acid in the total acidity was recorded to have higher voluntary intake than the one with higher content of acetic acid in total acidity. Sarwatt *et al.* (1992) working with sheep reported lower voluntary DM intake (47.4 g/kg$W^{0.75}$) for untreated Rhodes grass silage with 50.9, 42.1, 5.6 and 1.8 g kg^{-1} DM and 6.2 (% of total N), concentration of lactic, acetic, propionic and butyric acids and ammonia - N, respectively. While the corresponding silage with 3% molasses, showed higher voluntary DM intake (52.4 g/kg$W^{0.75}$), due to it's higher content of lactic and acetic acid (57.8 and 57.7 g kg^{-1} DM, respectively) and lower concentrations of butyric acid and ammonia - N which were 0.6 g kg^{-1} DM and 4.8 (% of total N), respectively.

However, ingestion of a low pH lactate silage, might alter the normal rumen pH, which ultimately lower the voluntary intake of silage (McLeod *et al.*, 1970; Thomas and

Wilkinson, 1975). To overcome the above problems and increase DM intake of acidic silage Erdman (1988) suggested supplementation with sodium bicarbonate as necessary for partial neutralization of the acidity. Although Lancaster and Wilson (1975) did not reveal any improvement with supplementation of sodium bicarbonate to silage fed dairy cows.

2.7 Factors which modify the quality and feeding value of silage

Proper management of the silage making operations enhances production of good quality silage thus improve productivity of dairy animals, and ensure a profitable dairy enterprise. In order to achieve such a goal McCullough (1976) and Skerman and Riveros (1990) itemized several factors which manipulate the quality and feeding value of tropical silage. These include use of forage species with high productivity, harvested at an optimum stage with maximum accumulation of nutrients, pre conditioning of forages through either wilting or chopping, use of additives and selection of type of silo that can suit size of production enterprise. Detailed review on influences of some of the above factors on the quality of silage are explained below.

2.7.1 Effects of chopping on the quality and nutritive value of silage

Chopping of forages prior to ensiling facilitate better compaction of the ensiled material (Wilson and Bridgestocke, 1981; Raymond *et al.*, 1982). This allows effective exclusion of air and minimize nutrients losses due to aerobic deterioration. Panditharatne *et al.* (1986) obtained lower mean percentage dry matter losses from fine chopped (1.5cm) *Panicum maximum and Pennisetum. hybrid* (NB 21) compared with 7.5 and 15cm lengths, although the differences were very small (2.5, 2.7 and 2.8%, respectively).

Apart from facilitating better compaction, chopping prior to ensiling was observed to increase the surface area of forage particles for microbial attack during fermentation (Dulphy and Dermaquilly, 1973; Deswysen *et al.*, 1978). Consequently, this improved the fermentation quality, digestibility and intake of silage (Dulphy and Dermaquilly, 1973; Deswysen *et al.*, 1978; Wilson and Bridgestocke, 1981; Panditharatne *et al.*, 1986). Slightly lower pH (4.3) and butyric acid concentration (25.6 g kg^{-1} DM) were recorded from chopped rye grass silage compared with long silage with pH and butyric acid concentration of 4.4 and 50.7 g kg^{-1} DM, respectively (Deswysen *et al.*, 1978). From their observations, dry matter intake by sheep was significantly higher for the chopped than long silage with values of 41.2 and 35.1 $g/KgW^{0.75}$, respectively. But digestibility was slightly altered by chopping (with 67.2 vs 68.8% IVDMD and 71.8 vs 73.7% IVOMD for long and chopped silage, respectively). Thus Wilson and Bridgestocke (1981), suggested fine chopping at lengths between 2.5 to 5cm as enough to allow easy compaction, which lead to production of nutritious silage containing low levels of butyric acid and, degraded proteins.

Chopping of silage just before feeding was found to improve dry matter intake of sheep by 9.3% units as recorded by Deswysen *et al.*(1978). This was caused by reduction in size of feed particles which increased rate of passage of feed from the rumen to the hind gut (Ørskov, and Ryle, 1990); although the improvement was slightly lower when compared with grasses chopped before ensiling.

2.7.2 Silage additives

Use of additives to enhance lactate fermentation in a well preserved silage has been documented by many researchers working on preservation of temperate and tropical pastures. This has been achieved through direct acidification of the crop with minerals or organic acids, inoculation with lactic acid bacteria or addition of readily fermentable carbohydrates. Currently, attention is not paid only on the use of silage additives to control fermentation pattern, but also to improve the nutritive value of the product and to reduce DM losses (Wilkinson, 1983b; Done and Appleton, 1990; Otieno *et al.*, 1990; McDonald *et al.*, 1991; Sarwatt *et al.*, 1992; Tobioka *et al.*, 1993; Sarwatt, 1995).

McDonald *et al.* (1991) classified silage additives into five main categories (Table 2.3) Those in groups one and two are concerned with fermentation control and act by stimulating lactic acid fermentation or by partial or completely inhibition of microbial growth (inhibitors). The third group combine additives which inhibit aerobic deterioration of silage, The fourth include nutrients which when added to the crops at the time of ensiling improve the nutritive value of resulting silage and the fifth category include absorbent which when added to low DM forages reduce nutrients losses and pollution of water courses by effluent. Molasses is the only additive which will be discussed in detail in this text since it was the only additive used in this study.

2.7.2.1 Effects of molasses on quality and nutritive value of silage

Recently, molasses has gained popularity over chemical additives as a cheap and non toxic silage preservative in many tropical countries where sugar cane and beets are grown. In Tanzania, for instance, molasses form the most abundant by - product of sugar extraction produced from about four sugar processing factories found within the whole country. However, it's availability for small holder farmers has been limited by high transportation costs which can however be overcomed by establishing molasses collection centres within the reach of farmers. As indicated in Table 2.3, molasses was classified both as a fermentation stimulant and as a nutrient. Dry matter contents ranging between 700 - 750 g kg^{-1} and soluble carbohydrates content of about 650g kg^{-1} were recorded from molasses in which sucrose form the major component of soluble sugars (Thomas, 1978; McDonald *et al.*, 1991).

As previously mentioned (section 2.5.3.2) tropical forages contain low levels of WSC. Therefore, to minimize risks of secondary fermentation, addition of molasses during ensiling of tropical forages (especially unwilted fresh grasses with less than 2% WSC) become a prerequisite (Wilkinson, 1983a).

Addition of more than 4% molasses was found to be enough to stimulate production of required levels of lactic acid for stable preservation of silage when the content of WSC in herbage were below 3 percent (Catchpoole, 1966). Addition of 4 and 6% molasses at the time of ensiling of *Setaria sphacelata* grass with DM content ranging between 25 - 30% produced good quality silage, with pH values ranging from 3.9 to 4.2, without traces of mouldy and the silage was of acceptable quality in terms of physical characteristics (Sunarso *et al.*, 1995). Also when Rhodes grass with 32% DM was mixed with 3% molasses at ensiling a satisfactory silage was produced with pH 4.6, ammonia - N 4.8 (% of Total N) and lactic, acetic, propionic and butyric acids concentrations of 47.1, 23.8, 7 and 1.5 g kg^{-1} DM, respectively (Sarwatt *et al.*, 1992). These improvements in fermentation qualities were concomitantly associated with improvements in voluntary intake (616.5 gDM/day), *in vitro* DMD (63.6%) and *in vivo* DM (56.2%) and OM (58.8%) digestibilities by sheep.

From a study made by Otieno *et al.* (1990) addition, of 5% molasses to bana grass at ensiling, improved appearance and smell of the resulting silage thereby improved it's palatability and acceptance by the animals. They also reported improved DM content from 16 to 19.8% and lowered pH 4.2 when molasses was added compared with bana silage without molasses which had approximately 17% DM and pH of 5.2 associated with putrefaction. Their findings were not very far from those obtained by Ojala *et al.* (1990) for the quality of 5% molasses treated napier silage, in which OM digestibility and intake by lactating dairy cows were 56.9% and 8.9 kgDM /cow/day with a production of an average of 6.4 kg of FCM per cow /day.

On the other hand, addition of too little molasses was observed to give worse results than none at all, and may even increase the concentration of butyric acid (Catchpoole and Henzell, 1971). Singh and Pandit (1978) did not reveal any significant changes in the pattern of fermentation of sorghum ensiled with 1% molasses when compared with the control which had no molasses.

However, from conclusions made by several workers, stable silage of higher pH (4.8 and above), with low to medium concentration of volatile fatty acids and moderate to high amounts of ammoniacal nitrogen was recovered from some tropical grasses without use of additives (Catchpoole and Henzell, 1971; Wylie, 1975; Skerman and Riveros, 1990). Decreased water activity coupled with increased osmotic pressure of the plant cell sap which limit growth of clostridia bacteria have sometimes being explained as the main reasons responsible for maintenance of such a stability (Wylie. 1975). However, specific reasons are not yet established, though in some literatures acetic acid has been reported to be associated with maintenance of such a stability of tropical grass silage (Aguilera, 1975).

During the first few days of ensilage alot of sugars have been reported to be lost through respiration and aerobic decomposition (McDonald *et al.*, 1991). Therefore, apart from initiating lactate fermentation addition of higher levels of molasses have been reported to minimize the hydrolytic activity of water in silage (Catchpoole, 1970), thereby preventing secondary fermentation and compensate for the losses of nutrients occurring during ensiling (Catchpoole, 1970).

Table 2.3 Classification of silage additives

Fermentation stimulants		Fermentation inhibitors		Aerobic deterioration inhibitors	Nutrients	Absorbents
Bacterial cultures	Carbohydrate sources*	Acids	Others			
Lactic acid bacteria	Glucose	Mineral acids	Formaldehyde	Lactic acid bacteria	Urea	Barley
	Sucrose	Formic acid	Paraformaldehyde	Propionic acid	Ammonia	Straw
	Molasses	Acetic acid	Glutaraldehyde	Caproic acid	Biuret	Sugarbeet pulp
	Cereals	Lactic acid	Sodium nitrite	Sorbic acid	Minerals	Polymers
	Whey	Benzoic acid	Sulphur dioxide	Pimaricin		Bentonite
	Beet pulp	Acrylic acid	Sodium metabisulphate			
	Citrus pulp	Glycollic acid	Ammonium bisulphate	Ammonia		
	Potatoes	Sulphamic acid	Sodium chloride			
	Cell wall degrading enzymes	Citric acid	Antibiotics			
		Sorbic acid	Carbon dioxide			
			Hexamethylenetetramine			
			Sodium hydroxide			

Most additives listed under carbohydrates source can also be listed as nutrients source

Source: McDonald *et al.* (1991)

2.7.3 Types of silos for forage conservation

There are several types of silos used for forage conservation. These vary from simple clamp silos to very complicated tower types (Pizarro and Vera, 1980; Zimmer, 1980; FAO, 1993; Sarwatt, 1995). Whatever type of silo to be used, it must be able to fulfil the following basic requirements; First, provision of a solid surface to facilitate easy compaction of the mass in order to eliminate air. Secondly, protection of the ensiled material from the impacts of air, environmental temperature changes and water for the whole period of storage (McCulough, 1975).

Therefore, according to the function and use, types of silos used under field conditions can be arbitrarily divided into large scale and small scale silos. These may offer large quantities of silage for feeding dairy animals during periods of feed scarcity. Use of these silo types in research can also give sufficient amount of silage needed for laboratory analyses as well as feeding trials with animals. Thus giving detailed information on efficiency of various ensiling techniques on the feeding value of silage. Apart from that costs of production in relation to quality and quantity of silage produced can be assessed thereby giving a real picture of the suitability of an ensiling technique.

The most common large scale silos used in many tropical countries include the earth and concrete walled trench silos, with a capacity of holding up to 100 tons of silage at the same time (Skerman and Riveros, 1990; FAO, 1993). These are commonly used in medium and large government, parastatals, cooperative or institutional dairy farms.

In this study more emphasis will be put on small scale silos which are commonly used for ensiling small quantities of forages by small holder dairy farmers in several tropical countries.

2.7.3.1 Types of silos for small scale silage production in the tropics

Most common types of silos used by small scale farmers in tropical countries include earth pits/trenches and concrete/bunker silos (Urio *et al.*, 1988; Sarwatt, 1995). Their sizes and capacities are smaller than those of the large scale silos. According to Kinsey (1993) however their sizes and capacity vary greatly depending on the amount of forage available, amount of silage needed and financial situation of the farmer.

Earth pit silos are normally dug as a trench sloping in one direction to allow effluent and rain water to easily run away, therefore most of the silage is being preserved under the ground (Diamond, 1973). These silo structures are simple in construction and their making can be easily understood by the small scale farmers in villages. The walls of these silos can be covered by the plastic sheet to reduce losses due to soil contamination. Additionally to prevent erosion that can occur on the walls of the silos and make the silos unusable the following year, the walls and floor can be cemented or reinforced by the use of burnt earth bricks which can cheaply be produced by the farmers in villages. The top of the pit silos are usually not roofed, however roofing can be done by the use of cheaply available roofing materials such as thatched grass inclined at an angle that allow rain water to easily run away and to reduce absorption of excess heat into the silo during sunny days.

Concrete silos commonly used in the tropics are usually made of concrete blocks raised above ground (Sarwatt, 1995). In order to facilitate drainage these silos should be constructed on a gentle sloping site similar as done for the earth pits. in addition a draining pipe should be placed at the lower end of the floor to allow easy passage of effluent (Raymond *et al.*, 1982). This type of silo is advantageous as it make a permanent structure which does not need to be reconstructed year after year. However the initial cost incurred for it's construction are usually high and most often unaffordable to small holder farmers living in villages where cement is scarce and very expensive. Although use of concrete silos ensures total elimination of losses due to soil contamination, the direct contact between the silo walls and sun rays might increase absorption of the excess heat through the walls thereby affecting normal condition for silage fermentation (Raymond et al., 1982; FAO, 1993). On that basis, Pizaro and Vera (1980) reported total DM losses of about 25 and 9% from maize silage preserved in concrete bunker and trench silos, respectively. Additionally, Sarwatt (1995) reported non - significant differences on average dry matter losses of the three tropical silages recovered from the earth pits and concrete silos, with about 21.7 and 19.6% ± 0.3 DM losses respectively. Thus suggests permanent roofing for the above ground concrete silos which are more exposed to direct effects of environmental temperature changes that may affect the preservative quality of the silage.

2.8 Nutrients losses due to ensiling

Several authors have discussed different nutrients losses which might be encountered during ensilage (Pizzaro and Vera, 1980; Webster and Wilson, 1980; Zimmer and Wilkins, 1984; Woolford, 1984; Lampila *et al.*, 1988). From about 800 experiments performed by Watson and Nash (1960), higher DM and Nitrogen losses were recorded from silage recovered from high moisture grass compared with wilted herbage. Similar findings were reported from different experiments conducted by Lampila *et al.* (1988) who recorded average DM losses of 19.0 and 13.4% from unwilted and wilted silage, respectively. In the tropics, Webster and Wilson (1980) reported dry matter losses ranging between 9 to 12% as common from well preserved *P. purpureum* grass. However, these losses might easily exceed 20% of DM ensiled without taking proper precautions. According to Zimmer (1980), factors which determine the extent of loss of DM in silage were listed as plant enzymes, moisture content and nutrients composition of ensiled crop, pH, temperature, ensiling technique applied and air/oxygen ratio maintained inside the silo.

McDonald *et al.* (1988) classified nutrients losses into four main groups; these include field, oxidation, fermentation and effluent losses.

2.8.1 Field losses

These include losses which may occur during harvesting of the forage for ensilage. Their extent vary depending on mechanical handling of forage, biochemical changes and leaching of nutrients as influenced by climatic conditions. Field losses from either unwilted grass or grasses wilted for less than 24 hours are generally low and cannot exceed 1 to 2.5% of the dry matter (Zimmer and Wilkins, 1984; McDonald *et al.*, 1988). Longer periods of field wilting (5 to 8 days) increase plants respiration rate and mechanical losses which might increase dry matter losses to as much as 6 to 10% of forage ensiled (McDonald *et al.*, 1988). However, DM losses might reach as high as 30% on cut herbage damaged by the impact of rains (Zimmer and Wilkins, 1984). Main nutrients subjected to field losses due to impact of rains include water soluble carbohydrates and proteins which are being hydrolysed to amino acids.

2.8.2 Effluent losses

The amount of dry matter lost in silage effluent is determined by several factors. These include the dry matter content of ensiled material, silo type, chopping, degree of consolidation, and extent of sealing the silo to protect ensiled material from impacts of rains and humidity. However, the DM content of ensiled forage has been explained to control all other factors in determining the amount of seepage (Woolford, 1984; Lampila *et al.*, 1988; McDonald *et al.*, 1988; Rinne, 1991; Van Der, 1994).

Effluent DM losses of up to 10% were observed from grass silage made from forages with DM contents below 30% (Woolford, 1984; Lampila *et al.*, 1988; McDonald *et al.*, 1988). Van Der (1994) reported a range of 30 - 35% DM in maize crop as optimum for it's ensilage and results into minimum losses of nutrients in effluent.

Lampila *et al.* (1988) as supported by Rinne (1991) concluded that, higher amounts of nutrients can be lost in seepage when high moisture crops (with DM below 30%) are ensiled in vertical than in horizontally arranged trench silos. According to the authors this is caused by high internal pressure created in the former type of silo as a result of increased efficiency of consolidation of forage materials inside the silo.

The most important nutrients subjected to effluent losses include soluble sugars and nitrogenous compounds, minerals, vitamins and fermentation acids which if not controlled, might cause marked decline in silage intake, digestibility and it's efficiency of utilization by animals.

2.8.3 Fermentation losses

Extent of losses during fermentation is mainly determined by the type of micro organisms responsible for fermentation (McDonald *et al*., 1988). Under purely anaerobic conditions, dry matter losses has been considered to be low in fermentation dominated by homo lactic bacteria than heterolactic bacteria. Under such conditions. McDonald *et al*. (1988) reported DM losses not exceeding 5 percent. Whereas. in Clostridial fermentation nutrients losses should be expected to be high as a consequence of evolution of gases such as carbon dioxide, hydrogen and ammonia.

2.8.4 Oxidation (aerobic) losses

These occur as a result of oxidation of sugars present in ensiled forage by the action of plant and microbial enzymes, leading into production of heat, Co_2 and water (McDonald *et al*., 1988). In a rapidly filled, effective consolidated and sealed silo, very little oxygen might be entrapped within the plant tissues; Causing minimum losses of dry matter, usually not exceeding 1 percent (McDonald *et al*., 1988). These losses due to aerobic respiration may only be restricted to a thin layer on the upper most surface and on the sides of the silo. However, if excess oxygen is allowed, plant enzymatic activities will continue, causing drastic increase in temperature and accelerated respiration which might end up into losses as high as 75% of the total dry matter ensiled (McDonald *et al*., 1988).

2.9 Economic feasibility of ensiling methods

In evaluating efficiency of any forage conservation technique, one should take into consideration not only the nutritive value of the product conserved, but also various costs incurred in relation to the quality, feed value and performance of animals utilizing such a product.

Few attempts if any have been carried to estimate either technical or economic efficiency of conservation methods. Some of which were conducted in temperate countries (Raymond *et al.*, 1982). Rains (1963) emphasized on the use of costs of production per unit of digestible constituents as the only criteria of assessing economic value of hay or silage making techniques. Raymond *et al.* (1982) reported a method of estimating costs of ensiling technique by measuring costs per unit of silage dry matter stored. Which was calculated as:

cost per unit of silage DM stored =

(storage cost per m^3 / % DM in silage) + % charge for storage losses.

In tropical countries, cost analysis has been geared mainly towards methods of improving feeding value of low quality roughages (Mlay, 1986; Kilongozi, 1992).

In Tanzania, Kilongozi (1992) analyzed costs of treatment of maize stover with urea in relation to improvement in it's feeding value. The author did so by estimating total costs incurred to produce 1kg DM of urea treated maize stover in relation with the eight gain of calves fed such a diet. According to him, all the variables with differential costs in the process of urea treatment of maize stover were recorded separately from those which incurred similar costs. Total cost was calculated as the summation of both differential and similar costs incurred in the whole process of producing one kilogram DM of urea treated maize stover.

However, in making estimates of costs of production per unit value of silage produced, it is necessary to bear in mind that the most efficient method of silage making for small holder farmers is the one in which:

- The silo is placed at shorter distance from the field were crops are cut. and nearby to where animals are fed in order to minimize transportation costs. labour and time of filling the silo.
- The silo has optimum capacity of 4 - 5 m^3 of silage to minimize high costs from big silos and too much losses with very small silo.
- Decision on number of silos to be made taking into consideration the number of animals to be fed, amount of feed required by each animal and surplus forage available for silage.
- Cheapest and most available additive is utilized and all precautions to be taken to avoid losses have been considered (FAO, 1993).

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Forage material used

In the context of this study, napier grass was used as a forage of choice. This was influenced by it's abundant production in almost all potential and sub potential regions of Tanzania during the rain season, and especially due to it's high popularity within localities of small holder dairy farmers, where it is cut and fed freshly to zero grazed dairy animals.

In order to maintain uniformity in the experiment, a three years old stand of the hybrid variety of napier grass (*P. purpureum x P. typhoides*, bana) was used. These were obtained from an established elephant grass germ plasm evaluation plot at Magadu dairy farm of Sokoine University of Agriculture Morogoro. Initially the germplasm was obtained from Zanzibar.

3.1.1.1 Management and preparation of the forage material

At the beginning of short rains of November, 1994, an area of 0.25 ha of a regrowth of napier grass was uniformly cut at a height of about 15 cm above ground, using bush knives. The cut forage was collected and removed from the area. Two weeks later, weeds, old stems and unwanted grass species were removed and farm yard manure from dairy cattle applied at a rate of 12.5 tons/ ha. This was followed by mulching and irrigation using a horse pipe during hot sunny days, which were almost five weeks for the whole period of regrowth. The meteorological data for the whole period of a new regrowth are indicated in Appendix 1. The forage material for ensilage was cut after 10 weeks of a new regrowth using bush knives, when most of the plants had attained a height of between 1 - 1.2 meters high.

3.1.2 Additive used (Molasses)

Molasses was the only additive used in this study. This was purchased from Mtibwa sugar factory about 50 kilometres from Morogoro municipality. On each day of ensiling, molasses solution was prepared for the treatments which were mixed with molasses. Molasses was applied at a rate of 3% of the total weight of fresh forage to be ensiled. Thus each silo with 500kg forage received about 15kg of molasses, which was diluted with an equal amount of water before application. The dilution was made to ensure uniform spread of the molasses which is normally thick and viscous.

3.1.3 Preparation of silos

Earth pits and concrete silos were the only types of silos used in this study, as they were the most common types of silos used for small scale silage production in several tropical countries.

3.1.3.1 Earth pit silos

Earth pits were made on a sloping ground to stop spoilage of silage by the run offs which can penetrate inside the silo. These were 1m deep, 1m wide and 3m long such that each $3m^3$ silo had a capacity of holding about 600 - 800 kg of fresh forage (Plate 1).

Plate 1. Earth pit silo used in this study.

3.1.3.2 Concrete silos

These silos were constructed by using cement blocks raised above the ground. their size and capacity were similar as those of the earth pit silos uses in this study. At the lower end of these silos an effluent draining pipe was fitted to facilitate easy drainage of effluent (Plate 2).

Plate 2. Concrete silos used in this study

3.2 Ensiling process

3.2.1 Treatment of forage materials prior to ensiling

After harvesting, the forage materials were packed into a trailer mounted to the tractor and immediately sent to the silos site, where they were weighed. Since the aim was to test the effects of chopping and addition of 3% molasses on the quality of napier silage produced in either pits or concrete silos, each of the four equal weighed portions was subjected to one of the four different test treatments, before being ensiled in either pits or concrete silos. The four test treatments were;

T1 - 5 cm chopped grass, 3% molasses

T2 - 5 cm chopped grass, 0% molasses

T3 - Unchopped grass, 3% molasses

T4 - Unchopped grass, 0% molasses - control.

3.2.2 Experimental set up

Formally this experiment was set with the aim of producing silage in duplicate silos for each treatment and type of silo. Thereby taking precautions for any environmental changes that might spoil the silage, and affecting the precision of the experiment. Basing on this, the original experiment layout was as indicated in Table 3.1, ending up with eight earth pits and eight concrete silos in which each test treatment had it's duplicate.

Table 3.1 Original experimental layout

		Treatments			
Type of silo	Replications	T1	T2	T3	T4
Earth pit	1	x	x	x	x
	2	x	x	x	x
Concrete	1	x	x	x	x
	2	x	x	x	x

However, due to unavoidable circumstances, the forage material obtained were not sufficient to fill all 16 silos, also time was so limited to allow another regrowth of extra forage. Hence, duplication was carried out for the earth pits only, leaving unduplicated treatments for the concrete silos, as these were assumed to be subjected to a very little chances of getting spoiled. The experiment was set as shown in Table 3.2 below.

Table 3.2 Experimental layout used

		Treatments			
Type of silo	Replications	T1	T2	T3	T4
Earth pit	1	x	x	x	x
	2	x	x	x	x
Concrete	1	x	x	x	x

3.2.3 Preparation of napier silage in earth pit silos

Napier grass was ensiled in eight earth pit silos. The whole process took two days. whereby four silos each with a different treatment were ensiled on the first day. and the duplicate silos on the next day.

Plastic sheets (With a thickness of 800 mm gauge) were spread to cover all the side walls of each silo to prevent contamination between ensiled forage and soil. At the bottom, a layer of about 5 cm depth of dry grass was laid to allow seepage of effluent and to prevent direct contact between ensiled forage and soil (Plate 1).

The initial ensiling procedures followed on each individual silo differed from the other depending on the treatment imposed. In the first silo, the forage material for treatment number one were chopped to about 5 cm length using tractor driven forage chopper, weighed (to 500 kg) then evenly spread inside the silo where they were sprinkled with a known weight of 3% molasses solution layer after layer. In the second silo, the forage material chopped and weighed as in treatment one above were evenly spread inside the silo without addition of molasses. In the third silo, 500 kg of unchopped grass for treatment number three, were laid parallel to fill the silo and sprinkled with a known weight of 3% molasses solution layer after layer. While in case of the fourth silo with treatment number four, 500 kg of unchopped grass were laid parallel to fill the silo without addition of molasses. Within this period, two forage samples weighing about 400 g were taken from each treatment ensiled, one part was air dried for degradability studies while the other portion was stored in a frozen condition ready for freeze drying to determine dry matter and analysis of chemical composition parameters. Ensiled material was thoroughly compacted by using a heavy weight concrete block of approximately 50kg on layer after layer until the silos were filled. The top most layer of each silo was then covered by an overlapping plastic sheet, followed with earth material and pressure of about 50 kg m^{-2} from heavy stones to ensure total exclusion of air. After three months, the silage was ready. One silo was opened per day, and resulting silage weighed and sampled. The remaining good silage was filled in large plastic bags ready for intake rate experiment, while the spoiled silage was discarded. Meteorological data during ensiling and the whole period of fermentation are indicated in Appendix 1.

3.2.4 Preparation of napier silage in concrete silos

Napier grass was ensiled in four concrete silos each containing a different treatment with exactly 500 kg of forage. To avoid contaminations, plastic sheets were laid in all sides of the silos except at the bottom part. The bottom of the concrete silos were not covered with any material so as to allow seepage of effluent from the silage, which were directed by the floor into the outlet pipes incorporated.

The ensiling procedures followed similar trend as those applied for the four different treatments ensiled in earth pits as explained in section 3.2.3. Similarly two forage samples each containing about 400 g were taken from each treatment ensiled, through which, one part was air dried for degradability experiment, while the other portion was stored in a frozen condition ready for freeze drying and analyses for chemical composition. After three months, the silage was ready, and one silo opened on each day and resulting silage sampled, while the remaining good silage was packed in large plastic bags ready for intake rate experiment.

3.3 Determination of dry matter losses

Immediately, on opening each silo, all portions of silage that were considered spoiled were removed and weighed. It was through physical assessment of colour, smell, texture and mould growth, that a silage portion was considered spoiled. The good silage was also weighed. About 400 g of spoiled and well preserved samples were taken from each silo, these were stored under deep frozen conditions. There after, dry matter content for both the spoiled and good silage samples was determined by freeze drying in a lyophilizer at -40°C for 24 effective drying hours to their constant dry weights.

The amount of dry matter lost from the silos was then calculated as the difference between the kgDM contained in the original ensiled material and that found in the silage recovered as follows;

kgDM losses = kgDM of ensiled forage material - kgDM of recovered silage

whereby:

kgDM of recovered silage = kgDM of good silage + kgDM of spoiled silage

These losses were then expressed as the DM loss as a percentage of DM present in the original ensiled forage material.

3.4 Assessment of silage quality

Silage quality is determined by it's fermentation characteristics and acceptance of the final product by the animals. In this study, parameters used to evaluate the quality of napier silage included sensoric tests, biochemical analyses of the concentration of fermentation products, determination of chemical composition, *in vitro* DM and OM digestibility experiment, degradability studies and assessment of silage intake rate by dairy heifers as a measure of it's acceptance by the animals.

3.4.1 Preparation of silage samples for analysis

Immediately on opening each silo, three silage samples were collected from different depths of the silo, mixed thoroughly and sub sampled into 5 separate polythene bags each containing about 400 g sample for volatile fatty acids and lactic acid determination; pH assessment; ammonia - Nitrogen determination; well preserved silage to be freeze dried for determination of DM, *in vitro* DM and OM digestibility and other chemical analyses; and well preserved silage to be air dried for degradability studies. The spoiled silage was then mixed thoroughly and a composite sub sample of about 200 g placed in a polythene bag for determination of dry matter used in calculation of DM losses.

All the samples collected were immediately placed in a cool ice box, and taken to the analytical laboratory of Department of Animal Science and Production of Sokoine University of Agriculture, where sample for pH determination was analyzed on the same day, and the sample to be air dried was weighed and placed on a drying barn on the same day. Those for ammonia - N determination and for freeze drying were deep frozen to be analyzed latter. In the case of the sample for VFA's and lactic acid determination, silage extract was made by mixing 100 g of the silage sample with 600 ml. of chilled distilled water (to minimize loss of volatile acids) then macerated in a waring blander for 10 minutes (Lessard *et al.*, 1960). The extract was then put in test tubes in duplicate, and sealed with parafilm, then centrifuged at 400 r.p.m for 15 minutes (Playne, 1985). The supernatant was poured into another test tube closed with a tight cap and sealed by a parafilm and immediately deep frozen. The frozen supernatant samples together with frozen good quality and spoiled silage samples were then taken to applied microbiology unit of the University of Dar es Salaam for further analysis.

3.4.2 Sensoric tests

On opening each silo, the silage was physically assessed in terms of appearance, smell and texture. This was done by a selected panel of 10 assessors each marking the appropriate score grade of the silage appearance, smell and texture on an arbitrary organoleptic test chart (appendix 6) prepared for each treatment silo.

3.4.3 pH determination

40 g of the silage from each silo were soaked in 200 ml. of distilled water (ratio of 1:5 parts of silage to water) for 12 hours, under normal room temperature. then filtered through whatman filter paper. The filtrate was then divided into 6 equal portions from which their pH was read on a portable pH meter and mean pH value obtained from statistical analysis of those 6 observations per treatment sample.

3.4.4 Ammonia nitrogen determination

Ammonia - nitrogen (expressed as a percentage of total N) of the silage from the frozen samples for each treatment silo was determined by following routine Kjeldahl method (AOAC, 1990). This was done by first determining the total nitrogen contained in each silage sample in duplicate, followed on by direct steam distillation of a homogenous mixture of 5 g of frozen silage sample with 75 ml. of distilled water to obtain the total amount of free nitrogen present as ammonia, also in duplicate. Thereafter, percentage concentration of ammonia - N present in the silage samples was calculated as a ratio of ammonia - nitrogen (obtained after steam distillation: total nitrogen (present in silage DM), multiplied by 100.

3.4.5 Volatile fatty acids and lactic acid determination

Supernatant from the centrifuged silage samples in tight test tubes were transported to the University of Dar es Salaam in a cool ice box for VFA's and lactic acid analyses. Both VFA's and lactic acid were determined by gas chromatography (Playne. 1985) using a glass coiled column packed with 80/100 chromosorb material. The column temperature was maintained at 190°C and the carrier gas (N_2) flow rate was at 30 ml/

minute. Detection was done by hydrogen flame ionization and quantities were expressed by an integrator.

Before injection, samples for VFA's analysis were pipetted into an eppendorf tube and mixed with isobutyric acid (as an internal standard) and 20% orthophosphoric acid as an acidifying reagent. Those for lactic acid determination were mixed with malonic acid as an internal standard, 50% sulphuric acid as an acidifying reagent and methanol to increase volatile capacity of lactic acid for easy detection. Analyses for the individual volatile fatty acids (acetic, propionic and butyric acid) and lactic acid were conducted in duplicate samples for each treatment.

3.4.6 Intake rate (Acceptability) experiment

3.4.6.1 Experimental animals and their management

Six dairy heifers (Friesian * Ayrshire cross) were selected from Sokoine University Magadu dairy farm. The heifers body weights ranged between 215 to 299 kg, giving an average weight of 255 kg. Animals were confined in individual stalls where they were supplied with feed and drinking water. All animals were dewormed 14 days prior to the start of the experiment using Parasitol (Levamisole hydrochloride).

Before beginning the experiment, heifers were fed on green pastures. therefore in order to accustom the animals to the experimental diets 7 days prior to experiment. each animal was offered 14 kg of napier silage (19.2% DM) and 2kg of concentrate at 0900 hours and 7 kg of fresh Brachiaria brizantha (29.4% DM) at 1600 hours. The basal ration together with concentrates were formulated to meet energy and protein requirements for maintenance and growth (Table.3.3) at an intake level of about 2.6% of the body weight (Kearl, 1982). Water was provided ad libitum throughout the experiment.

In the evening before feeding the experimental meals, heifers were fasted for 12 hours to activate intake of the experimental meals. They were again offered a mixture of 10 kg napier silage and 5 kg fresh Brachiaria brizantha. and 2 kg of concentrate mixtures (as indicated in Table 3.3) at 0900 hours next morning after being assigned to experimental meals, and fasted again at 1800 hours. Similar feeding regime was followed for the whole period of experiment.

3.4.6.2 Feeding of the experimental meals

Chopped napier silage recovered from experiment silo opened early at 0400 hours on each day of experiment was weighed into plastic bags each containing 5000 g meal for each of the six animals. Weighing was repeated until 5 meals for each animal were prepared. The experiment begun at 0700 hours with one person holding a stop watch, 6 men each took a single plastic bag with 5000 g of experimental silage meal and spread the meal on the plastic sheet covered feeding trough present in each individual animal stall. The heifers were allowed to eat every meal for 10 minutes only. At the end of 10 minutes, the animals were prevented to take any more bite, and refusals together with spilled silage on the platform and on the floor collected. The collected uneaten silage was weighed and the weight subtracted from 5000g to get the intake in 10 minutes.

The intake rate of the silage treatment was then calculated as:

Intake rate (g/minute) = grams eaten (for 10 minutes)/10 minutes.

There after, this was converted into dry matter intake rate per minute (g DM/minute) Similar procedures were followed until all 12 treatment silos were opened.

Table 3.3 Proportions of various feed ingredients used to formulate ration of heifers

Ingredients	**Proportion** % DM of the diet
Basal diet:	
Napier silage	40.00
Brachiaria brizantha	30.00
Concentrate:	
Sunflower cake	14.70
Maize bran	15.00
Minerals (Maclik super[R])	0.30
Total	100.00

[R] Maclik super composition:	Ca	P	Mg	Fe	Cu	Mn	Zn	S
Elemental %	18.51	11.0	3.0	0.5	0.1	0.4	0.5	0.4
	Co	I	Se	Mo				
"	0.02	0.02	0.0045	0.0002				
	Nacl	Ca:P ratio						
Compound %	27.0	1.68:1 (Cooper, Kenya Ltd)						

3.4.7 Rumen degradation studies

3.4.7.1 Experimental animals and their management

Two rumen fistulated mature Boran steers with initial body weights of 270 and 300 kg were used. The animals were fitted with a cannulae of 10 cm effective diameter.

Throughout the experimental period the steers were fed a standard ration which comprised of 70% mixed pasture hay and 30% concentrate. The total dry matter intake was estimated at 3% of their body weight (Kearl, 1982). The concentrate was formulated by mixing 1 part of maize bran and 2 parts of sunflower cake. Mineral mix (Maclik super) and vitamins premix (Vitamix) comprised 2% of the total ration were mixed in the ratio of 2:1 Maclik super to Vitamix, respectively to maintain a suitable rumen environment for microbial activities. All the animals were fed individually in separate stalls and feeding was done twice a day at 0900 hours and 1500 hours. Drinking water was provided in ad libitum. A period of 14 days was allocated for adaptation of the animals to the standard diet before starting incubation of the bags containing the ensiled forage materials and silage treatment samples in their rumen.

3.4.7.2 Preparation of the samples for degradability experiment

Preparation of samples for incubation using nylon bags techniques was done as outlined by Ørskov, *et al.* (1980). Air dried samples of ensiled forage materials and silage treatments were ground to pass through a 2 mm sieve in a hammer mill. The samples were placed in an air tight bottle. Two grams of each test sample of ensiled forages and silage treatments were put in two sterilized and weighed nylon bags per animal per incubation time. The nylon bags had effective size of 270 x 115 mm and mean pore size of 40 m, the bags containing samples were labelled, fastened using rubber bands and anchored into three separate plastic tubes which were then ready to be incubated into the rumen of three fistulated steers with a permanent cannulae. The rumen degradability of the samples were assessed at six different incubation times, which were 12, 24, 48, 72, 96 and 120. After which they were withdrawn, washed in running tap water. Then dried in an oven (set) at 60°C for 48 hours to get a constant weight. The samples were then cooled in a desiccator, weighed and the dry matter loss calculated. Degradability at zero hour was determined by soaking the duplicate bags with samples in water for 24 hours. The bags were then dried for 48 hours at 60°C, cooled in the desiccator, weighed and dry matter loss calculated.

3.4.7.3 Calculation of DM degradability and degradation characteristics

Degradability of dry matter for the samples of ensiled forage materials and recovered silage was calculated from the disappearance of DM from the bags after either washing or incubation into the rumen using the following formula:

% Dry matter loss (DML) =

$$\frac{\text{Weight of DM incubated} - \text{weight of DM in the residue}}{\text{Weight of DM incubated}}$$

The % DM degradability and degradation constants were calculated according to mathematical model proposed by Ørskov and McDonald (1979).

$$P = a + b(1 - e^{-ct})$$

Where:

P = the percentage degradability at time t.

a = water soluble fraction assumed to disappear instantly

b = not water soluble but potentially rumen degradable part

a + b = potentially rumen degradable part (asymptote)

c = rate constant at which insoluble material is degraded

e = the base of natural logarithms

t = incubation time

Calculation of the degradability constants and fitted degradability values were executed using SAS program Proc " NAWAY" (SAS, 1988).

Effective degradability of the samples were calculated by using SUPERCAL computer package at a passage rate of 0.01 using formula of Ørskov, and McDonald (1979).

$$Y = a + bc/(c + k)$$

where:

Y = effective degradability

a = water soluble component

b = insoluble but potentially rumen degradable part

c = rate of degradability of insoluble material

k = passage rate

3.4.8 Dry matter content determination

For better comparisons and to maintain uniformity in analyses, dry matter content of the samples of forage treatments to be ensiled, good and spoiled silage samples were determined by freeze drying duplicate weighed samples to their constant weights in a lyophilizer maintained at 40°C for 24 hours (Larsen and Jones, 1975).

Another batch of samples of treated forage material to be ensiled and good silage were air dried each for 4 days and utilized for degradability studies.

3.4.9 Chemical composition analysis

All dried samples for chemical analysis were grounded to pass through a 1 mm screen in a hammer mill. Duplicate grounded samples of freshly harvested forage, treated forage material to be ensiled and silage were then chemically analyzed for DM, total nitrogen (followed with crude protein) ash and ether extract according to standard procedures (AOAC, 1990).

Duplicate samples of the same materials used above, were also analyzed for neutral detergent fibres (NDF), acid detergent fibres (ADF) and acid detergent lignin (ADL) according to the scheme of fibres analysis as outlined by Goering and Van Soest

(1970).

Water soluble carbohydrates (WSC) content was determined spectro photometricaly by the method described by Thomas (1977).

In vitro DM and OM digestibility for the duplicate ground samples of treated forage materials before being ensiled and silage were determined following a two stage *in vitro* digestion technique as outlined by Tilley and Terry (1963).

Chemical composition of molasses, fresh *Brachiaria brizantha*, mixed grass hay, maize bran and sunflower cake used to formulate basal ration of heifers and standard diet for the fistulated steers were also determined interms of DM, CP. CF. ash, EE and NFE contents following standard procedures (AOAC, 1990).

3.5 Analysis of costs of ensiling napier grass under different ensiling techniques in relation with the silage dry matter recovered

Costs involved during ensiling of 500 kg of napier grass under each of the four different treatments in either earth pits or concrete silos were recorded. The costs were divided into two parts. The first group comprised of all variables which had differential costs (in the process of ensiling different treatments in either earth pit or concrete silo). These included costs incurred for the construction of silo, costs of molasses, watering can, forage chopper and labour used for chopping, mixing and sprinkling of molasses, ensiling, compaction and sealing of ensiled material between the two different silo types. The second group combined the fixed costs for all variables or activities which were conducted similarly during ensiling of different treatments such as labour used for harvesting and transportation of forage to the silo site, fuel for transportation and costs of polythene sheets used to cover the walls of silos as their sizes were similar due to equal dimensions of the silos. All calculations were based on the present open market prices.

Formula used was:

$TC_{(st)} = FC_{(st)} + VC_{(st)}$

Whereby:

$TC_{(st)}$ = Total costs for ensiling napier grass in each treatment silo

$FC_{(st)}$ = Fixed costs for variables which had the same cost during ensiling of napier grass under each treatment silo

$VC_{(st)}$ = Variable costs for ensiling napier grass under each treatment silo

Then total costs incurred for ensiling napier grass under each treatment silo was related with the total silage dry matter recovered from the same silo. Hence the efficiency of each ensiling technique was reported in terms of costs/ kg DM of silage recovered.

3.6 Experimental design and statistical analysis

3.6.1 Experimental design

Data on chemical composition and degradability of the pre ensiled treatments of napier grass were laid out as 2^2 factorial arrangement in a completely randomized design as described by Snedecor and Cochran (1989). There after, data for experiments on chemical composition, *in vitro* DM and OM digestibility, fermentation products, sensoric quality, dry matter losses, intake rate and DM degradability of the silage obtained were set in 2^3 factorial arrangement again in a completely randomized design.

3.6.2 Statistical analysis

General linear model (GLM) procedures of Statistical Analysis System (SAS, 1988) with SS1 option for analysis of variance was used to analyse the data. The levels of significances were marked by NS for non - significant differences, * for $P < 5\%$, ** for $P < 1\%$ and *** for $P < 0.1\%$.

The mathematical model used for analysis of chemical composition and degradability of the four pre - ensiled treatments of napier grass was:

$$Y_{ij} = \mu + a_i + b_j + ab_{ij} + e_{ij}$$

where:

Y_{ij} = quality attributes of pre ensiled treatment of napier grass: DM, CP, Ash, EE, NDF, ADF, ADL, WSC, *in vitro* DM and OM digestibility and DM degradability.

μ = fixed general effect

a_i = effect of i^{th} physical preparation method (chopped: unchopped)

b_j = effect of j^{th} additive level (3% molasses: 0% molasses)

ab_{ij} = interaction of i^{th} preparation method and j^{th} additive level

e_{ij} = random error

Means for the interaction between physical preparation method and additive level were the only data presented for results of chemical composition and degradability of the four pre - ensiled forage treatments. The means were compared using GLM (PDIFF) procedure to test the differences between the pre ensiled forage treatment means.

The mathematical model used for analysis of effects of the three factors studied on quality, feeding value and costs of producing napier silage was:

$$Y_{ijk} = \mu + a_i + b_j + c_k + ab_{ij} + ac_{ik} + bc_{jk} + abc_{ijk} + e_{ijk}$$

where:

Y_{ijk}	=	quality attributes of napier silage: chemical composition, *in vitro* DM and OM digestibility, pH, fermentation products, sensoric quality scores, dry matter losses, DM degradability, together with costs analysis data
μ	=	fixed general effect
a_i	=	efect of i^{th} type of silo (earth pit: concrete)
b_j	=	effect of j^{th} pre ensiling preparation method (chopped: unchopped)
c_k	=	effect of k^{th} additive level (3%molasses: 0%molasses)
ab_{ij}	=	interaction of i^{th} silo and j^{th} pre ensiling physical preparation
ac_{ik}	=	interaction of i^{th} silo and k^{th} additive level

bc_{jk} = interaction of j^{th} pre ensiling physical preparation and k^{th} additive level

abc_{ijk} = interaction of i^{th} silo, j^{th} pre ensiling physical preparation and k^{th} additive level

e_{ijk} = random error

Data for effect of the three factors studied on rate of intake of napier silage by heifers were analysed separately using the following mathematical model:

$$Y_{ijkl} = \mu + a_i + b_j + c_k + d_l + ab_{ij} + ac_{ik} + bc_{jk} + abc_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = rate of intake of napier silage by heifers

μ = fixed general effect

a_i = effect of i^{th} type of silo on silage intake rate

b_j = effect of j^{th} pre ensiling preparation method on silage intake rate

c_k = effect of k^{th} additive level on silage intake rate

d_l = effect of l^{th} heifer on silage intake rate

ab_{ij} = interaction effect of i^{th} silo and j^{th} pre ensiling physical preparation

ac_{ik} = interaction effect of i^{th} silo and k^{th} additive level

bc_{jk} = interaction effect of j^{th} pre ensiling physical preparation and k^{th} additive level

abc_{ijk} = interaction effect of i^{th} silo, j^{th} pre ensiling physical preparation and k^{th} additive level

e_{ijkl} = random error

The F - ratios were used to test any significant between the main effects for the factors studied, and the mean values with different superscripts (a, b) within the same row were reported to be significantly different ($P < 0.05$). The means for interaction effects were compared using GLM (PDIFF) procedure to test the difference between the interaction means, through which the differences were tested at $P < 0.05$.

4. RESULTS

4.1 Chemical composition, *in vitro* dry matter and organic matter digestibility of napier grass at the time of harvest and ensiling

Mean chemical composition of fresh napier grass at the time of harvesting and that of different treatments to be ensiled in earth pits and concrete silos are shown in Table 4.1. The dry matter contents of the fresh forage at harvesting, 5cm chopped and unchopped napier grass treatments without molasses (T2 - CW and T4 - UW) were almost similar and significantly ($P < 0.05$) lower than that observed on 5cm chopped and unchopped treatments with 3% molasses (T1 - CM and T3 - UM), respectively.

The mean crude protein contents of the fresh napier grass at harvest and all the pre - ensiled forage treatments (T1 - CM, T2 - CW, T3 - UM and T4 - UW) showed very minor variations, similar trend was also observed for the ether extract, ash and the fibre components as measured in terms of NDF, ADF and ADL fractions. Results show significantly ($P < 0.05$) higher content of water soluble carbohydrates in pre ensiled napier grass T1 - CM and T3 - UM, with the least values observed in T2 - CW, T4 - UW and freshly harvested napier grass.

Table 4.1 Mean chemical composition, *in vitro* dry matter and organic matter digestibility of napier grass at the time of harvesting and ensiling

Forage	DM (%)	CP	EE	Ash	NDF	ADF	ADL	WSC	IVDMD (%)	IVOMD (%)
		Parameter $gkg^{-1}DM$								
Napier grass (at harvest)	16.0	71.9	12.2	125.7	561.5	341.5	36.8	29.0	57.1	57.2
Napier grass (treatments ensiled)										
T1 - CM	18.3 [a]	71.8	10.7	132.0	566.6	341.8	36.2	54.5 [a]	64.9 [a]	64.2 [a]
T2 - CW	16.1 [c]	71.7	11.5	125.6	562.5	340.4	37.2	29.2 [b]	56.9 [b]	56.7 [b]
T3 - UM	17.8 [b]	71.2	10.5	127.8	553.7	341.5	37.7	43.8 [a]	61.5 [a]	62.9 [a]
T4 - UW	16.1 [c]	71.3	12.0	124.1	560.4	342.6	36.4	29.3 [b]	57.2 [b]	57.4 [b]
SEM	0.15	0.93	0.60	3.92	11.24	5.88	0.70	4.32	2.09	1.83

Note: T1 - CM - 5cm chopped grass. with 3% molasses; T2 - CW - 5cm chopped grass. 0% molasses; T3 - UM - unchopped grass. with 3% molasses; T4 - UW - unchopped grass, 0% molasses

n = 6 per treatment

SEM - standard error of the mean

a.b.c - mean values within the same column followed by different superscripts are significantly different ($P < 0.05$)

Significantly ($P < 0.05$) higher mean IVDMD and IVOMD percentage values were observed in T1 - CM, and T3 - UM, in comparison with the pre ensiled napier grass T2 - CW and T4 - UW and the freshly harvested grass.

4.2 Rumen dry matter degradability of the pre ensiled treatments of napier grass

Mean values of dry matter degradability characteristics, degradation rate, effective degradability and 48 hours dry matter degradability percentages of the pre ensiled treatments of napier grass (T1 - CM, T2 - CW, T3 - UM and T4 - UW) are shown in Table 4.2 and Figure 1.

The effective DM degradability measured at an out flow rate of 0.01 for forages and 48 hours DM degradability values were significantly ($P < 0.05$) higher for napier grass T1 - CM and T3 - UM than in T2 - CW and T4 - UW, respectively. Results also indicated significantly ($P < 0.05$) higher rates of degradation "C" and higher content of soluble materials as indicated by "A" fraction, in 3% molasses added treatments (T1 - CM and T3 - UM) compared to the forage treatments without additive (T2 - CW and T4 - UW). In contrast the proportion of insoluble but actual rumen degradable materials "B" was significantly ($P < 0.05$) higher in ensiled forage T2 - CW and T4 - UW than T1 - CM and T3 - UM, respectively.

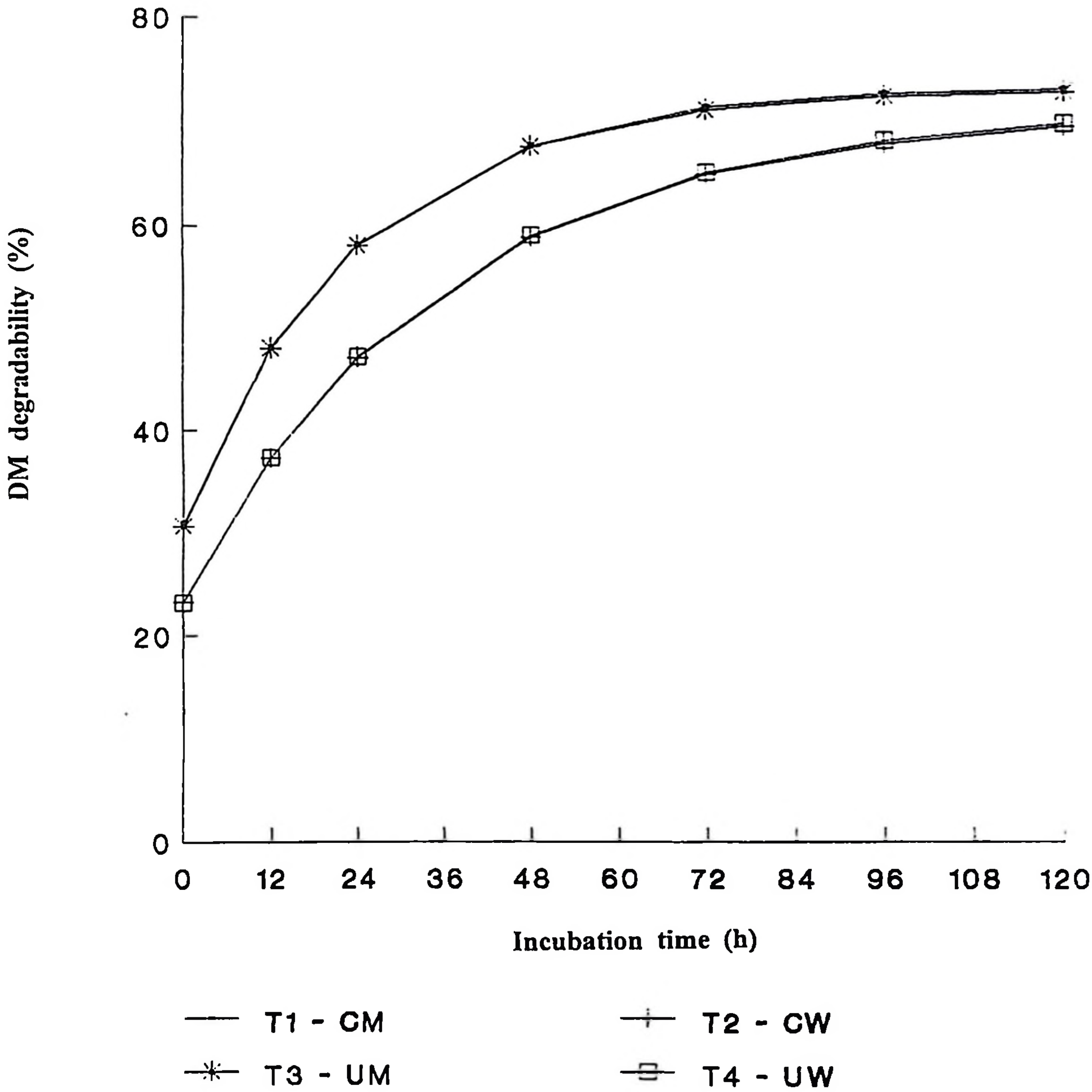
Table 4.2 Mean degradability characteristics of DM, effective degradability and 48 hours DM degradability of the various treatments of napier grass at pre ensiling

Forage treatment	Parameters					
	Degradability constants					
	A	B	A + B	C	Effective degradability (%)	48 h DMD (%)
Napier grass:						
T1 - CM	30.9^{a}	42.0^{b}	72.9^{a}	0.044^{a}	65.1^{a}	67.7^{a}
T2 - CW	23.4^{b}	47.3^{a}	70.7^{a}	0.029^{b}	58.5^{b}	58.8^{b}
T3 - UM	30.7^{a}	41.9^{b}	72.6^{a}	0.045^{a}	64.9^{a}	67.5^{a}
T4 - UW	23.2^{b}	47.8^{a}	71.0^{a}	0.029^{b}	58.7^{b}	58.9^{b}
SEM	1.04	0.96	0.80	0.0019	0.81	1.03

T1 - CM, T2 - CW, T3 - UM and T4 - UW - see footnote on Table 4.1 above

n = 6 per treatment

SEM - standard error of the means
a,b - mean values within the same column followed by different superscripts are significantly different ($P < 0.05$)



Note: T1 - CM & T3 - UM - were almost equal;
T2 - CW & T4 - UW -were almost equal

Figure 1: Degradability of pre - ensiled treatments of napier grass

4.3 Effects of pre ensiling physical preparation (chopping), additive (molasses) and type of silo on quality of napier silage

Effects for pre - ensiling physical preparation of the forage materials (chopping), additive and silo type were tested with respect to silage chemical composition, *in vitro* dry matter and organic matter digestibilities, concentration of fermentation products, arbitrary sensoric qualities, dry matter losses, intake rate (acceptability), dry matter degradability characteristics, effective degradability and 48 hours dry matter degradability percentage. The results of the least square means (LSM), standard error of the means (SEM) and probability levels for these parameters are presented in Tables 4.3 - 4.17, along with appendices 5.3 - 5.7. Further more different patterns of *in sacco* rumen degradation of napier silage as influenced by the above mentioned factors are shown in Figures 2 - 4, respectively.

4.3.1 Effects of pre - ensiling physical preparation (chopping)

Results for the effects of pre - ensiling physical preparation (chopping) of forage on chemical composition, *in vitro* DM and OM digestibilities, fermentation products, sensoric qualities, DM losses, intake rate, DM degradability characteristics, effective degradability and 48 hours *in sacco* DMD of napier silage are given in Tables 4.3, 4.4, 4.5, 4.6 and 4.7 respectively, along with Figure 2.

Pre chopping showed significant effects on chemical composition, *in vitro* DM and OM digestibilities of napier silage, except for the ash content. Chopping of napier grass to about 5cm length produced silage with significantly higher contents of dry matter (P < 0.05), crude protein (P< 0.001). ether extracts (P < 0.001) and water soluble carbohydrates (P < 0.01). Again, *in vitro* DM and OM digestibility percentage values were significantly (P < 0.001) highest for 5cm chopped napier silage than unchopped (long) silage. In contrast silage from unchopped grass had significantly (P < 0.05) higher concentrations of NDF and ADF and ADL (at P < 0.01) than 5 cm chopped napier silage. The amount of ash in 5 cm chopped silage was slightly higher than for unchopped silage although the difference was not statistically significant. But yet the crude protein, ash, WSC contents and *in vitro* DM and OM digestibility on both chopped and unchopped napier silages were lower than that of original ensiled forage treatments, while the DM increased slightly and EE, NDF, ADF and ADL values (per kgDM) being abit higher in chopped and unchopped silages than in the original ensiled forage. The results for pH and concentration of fermentation products (lactic, acetic, propionic and butyric acids and ammonia - N expressed as a percent of total N) indicated significant difference (P < 0.001) between the 5 cm chopped and unchopped napier silages respectively. Lower levels of pH, ammonia - N, butyric acid and propionic acid were observed for chopped napier silage than unchopped silage, whereas the lactic and acetic acid concentrations were higher in chopped silage than in unchopped silage.

In general 5cm chopped napier silage preserved well than unchopped silage. This was indicated by significantly higher (P < 0.001) mean score values for appearance, smell, texture and total sensoric quality for the 5 cm chopped napier silage compared to unchopped silages (Table 4.5 and Plates 3, 4, 5 and 6). The appearance for chopped napier silages was better than that of unchopped silage. Again, chopped silage happened to have pleasant estery aroma and non slippery texture, while unchopped silages had a slight pungent smell and slimy texture when felt between hands. The dry matter losses expressed as a percent of original forage ensiled was significantly ($P < 0.01$) lower, while it's reciprocal value for amount of useful silage significantly ($P < 0.01$) higher in chopped silage than in unchopped napier silage.

The dry matter intake rate in grams per minute was significantly ($P < 0.01$) higher for chopped than unchopped napier grass silage. Similar trend was also observed on intake rate as fed in g/min although the differences were not statistically significant.

The proportion of soluble materials "A" in chopped napier silage was significantly ($P < 0.001$) higher than in unchopped napier silage while the insoluble but potentially degradable fraction "B", was significantly ($P < 0.05$) higher in unchopped napier silage. However, the potential degradability which is the summation of A and B did not differ significantly between the chopped and unchopped napier silages. On the other hand the rate of degradation of chopped napier silage was slightly higher than for unchopped silage, though their differences were not statistically significant. The noted differences on the pattern of degradation between the chopped and unchopped napier silages are also summarized in Figure 2. The 48h DM degradability and effective DM degradability were significantly (P < 0.01) higher for chopped napier silage compared with the unchopped silage. These values however were lower than those of their corresponding fresh material.

Table 4.3 Effects of pre ensiling physical preparation (chopping) of the forage material on chemical composition, *in vitro* dry matter and organic matter digestibility of napier silage

Parameter	5 cm Chopped	Unchopped	SEM	Prob. level	Sign. level
DM (%)	18.4^{a}	17.1^{b}	0.31	.0189	*
g kg^{-1} DM:					
CP	61.1^{a}	54.9^{b}	0.57	.0001	***
Ash	121.8^{a}	119.8^{a}	2.37	.5668	N.S
E.E	28.9^{a}	23.4^{b}	0.31	.0001	***
NDF	630.9^{b}	674.6^{a}	10.70	.0206	*
ADF	402.6^{b}	444.3^{a}	8.50	.0298	*
ADL	49.8^{b}	60.9^{a}	2.18	.0067	**
WSC	17.8^{a}	13.2^{b}	0.71	.0018	**
IVDMD (%)	51.8^{a}	40.4^{b}	1.06	.0001	***
IVOMD (%)	52.3^{a}	41.4^{b}	0.92	.0001	***

n - 8 per treatment

SEM - Standard error of the means.

*** - Significantly different (P< 0.001)

** - Significantly different (P<0.01)

* - Significantly different (P<0.05)

N.S - Not significant (P>0.05)

a,b - Mean values within the same row followed by different superscripts are significantly different (P<0.05)

Table 4.4 Effects of pre ensiling physical preparation (chopping) on the fermentation products of napier silage

Parameter	5cm chopped	Unchopped	SEM	Prob. level	Sign. level
pH	3.99^{b}	4.65^{a}	0.008	0.0001	***
NH_3 N (%)	4.03^{b}	6.37^{a}	0.293	0.0005	***
VFA's (gkg^{-1} DM):					
Lactic acid	37.3^{a}	14.2^{b}	0.77	0.0001	***
Acetic acid	38.5^{a}	21.8^{b}	0.73	0.0001	***
Propionic acid	1.7^{b}	3.7^{a}	0.23	0.0003	***
Butyric acid	2.6^{b}	7.5^{a}	0.29	0.0001	***

n (pH) = 24 per treatment

n (fermentation acids and ammonia - N) = 8

SEM - standard error of the means

*** - significantly different ($P < 0.001$)

a,b - mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

Table 4.5 Effects of pre ensiling physical preparation (chopping) on sensoric quality of napier silage. (Condition score)

Parameter	5 cm chopped	Unchopped	SEM	Prob. level	Sign. Level
Appearance	3.3^a	2.6^b	0.06	0.0001	***
Smell	3.0^a	2.1^b	0.06	0.0001	***
Texture	2.7^a	1.7^b	0.05	0.0001	***
Total Score	8.9^a	6.4^b	0.12	0.0001	***

n - 40 per treatment

Scores used: 1 - Poor; 2 - Moderate; 3 - Good; 4 - Very good

SEM - Standard error of the means.

*** - Significantly different (P< 0.001)

a,b - Mean values within the same row followed by different superscripts are significantly different (P<0.05)

Table 4.6 Effects of pre ensiling physical preparation (chopping) on dry matter losses of napier silage

Parameter	5cm chopped	Unchopped	SEM	Prob. level	Sign. level
DM forage ensiled (kg)	88.7	87.5			
DM silage recovered (kg)	73.4	65.3	0.82	-	-
DM loss (kg)	15.3	22.2	0.82	-	-
DM loss as % of forage ensiled	17.4^{b}	25.7^{a}	0.89	0.0029	**
kgDM:					
silage recovered	73.4	65.3	0.82	-	-
spoiled silage	2.6	5.4	0.47	-	-
useful silage	70.8	59.9	1.04	-	-
DM useful silage as % of silage recovered	96.3^{a}	91.4^{b}	0.80	0.0075	**

n = 6 per treatment
SEM - standard error of the means
** - significantly different ($P < 0.01$)
a,b - mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

Table 4.7 Effects of pre ensiling physical preparation (chopping) on intake rate, dry matter degradability characteristics, effective degradability and 48 hours dry matter degradability of napier silage

Parameter	5cm chopped	Unchopped	SEM	Prob. level	Sign. level
Intake rate (gfresh/ min.)	153.3^{a}	137.4^{a}	6.0	0.0684	N.S
Intake rate (g DM/min.)	28.4^{a}	23.3^{b}	1.05	0.0017	**
DM degradability characteristics					
A	17.2^{a}	13.2^{b}	0.37	0.0001	***
B	48.3^{b}	52.1^{a}	1.01	0.0298	*
A+B	65.5^{a}	65.3^{a}	0.98	0.9012	N.S
C	0.033^{a}	0.025^{a}	0.004	0.1667	N.S
Effective degradability	53.6^{a}	49.6^{b}	0.57	0.0011	**
48 h DMD (%)	54.6^{a}	48.3^{b}	1.23	0.0071	**

n (intake rate) = 24 per treatment; n (degradability parameters) = 8 per treatment
SEM - Standard error of the means.
*** - Significantly different ($P < 0.001$)
** - Significantly different ($P<0.01$)
* - Significantly different ($P<0.05$)
N.S - Not significant ($P>0.05$)
a,b - Mean values within the same row followed by different superscripts are significantly different ($P<0.05$)

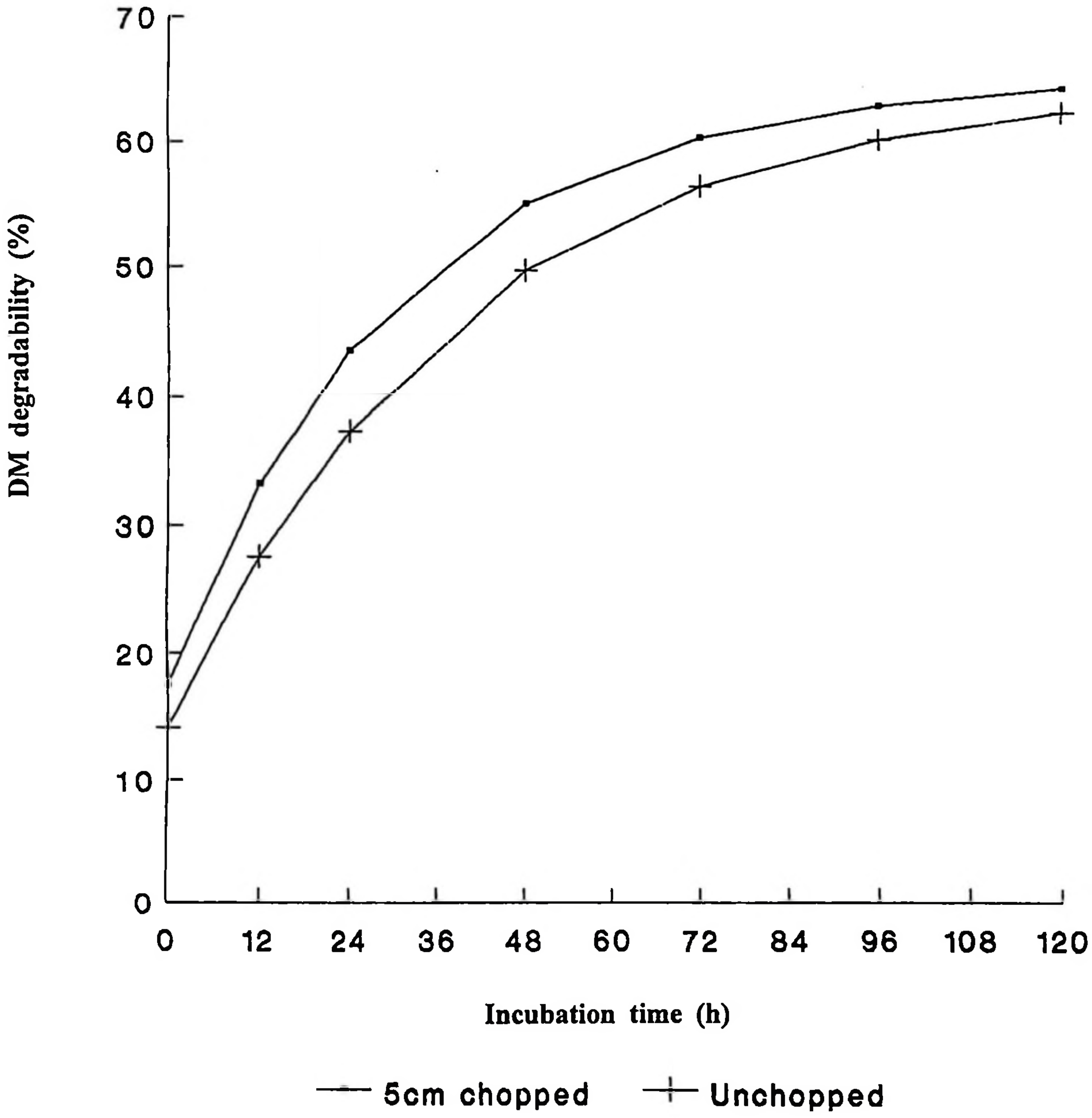


Figure 2: Effect of pre - ensiling physical preparation on degradability of napier silage

4.3.2.Effects of additive (molasses)

Results for the effect of additive (molasses) on chemical composition, *in vitro* dry matter and organic matter digestibility, fermentation products, sensoric qualities, dry matter losses, intake rate, dry matter degradability characteristics, effective degradability and 48 hours *in sacco* DM degradability of napier silage are given in Tables 4.8, 4.9, 4.10, 4.11 and 4.12 as well as Figure 3.

Addition of 3% molasses showed significant effects on chemical composition, *in vitro* dry matter and organic matter digestibilities of napier silage except for the ash, NDF and ADF components. Significantly ($P < 0.01$) higher dry matter and crude protein, as well as higher ($P < 0.001$) ether extracts, water soluble carbohydrates, *in vitro* dry matter and organic matter digestibilities were observed in silages treated with 3% molasses than in untreated napier silage. The ash content in 3% molasses added napier silage was slightly higher than in unmolassesed napier silage. On the other hand, the NDF and ADF values in untreated napier silage were slightly higher and ADL significant ($P < 0.05$) higher than in 3% molasses treated napier silage. Inspite of having high DM, EE and cell wall materials, molasses treated and untreated napier silages had a bit lower crude protein, ash, WSC's contents and *in vitro* DM and OM digestibilities than the original ensiled material with the lowest values observed on unmolassesed silages.

The pH value, concentration of ammonia - N, propionic acid and butyric acid were significantly (P < 0.001) lower in 3% molasses added silages than in untreated napier silages. In contrast lactic and acetic acid concentrations were significantly (P < 0.001) higher in 3% molasses added napier silage than in untreated napier silages.

Addition of 3% molasses significantly (P < 0.001) increased the mean score values for the appearance, smell, texture and overall total sensoric quality of napier silage. This was confirmed by yellowish green to brownish colour (Plate 3) and sweet estery aroma coming from the 3% molasses treated silages while unmolassesed silage was mostly dominated by pungent smell of ammonia, a blackish green colour with more patches of mould grown on the uppermost surfaces and corners of the silos (Plates 4 and 6). At the same time, the molasses treated silage had slightly firm texture than that observed on the tissues of untreated napier silage.

The dry matter losses expressed as a percent of fresh forage ensiled was observed to be significantly (P < 0.05) lower in 3% molasses added napier silage than in untreated napier silage. On the other hand, the total amount of DM of useful silage as a percentage of silage recovered was significantly (P < 0.05) higher in 3% molasses treated napier silage than in untreated silage. Significantly (P < 0.001) higher proportion of soluble materials were found in 3% molasses treated napier silage, while the insoluble but actual rumen degradable materials "B", potential degradability "A + B" and degradation rates did not differ significantly between the 3% molasses treated and untreated napier silage. The potential degradability and rate of degradation of 3% molasses treated napier silage in the rumen of steers were slightly higher compared with the untreated napier silage.

As a consequence the effective DM degradability was significantly ($P < 0.01$) increased and 48 hours *in sacco* dry matter degradability percent was a bit high for 3% molasses treated napier silage in comparison with untreated napier silage. Similarly DM intake rate was significantly ($P < 0.001$) higher in molasses treated than untreated napier silage with values of 29.2 and 22.5 g DM min^{-1} respectively.

Table 4.8 Effects of additive (molasses) on chemical composition, *in vitro* dry matter and organic matter digestibility of napier silage

Parameter	3% Molasses	0% Molasses	SEM	Prob. level	Sign. level
DM (%)	18.6[a]	16.9[b]	0.31	0.0042	**
g kg^{-1} DM:					
CP	59.5[a]	56.5[b]	0.57	0.0056	**
Ash	122.6[a]	118.9[a]	2.37	0.3168	N.S
E.E	29.0[a]	23.3[b]	0.31	0.0001	***
NDF	644.3[a]	661.2[a]	10.70	0.2957	N.S
ADF	410.9[a]	426.1[a]	8.50	0.0896	N.S
ADL	49.9[b]	60.7[a]	2.18	0.0084	*
WSC	19.3[a]	11.7[b]	0.71	0.0001	***
IVDMD (%)	50.1[a]	42.1[b]	1.06	0.007	***
IVOMD (%)	50.7[a]	43.0[b]	0.93	0.004	***

n = 8 per treatment

SEM - Standard error of the means.

*** - Significantly different (P< 0.001)

** - Significantly different (P<0.01)

* - Significantly different (P<0.05)

N.S - Not significant (P>0.05)

a,b - Mean values within the same row followed by different superscripts are significantly different (P<0.05)

Table 4.9 Effects of additive (molasses) levels on the fermentation products of napier silage

Parameter	3% Molasses	0% Molasses	SEM	Prob. level	Sign. level
pH	4.21^b	4.43^a	0.008	.0001	***
NH_3-N (%)	4.09^b	6.31^a	0.300	.0007	***
VFA's ($g\ kg^{-1}DM$):					
Lactic acid	36.8^a	14.7^b	0.77	.0001	***
Acetic acid	40.3^a	20.1^b	0.73	.0001	***
Propionic acid	1.9^b	3.5^a	0.23	.001	***
Butyric acid	3.8^b	6.4^a	0.29	.0003	***

n (pH) = 24 per treatment

n (Ammonia - N and fermentation acids) = 8

SEM - Standard error of the means.

*** - Significantly different ($P < 0.001$)

a,b - Mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

Table 4.10 Effects of additive (molasses) on sensoric quality of napier silage (condition scores)

Parameter	3% Molasses	0% Molasses	SEM	Prob. level	Sign. level
Appearance	3.3^{a}	2.5^{b}	0.059	0.0001	***
Smell	2.9^{a}	2.3^{b}	0.061	0.0001	***
Texture	2.4^{a}	1.9^{b}	0.056	0.0001	***
Total Score	8.6^{a}	6.7^{b}	0.115	0.0001	***

n = 40 per treatment

Scores used : 1 - Poor; 2 - Moderate; 3 - Good: 4 - Very good

SEM - Standard error of the means.

*** - Significantly different (P< 0.001)

a,b - Mean values within the same row followed by different superscripts are significantly different (P<0.05)

Table 4.11 Effect of additive (molasses) on dry matter losses of napier silage

Parameter	3% molasses	0% Molasses	SEM	Prob. level	Sign. level
DM forage ensiled (kg)	95.7	80.6			
DM silage recovered (kg)	77.5	61.2	0.82	-	-
DM Loss (kg)	18.2	19.4	0.82	-	-
DM loss as % of forage ensiled	19.1[b]	24.0[a]	0.89	0.0164	*
kgDM: Silage recovered	77.5	61.2	0.82	-	-
Spoiled silage	3.2	4.8	0.47	-	-
Useful silage	74.3	56.4	1.04	-	-
DM of useful silage as % of silage recovered	95.8[a]	91.9[b]	0.80	0.0249	*

n = 6 per treatment

SEM - Standard error of the means.

* - Significantly different ($P<0.05$)

a,b - Mean values within the same row followed by different superscripts are significantly different ($P<0.05$)

Table 4.12 Effects of additive (molasses) on intake rate, DM degradability characteristics, effective degradability and 48 hours *in sacco* DM degradability of napier silage

Parameter	3% molasses	0% Molasses	SEM	Prob. level	Sign. level
Intake rate (gfresh/ min.)	156.4^{a}	134.3^{b}	6.00	0.0133	*
Intake rate (gDM/ min.)	29.2^{a}	22.5^{b}	1.05	0.0001	***
DM Degradability characteristics:					
A	17.2^{a}	13.1^{b}	0.37	0.0001	***
B	48.7^{a}	51.8^{a}	1.01	0.0631	N.S
A+B	65.9^{a}	64.9^{a}	0.98	0.4803	N.S
C	0.032^{a}	0.026^{a}	0.004	0.2958	N.S
Effective degradability (%)	53.2^{a}	49.9^{b}	0.57	0.004	**
48 h DMD (%)	53.4^{a}	49.5^{a}	1.23	0.0508	N.S

n (intake rate) = 24 per treatment: n (degradability parameters) = 8 per treatment
SEM - Standard error of the means.
*** - Significantly different (P< 0.001)
** - Significantly different (P<0.01)
* - Significantly different (P<0.05)
N.S - Not significant (P>0.05)
a.b - Mean values within the same row followed by different superscripts are significantly different (P<0.05)

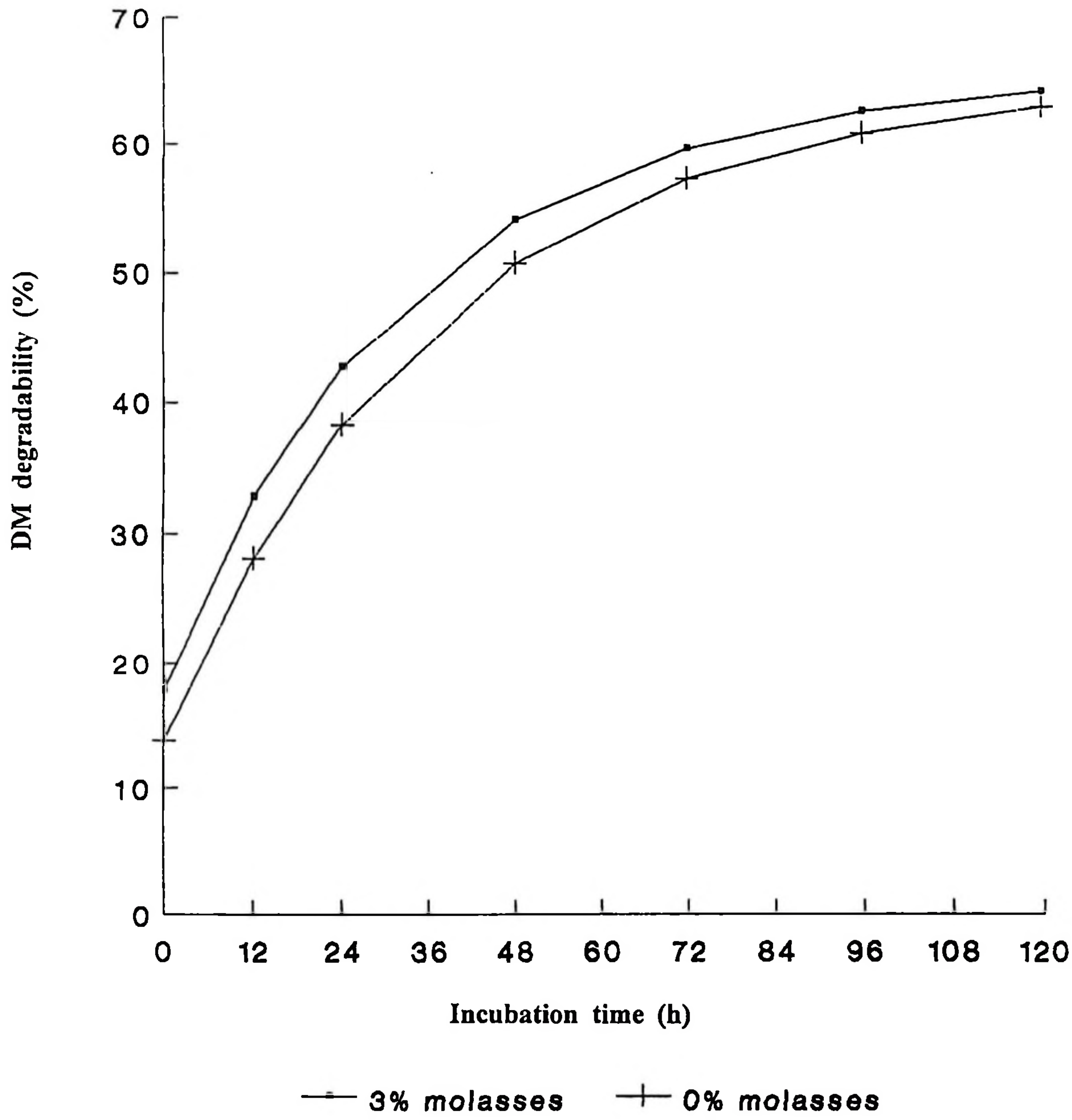


Figure 3: Effect of additive (molasses) level on degradability of napier silage

Plate 3. Chopped, molasses treated napier silage obtained in this study

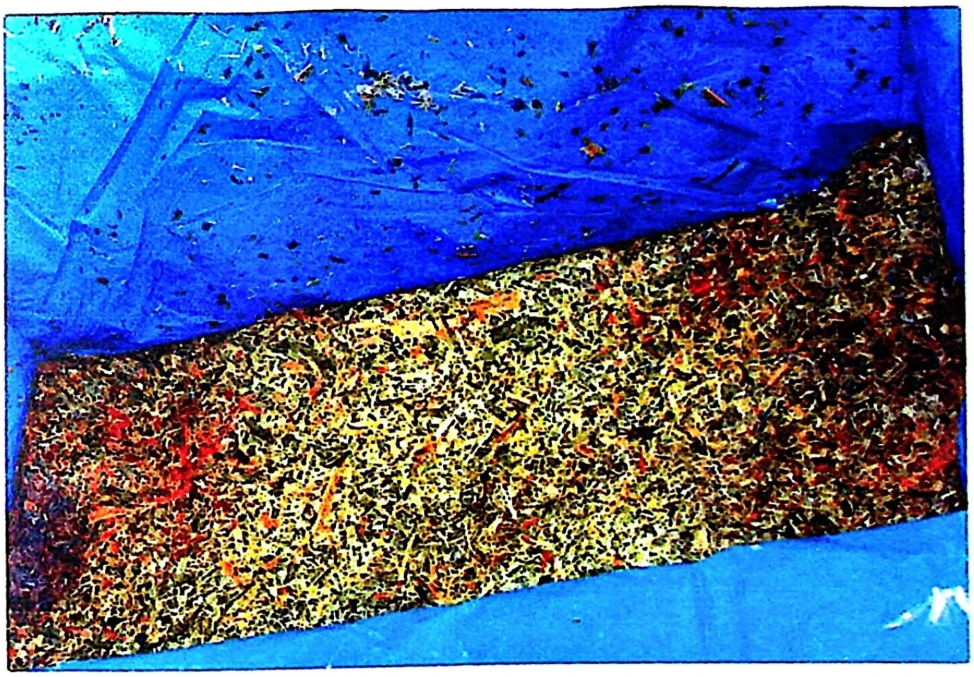


Plate 4. Chopped, unmolassesed napier silage obtained in this study

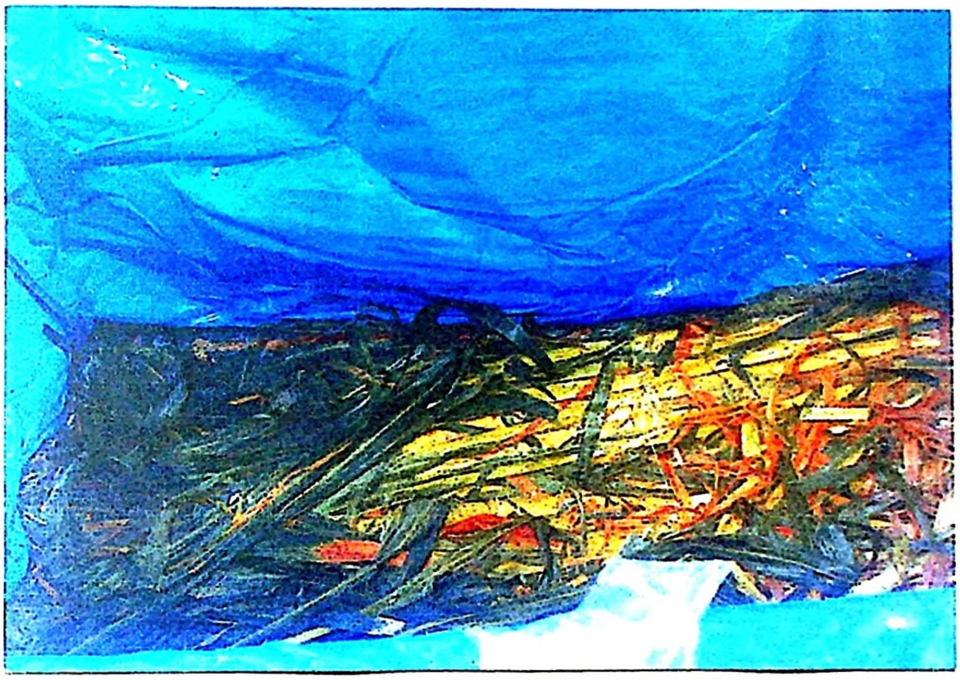


Plate 5. Long, molasses treated napier silage obtained in this study

Plate 6. Long, unmolassesed napier silage obtained in this study

4.3.3 Effects of type of silo

Effects of type of silo on chemical composition, *in vitro* dry matter and organic matter digestibilities, fermentation products, sensoric quality, dry matter losses, intake rate, dry matter degradability characteristics, effective degradability and 48 hours *in sacco* dry matter degradability of napier silage are shown in Tables 4.13, 4.14 4.15 4.16 4.17 and Figure 4 respectively.

The percentage dry matter content, crude protein, ash, *in vitro* dry matter and organic matter digestibilities of napier silage recovered from the earth pits revealed significantly ($P < 0.01$, $P < 0.001$, $P < 0.05$, $P < 0.01$ and $P < 0.05$ respectively) higher values than those observed for the silage recovered from the concrete silos. On the other hand, EE content was significant ($P < 0.05$) higher for silages obtained from the concrete than the earth pit silos, while NDF, ADF and ADL values of silages did not differ significantly between napier silage obtained in the two types of silos.

With the exception of the pH and concentration of acetic acid, the type of silo did not impart any significant effects on other organic acids and ammonia - N which determine the pattern of fermentation of napier silage in either earth pits or concrete silos. Napier silage recovered from the concrete silos showed slight but significant ($P < 0.001$) higher pH and acetic acid concentration than that from the earth pit silos. The concentration of butyric acid was slightly higher for silage recovered from the concrete silos although the differences were not statistically significant.

In general the overall sensoric quality measured in terms of appearance, smell, texture and overall total condition score was significantly ($P < 0.001$) better for napier silage obtained from the earth pits than the concrete silos. Again the percentage dry matter losses for napier silage recovered from the earth pit silos was lower than that observed from the concrete silos although the differences were not statistically significant.

In case of the parameters which measured the feeding value of napier silage intake rate, proportion of insoluble but rumen degradable material, potential degradability and rate of degradation did not differ significantly between silages produced in either of the two types of silos. However, the proportion of soluble materials, effective degradability and 48 hours *in sacco* DMD percentages were significantly ($P < 0.001$, $P < 0.001$ and $P < 0.05$, respectively) higher for napier silage recovered from the earth pit silos than concrete silos.

Table 4.13 Effect of silo type on chemical composition *in vitro* dry matter and organic matter digestibility of napier silage

Parameter	Earth Pit	Concrete Silo	SEM	Prob. Level	Sign. level
DM (%)	18.7^a	16.9^b	0.31	0.0033	**
g kg^{-1} DM:					
CP	61.6^a	54.4^b	0.57	0.0001	***
Ash	126.2^a	115.4^b	2.37	0.0119	*
E.E	25.4^b	26.8^a	0.31	0.0118	*
NDF	648.1^a	657.4^a	10.74	0.5567	N.S
ADF	417.2^a	434.4^a	8.55	0.2015	N.S
ADL	52.2^a	58.5^a	2.18	0.0769	N.S
WSC	15.9^a	15.1^a	0.71	0.4791	N.S
IVDMD (%)	48.7^a	43.5^b	1.06	0.0089	**
IVOMD (%)	48.9^a	44.8^b	0.93	0.0141	*

n = 8 per treatment silo

SEM - Standard error of the means.

*** - Significantly different (P< 0.001)

** - Significantly different (P<0.01)

* - Significantly different (P<0.05)

N.S - Not significant (P>0.05)

a,b - Mean values within the same row followed by different superscripts are significantly different (P<0.05)

Table 4.14 Effects of type of silo on the fermentation products of napier silage

Parameter	Earth Pit	Concrete Silo	SEM	Prob. level	Sign. level
pH	4.28[b]	4.35[a]	0.008	.0001	***
NH_3-N (%)	5.27[a]	5.12[a]	0.293	.7241	N.S
VFA's ($g\ kg^{-1}DM$):					
Lactic acid	25.9[a]	25.6[a]	0.77	.7095	N.S
Acetic acid	26.3[b]	34.1[a]	0.73	.0001	***
Propionic acid	2.5[a]	2.9[a]	0.23	.2585	N.S
Butyric acid	4.8[a]	5.3[a]	0.29	.2574	N.S

n (pH) = 24 per treatment silo

n (fermentation parameters) = 8 per treatment silo

SEM - Standard error of the means.
*** - Significantly different ($P< 0.001$)

N.S - Not significant ($P>0.05$)

a,b - Mean values within the same row followed by different superscripts are significantly different ($P<0.05$)

Table 4.15 Effects of type of silo on sensoric quality of napier silage (condition scores)

Parameter	Earth pit	Concrete	SEM	Prob. level	Sign. level
Appearance	3.1^{a}	2.7^{b}	0.06	0.0001	***
Smell	2.7^{a}	2.4^{b}	0.06	0.0001	***
Texture	2.4^{a}	1.9^{b}	0.05	0.0001	***
Total score	8.3^{a}	7.0^{b}	0.12	0.0001	***

n = 40 per treatment silo

Score used : 1 - Poor; 2 - Moderate; 3 - Good; 4 - Very good

SEM - standard error of the means

*** - significantly different ($P < 0.001$)

a,b - mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

Table 4.16 Effect of type of silo on dry matter losses of napier silage

Parameter	Earth pit	SEM	Concrete silo	SEM	Prob. level	Sign. level
DM forage ensiled (kg)	88.1		88.1			
DM silage recovered (kg)	70.6	0.67	68.1	0.94	-	-
DM Loss (kg)	17.5	0.67	20.0	0.94	-	-
DM loss as % of forage ensiled	20.1^{a}	0.72	23.0^{a}	1.02	0.0807	N.S
kgDM: Silage recovered	70.6	0.67	68.1	0.94	-	-
Spoiled silage	4.8	0.39	3.2	0.55	-	-
Useful silage	65.8	0.84	64.9	1.20	-	-
DM of useful silage as % of silage recovered	92.8^{a}	0.63	94.9^{a}	0.89	0.1245	N.S

n (earth pits) = 8

n (concrete silos) = 4

SEM - Standard error of the means.

N.S - Not significant (P>0.05)
a - Mean values within the same row followed by similar superscripts are not significantly different (P>0.05)

Table 4.17 Effect of type of silo on intake rate, dry matter degradability characteristics, effective degradability and 48 hours dry matter degradability of napier silage

Parameter	Earth pit	Concrete silo	SEM	Prob. Level	Sign. level
intake rate (gfresh/ min.)	136.8^{a}	153.9^{a}	6.00	0.0503	N.S
Intake rate					
(gDM/ min.)	25.7^{a}	25.9^{a}	1.05	0.8452	N.S
DM Degradability characteristics:					
A	17.1^{a}	13.3^{b}	0.37	0.0001	***
B	49.4^{a}	51.0^{a}	1.01	0.2932	N.S
A+B	66.5^{a}	64.4^{a}	0.98	0.1604	N.S
C	0.030^{a}	0.027^{a}	0.0040	0.6059	N.S
Effective degradability (%)	53.9^{a}	49.3^{b}	0.57	0.0005	***
48 h DMD (%)	54.3^{a}	48.6^{b}	1.23	0.0108	*

n (intake rate parameters) = 24 per treatment; n (degradability parameters) = 8 per treatment

SEM - Standard error of the means.

*** - Significantly different ($P< 0.001$)

* - Significantly different ($P<0.05$)

N.S - Not significant ($P>0.05$)

a,b - Mean values within the same row followed by different superscripts are significantly different ($P<0.05$)

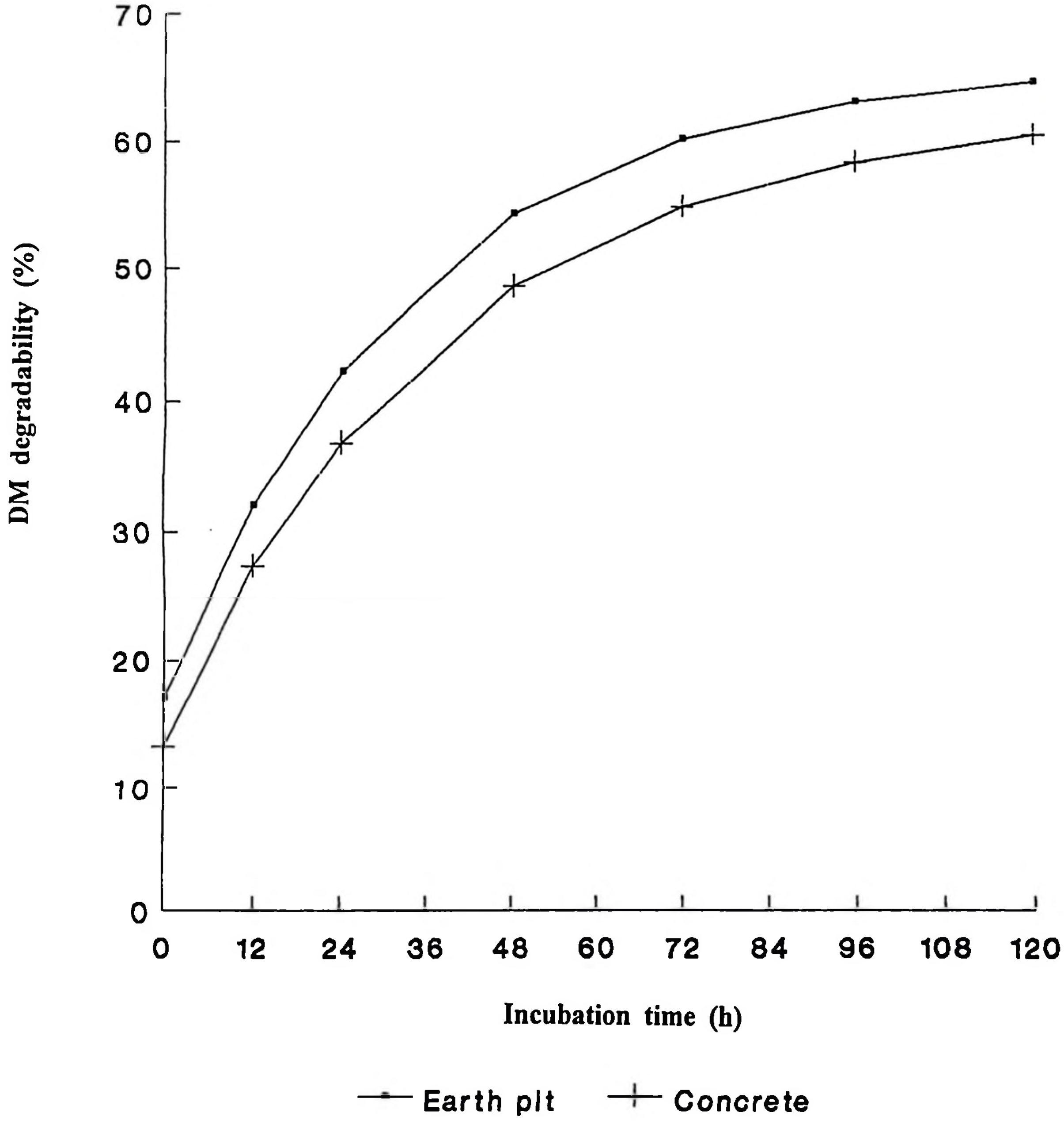


Figure 4: Effect of type of silo on degradability of napier silage

4.4 Interactions

Significant interaction effects between the main factors studied on quality of napier silage were observed in some of the parameters investigated (appendices 5.3. 5.4. 5.5 and 5.7). These parameters included ether extracts content, pH, concentration of acetic. lactic and butyric acids, smell, texture, total quality score, proportion of undegradable soluble materials (A) and effective DM degradability percentages. These results are presented in terms of the least square means (LSM) and standard error of the means for parameters which show specific interactions between the main effects (factors) studied as shown in Tables 4.18 - 4.21. Differences between the interaction means were tested at 0.05 probability level of the least significance differences (LSD) between means.

4.4.1 Effects of pre ensiling physical preparation and additive level on pH, ether extracts, lactic, acetic and butyric acids concentrations of napier silage

Results for combined effects of pre ensiling physical preparation and additive level on pH, ether extracts, lactic, acetic and butyric acids concentration are presented in Table 4.18.

The pH value and concentration of butyric acid were significantly lower ($P < 0.05$) for 5cm chopped napier silage treated with 3% molasses than in unchopped silage with molasses. However addition of 3% molasses in unchopped silage also showed to have significant but lower effect on the silage pH but none was observed on butyric acid concentration. Again the concentration of lactic acid was significantly ($P < 0.05$)

higher in napier silage treated with 3% molasses when the forage material were pre - chopped than if they were not chopped at the time of ensilage. On the other hand concentration of acetic acid and EE values were significantly (P < 0.05) increased by addition of 3% molasses in chopped napier silage. Irrespective of this however, addition of 3% molasses showed significant (P < 0.05) slightly lower effect on acetic acid and EE content in unchopped napier silage.

4.4.2 Effects of type of silo and pre ensiling physical preparation on pH, smell, texture, total quality score and proportion of soluble materials (A) of napier silage

Results for effects of silo type and chopping on pH, smell, texture, total score and proportion of undegradable soluble materials of napier silage are shown in Table 4.19.

Chopping significantly (P < 0.05) lowered the pH of napier silage more for the silage produced in the earth pit silos than the concrete silos. The sensoric scores for texture and overall total physical quality were significantly (P < 0.05) higher for chopped napier silage obtained from the earth pits than concrete silos. Type of silo did not affect the sensoric scores for smell in chopped silage, but unchopped silage smelled better in earth pits than concrete silos. The same trend was also observed on the proportion of soluble undegradable materials in napier silage recovered from the earth pits and concrete silos. Nonetheless, even without chopping smell, texture total quality scores and percentages of soluble materials in the silages were found to be slightly, but significantly ($P < 0.05$) higher in napier silage recovered from the earth pit silos compared with the concrete silos.

4.4.3 Effects of type of silo and additive level on pH, acetic acid, smell and effective DM degradability of napier silage

Results for combined effects of addition of molasses and silo design on pH, acetic acid concentration, smell and effective DM degradability percentage of napier silage are shown in Table 4.20.

Addition of 3% molasses significantly ($P < 0.05$) lowered the pH of napier silage more for the silage obtained in the earth pits than concrete silos. On the other hand molasses treatment significantly ($P < 0.05$) increased the concentration of acetic acid in napier silage. The increase was more prominent for the silage obtained in the concrete silos than in earth pits. Inspite of above findings, molasses treatment did not show significant effect on effective DM degradability of napier silage produced from the earth pit silos. However, differences were obvious for napier silage obtained in the concrete silos whereby 3% molasses treatment significantly ($P < 0.05$) increased it's effective DM degradability by steers from 46.7 to 52.0 percent. Addition of molasses improved the smell of napier silage and the improvement was highest in silages obtained from the earth pits.

4.4.4 Effects of type of silo, pre ensiling physical preparation and additive level on pH, acetic acid concentration, smell and proportion of soluble materials (A) in napier silage

Combined effects of silo design, pre ensiling physical preparation (chopping) and additive level on pH, acetic acid concentration, smell and proportion of soluble materials in napier silage are summarized in Table 4.21. The pH values from 5cm chopped napier silage treated with 3% molasses was lowest and did not differ significantly between the silage recovered from the earth pits and concrete silos. Without addition of molasses however, chopped silage obtained from the earth pits had lower pH values compared with that produced from the concrete silos. In contrast, significantly ($P < 0.05$) higher pH values were observed for unchopped silage recovered from the silos either when the forage was treated with or not treated with 3% molasses at the time of ensiling. Chopped, molasses treated napier silage obtained from the earth pit silos had significantly ($P < 0.05$) higher score values for smell than that obtained in the concrete silos. The lowest score however was obtained on long unmolassesed silage obtained from both types of silos used.

The proportion of soluble materials (A) showed very minor differences between chopped molasses treated napier silage obtained from the pits and concrete silos. However the long unmolassesed silage from the concrete silos had significantly ($P < 0.05$) lowest proportion of soluble materials than that observed for the earth pits.

Table 4.18 Effects of pre ensiling physical preparation and additive level on pH, ether extracts, lactic, acetic and butyric acids concentration of napier silage

	Pre ensiling physical preparation				
	Unchopped		Chopped		
Item	0% molasses	3% molasses	0% molasses	3% molasses	SEM
pH	4.67[a]	4.63[b]	4.19[c]	3.79[d]	0.011
EE ($gkg^{-1}DM$):	21.2[c]	25.6[b]	25.3[b]	32.4[a]	0.44
VFA's ($gkg^{-1}DM$):					
Lactic acid	10.9[c]	17.5[b]	18.4[b]	56.2[a]	1.08
Acetic acid	9.9[d]	33.7[b]	30.2[c]	46.8[a]	1.03
Butyric acid	8.1[a]	7.0[a]	4.6[b]	0.7[c]	0.41

n (pH) = 12 per treatment

n (EE) = 4 per treatment

n (fermentation acids) = 4 per treatment

SEM - standard error of the means

a,b,c,d - mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

Table 4.19 Effects of type of silo and chopping on pH, smell, texture, total quality score and proportion of soluble materials (A) in napier silage

	Type of silo				
	Earth pit		Concrete		
Item	Unchopped	Chopped	Unchopped	Chopped	SEM
pH	4.69^{a}	3.89^{d}	4.62^{b}	4.09^{c}	0.011
Smell^{i}	2.4^{b}	3.0^{a}	1.9^{c}	2.9^{a}	0.09
Texture^{i}	2.0^{c}	2.8^{a}	1.4^{d}	2.5^{b}	0.08
Total score	7.2^{c}	9.4^{a}	5.6^{d}	8.4^{b}	0.16
A (%)	16.0^{b}	18.2^{a}	10.5^{c}	16.2^{b}	0.52

n (pH) = 12 per treatment

n (smell, texture and total score grades) = 20 per treatment

n (A) = 4 per treatment

i - score

SEM - standard error of the means

a,b,c,d - mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

Table 4.20 Effects of type of silo and additive level on pH, acetic acid, smell and effective DM degradability of napier silage

	Type of silo				
	Earth pit		Concrete		
Item	0% molasses	3% molasses	0% molasses	3% molasses	SEM
pH	4.33^{b}	4.18^{c}	4.53^{a}	4.24^{c}	0.011
Acetic acid (gkg^{-1}DM)	17.5^{d}	35.0^{b}	22.6^{c}	45.5^{a}	1.03
Smell[i]	2.3^{c}	3.2^{a}	2.2^{c}	2.6^{b}	0.09
ED (%)	53.3^{a}	54.5^{a}	46.7^{b}	52.0^{a}	0.81

n (pH) = 12 per treatment

n (acetic acid) = 4 per treatment

n (smell) = 20 per treatment

n (ED) = 4 per treatment

i - score

SEM - standard error of the means

a,b,c,d - same as described on the footnote on Table 4.18

Table 4.21 Effects of silo type, pre ensiling physical preparation and additive level on pH, acetic acid concentration, smell and proportion of soluble materials (A) in napier silage

Silo type	Physical preparation	Additive level	pH	Acetic acid gkg-1DM	Smell^{i}	A (%)
			Item			
Earth pit	Chopped	3% Molasses	3.81^{f}	43.4^{b}	3.6^{a}	18.8^{ab}
		0% Molasses	3.96^{e}	25.8^{d}	2.5^{c}	17.6^{b}
	Unchopped	3% Molasses	4.67^{ab}	26.6^{d}	2.8^{bc}	18.9^{ab}
		0% Molasses	4.70^{a}	9.2^{e}	2.1^{d}	12.9^{c}
Concrete	Chopped	3% Molasses	3.77^{f}	50.2^{a}	3.0^{b}	20.2^{a}
		0% Molasses	4.41^{d}	34.6^{c}	2.8^{bc}	12.1^{cd}
	Unchopped	3% Molasses	4.60^{c}	40.9^{b}	2.1^{d}	11.0^{cd}
		0% Molasses	4.64^{bc}	10.6^{e}	1.6^{e}	9.9^{d}
SEM			0.016	1.46	0.12	0.74

n (pH) = 6 per treatment; n (acetic acid) = 2 per treatment
n (smell) = 10 per treatment
n (A) = 2 per treatment
i - score
SEM - standard error of the means
a,b,c,d,e,f - mean values within the same column followed by different superscript are significantly different ($P < 0.05$)

4.5 Comparison of efficiency of applying different possible ensiling techniques (studied) to produce napier silage

Economic efficiency of various ensiling techniques studied were assessed in terms of costs per unit of useful silage dry matter recovered. The results obtained are summarized in Table 4.22. On average costs of producing 1kgDM of useful napier silage from various treatments ensiled in pit silos ranged between 202.80 - 255.30 Tsh/kgDM, these were significantly ($P < 0.05$) lower than a range of 762.20 - 1103.20 Tsh/kgDM incurred for the concrete silos. The higher costs experienced with the concrete silos were caused by the higher initial costs incurred for the concrete silos construction as itemized in appendix 6.

Furthermore, costs incurred under each treatment method applied differed significantly from the other. Nevertheless, expenses of production of 1kgDM of useful silage from T1 in pit silo did not differ significantly from T3 and T4 although it was significantly ($P < 0.05$) lower than T2. In concrete silos however costs of producing 1kgDM of useful silage from T1 was significantly ($P < 0.05$) lower than that incurred for other treatments (T2, T3 and T4). These were mainly attributed by the differences in amounts of useful silage obtained for each treatment method applied.

Table 4.22 Costs of preparing napier silage under the different ensiling techniques (studied) in relation with the dry matter of useful silage obtained

	Earth pit					Concrete silo				
Item	T1	T2	T3	T4	SEM	T1	T2	T3	T4	SEM
Total cost (Tsh)[p]	17,731.50	15,772.15	14,047.73	12,093.80	6.43	59,833.50	57,883.90	56,136.30	54,190.30	9.10
Amount of useful silage (kgDM)	80.2[a]	61.8[d]	69.3[c]	52.0[e]	1.7	78.5[ab]	62.7[cd]	69.2[bcd]	49.1[e]	2.4
Cost per unit useful silage obtained (Tsh/kgDM)	221.15[fg]	255.30[e]	202.80[g]	232.88[f]	5.55	762.20[d]	922.75[b]	810.86[c]	1103.20[a]	7.84

T1 - 5cm chopped grass with 3% molasses, T2 - 5cm chopped grass without molasses.
T3 - unchopped grass with 3% molasses and T4 - unchopped grass without molasses.
n (earth pits) = 8

n (concrete silos) = 4

p - prices based on the prevailing 1995/96 economic condition

a,b,c,d,e,f,g,h - mean values within the same row followed by different superscripts are significantly different ($P < 0.05$)

5. DISCUSSION

In the present study an attempt was made to conserve napier grass as silage for the ultimate feeding of zero grazed dairy cattle reared by small holder farmers. Effects of various techniques which can facilitate it's preservation as silage were investigated.

5.1 Chemical composition and *in vitro* dry matter and organic matter digestibilities of napier grass at the time of harvesting and ensiling

Lower values obtained in this study for DM content of freshly harvested napier grass (variety bana) and the pre ensiled treatments of the same forage without molasses (Table 4.1) were almost similar with those reported by Otieno *et al.* (1990) from the first cut of bana grass harvested at a vegetative stage and about 1.0m height. Almost similar DM values were obtained by Muinga *et al.* (1991) and Panditharatne *et al.* (1986) from the same variety harvested at the same height as the forage used in this work. However, Mwakajumba (1991) reported slightly higher DM values of about 18 percent from various local cultivars of napier grass harvested at their vegetative stage in Tanzania. Muinga *et al.* (1991) reported the DM averaging 18.0 percent from bana variety harvested at about 1.5m height. From above findings it is obvious that the variety used and the younger stage at which the fodder was cut mainly contributed to lower DM values of the forage used in the present study. As documented by Crowder and Chheda (1982) the percentage increase in DM content in most tropical grasses. is associated with the increase in cellwall components especially the ADF and lignin parts. These increase downwards along the stem axis, however extent vary depending on the genotype concerned. Therefore the characteristic low dry matter content of bana variety was caused by it's higher leaf : stem ratio compared with other varieties of napier (Karanja, 1988). The condition which is more prominent when the fodder is cut at an earlier vegetative stage (about 1 to 1.2m height) while the herbage is high in moisture content.

Addition of 3% molasses slightly improved the DM content of napier grass in T1 - CM and T3 - UM by approximately 2.2 and 1.7 percent respectively. This was expected since molasses itself had the DM content of 651g kg^{-1} (Appendix 2), which mainly comprised of soluble sugars. Dixon (1982) and McCullough (1983) suggested that the best silage from high moisture forage can be obtained when the fodder is wilted to a minimum of 25% dry matter. This may be rather difficult for napier grass grown under the tropical conditions with irregular periods of rains and dry spell. Also wilting of napier grass may create difficulties in compaction of the forage inside the silo thus allowing retention of large quantity of air which can spoil the silage (Crowder and Chheda, 1982).

Muinga *et al.* (1991) reported a CP content of 72 gkg^{-1} DM for napier variety bana harvested at a vegetative stage similar as that applied in this study. Tisian (1994) reported slightly higher CP of about 81 g kg^{-1} DM from the same variety harvested at similar conditions with those of this study. Mtengeti *et al.* (1989) reported high CP content of 129 g kg^{-1} DM from napier harvested at the same stage as those used in the present study. Where as Muinga *et al.* (1991) obtained CP value of 56 g kg^{-1} DM from bana grass cut at about 1.5m height.

The big variation observed on CP content of napier grass was mainly caused by differences in stage of cut and the level of soil fertility. In the present study, napier grass was applied FYM at a rate of 12.5 Tons/ha, where as Mtengeti *et al.* (1989) under the same environment, applied sulphate of ammonia at an application rate of 200 kg N/ha. The lowest CP values reported by Muinga *et al.* (1991) from bana grass harvested at 1.5m height were attributed by advanced maturity of the fodder. The main disadvantage of napier grass as silage crop is it's great variation in CP content when established under different soil conditions, therefore in order to increase the protein value of napier grass for production of high protein containing silage, harvesting need to be done while the fodder has attained a height of 1.0m high and the soil has an appreciable amount of nitrogen. Alternatively the crude protein content of napier grass for silage making can be improved by addition of low levels of urea (Sarwatt, 1995) or mixing with a forage legume prior to ensiling (Dixon, 1982).

The NDF, ADF and ADL values for napier grass used in the present study, were lower than those of 784.8, 471.9 and 157.1 g kg^{-1} DM reported by Otieno *et al.* (1990). It should however be understood that the hemicellulose component (obtained as the difference between NDF and ADF values) form an important structural carbohydrate in forage which is used as a substrate for silage fermentation (McDonald *et al.*, 1960: Soares *et al.*, 1980; Wilkinson *et al.*, 1982). Therefore it is obvious that napier grass used in the present study had offered lower hemicellulose for silage fermentation as revealed by smaller value of the difference between the NDF and ADF values which averaged 219.3 g kg^{-1} DM compared to 312.9 g kg^{-1} DM reported by Otieno *et al.* (1990).

The observed lower content of water soluble carbohydrate in the freshly harvested and the pre ensiled forage treatments without molasses, were in agreement with the findings of Andrade and Gomide (1971) who observed a relatively low level of WSC (below 3%) when *P. purpureum* was harvested at an age below 12 weeks.

Addition of 3 percent molasses further improved the WSC content in TI - CM and T3 - UM by 25.3 and 14.5 gkg^{-1} DM respectively above the untreated forage. This can be explained by the fact that the molasses used had high concentration of WSC (Appendix 2). The findings which are supported by observation of McDonald *et al.* (1991) who reported significant high WSC content in molasses amounting 650 g kg^{-1} DM.

Alternatively ensiling of the 3rd or 4th harvest of napier grass in the growing season, could have increased the availability of soluble carbohydrates for microbial fermentation inside the silo. As reported by Woodard *et al.* (1992) the amount of

WSC's in napier cultivars increased from 26.2 to 83.7 g kg^{-1} DM in the first and the third cuts per growing season respectively.

The *in vitro* DMD and OMD values in the pre-ensiled napier grass was improved by addition of molasses. This is because, soluble sugars present in molasses provided excess energy which act as a useful substrate for survival and multiplication of rumen cellulolytic microbes responsible for degradation of fibrous forages eaten by ruminants (McDonald *et al.,* 1973). The condition which could be expected to be transferred into the resulting silage with molasses treatment.

5.2 Degradability of the pre - ensiled treatments of napier grass

Muinga *et al.* (1995) obtained much lower effective DM degradability about 49.3% for the same variety cut at about 1.5m height with lower CP and higher NDF values of 56 and 709 g kg^{-1} DM respectively when compared to those of the pre ensiled forage treatments used in the present study. According to these findings, cutting of napier grass at a younger stage (about 1m height) significantly increase degradation of the forage by rumen microbes that is accentuated by the slightly lower proportion of fibrous materials. The condition which can also be reflected by the silage produced.

Apart from that, addition of 3% molasses in some of the forage treatments used in this study assisted to improve degradation of the cellwall content of pre ensiled materials. This was probably attributed by the extra soluble sugars from molasses which occupy the largest portion of the soluble materials which when combined with the forage offers excess energy for growth and multiplication of the rumen microbes responsible for fibre digestion. As reported by Preston and Leng (1987), rumen fermentation of 1kg of carbohydrates from the roughage diet produce microbial ATP's about twice of that obtained from fermentation of the same amount of a protein source. Therefore higher DM degradability represented by better effective degradability, 48h DM disappearance and high potential degradation as evident from the asymptotes of degradability curves in Figure 1 reflects increased cellulolysis of the molasses treated than unmolassesed forage treatments used in the present study.

Amounts of molasses to be supplemented in forages should however be low, as large concentrations may depress the rumen pH (below 6) and increase level of fermentable sugars in rumen fluid which attracts the rumen protozoa and reduce their cooperation with the cellulolytic bacteria in degradation of fibres in forages (Mould and Ørskov, 1984).

5.3 Effects of pre ensiling physical preparation on quality of napier silage

Effects of chopping regardless of either the silage was treated with molasses or obtained from either type of silo are discussed in this section. In general, chopping of the forage materials before ensiling improved the quality of napier silage and consequently it's acceptance by the animals as measured in terms of intake rate when the silage was fed to dairy heifers.

5.3.1 Chemical composition and *in vitro* DM and OM digestibilities of napier silage as influenced by chopping

The observed higher DM content on chopped napier silage compared with unchopped silage were in a similar trend as that reported by Panditharatne *et al.* (1986), who observed higher DM in napier hybrid (NB 21) silage chopped at 7.5cm than 15.0cm lengths. The main reason could be attributed to minimal aerobic nutrients losses in short chopped compared to long silage as short chopping facilitate effective exclusion of air within the ensiled forage. This is also in agreement with the findings of Wilson and Bridgestocke (1981) that, chopping of materials to lengths of between 2.5 - 5cm favours production of good quality silage with a minimum loss of essential nutrients.

Very fine chopping to such high moistured forages might however cause considerable nutrients losses in effluent as those created by aerobic respiration in unchopped silages. This was proved by Panditharatne *et al.* (1986) who reported almost the same lower DM values for 1.5cm and 15cm chopped compared to 7.5 cm chopped silages. But yet, the DM values observed for silages in this study were a bit high compared with the original harvested fresh forage probably due to some losses of cell contents in silage effluent leaving higher proportion of the structural carbohydrates which form a greater proportion of the total silage dry matter.

The difference in CP contents between chopped and unchopped napier silages was highly significant with the chopped silage having the highest CP with an excess of 6.2

g kg^{-1} DM above that of unchopped silage. Various studies on chemical composition of napier silage, have not taken much attention to investigate the protein values between the chopped and unchopped napier silage. Therefore, the observed lower protein values for unchopped napier silage compared to chopped silage could probably be caused by increased extent of protein degradation and nitrogen losses associated with heat and ammonia production occurring in poorly compacted unchopped material. This agrees with the argument of McDonald (1976) and Fairbairn *et al.* (1988) that increased proteolysis in uncontrolled fermentation of poorly consolidated high moistured crops may reduce more than 50% of the total N present in herbage.

Apart from losses of N due to proteolysis, the lower CP values observed in the silage compared with the ensiled material, might be contributed to some effluent and aerobic N losses occurring during fermentation inside the silo. Excessive aerobic respiration in unchopped forage might be the main reason for further N losses in unchopped napier silage. This is evident as the 5cm chopped and unchopped napier silages obtained in this study had crude protein deficits of 10.8 and 17.0 g kg^{-1} DM, respectively below that of the fresh forage ensiled.

This trend is in agreement with the observations of various workers who reported decreased CP values in silage compared to their respective ensiled forage (Ojala *et al.*, 1988; Otieno *et al.*, 1990). The CP values reported by Otieno *et al.* (1990) in bana silage were however higher than those observed in the present study. The reason could be due to higher CP content of the forage used compared to that used in this study, which might be caused by variation in the nitrogen status between the different soils.

The EE value observed for chopped napier silage used in the present study was some what large, 28.9 g k^{-1} DM as compared to 21.0 g kg^{-1} DM reported by Olubanjo *et al.* (1989) from similar forage chopped at lengths of between 2 to 6 centimetres. This higher EE value in chopped napier silage might be created by it's higher content of lactic and acetic acids (Table 4.4) as these occupy a greater proportion of total organic acids present in silage. Since, as stated by McDonald *et al.* (1988) among other components, the EE value combines the total organic acids present in a feed. On this basis it is obvious that chopping prior to ensiling expose more surfaces of the forage for microbial attack especially the lactic acid bacteria which enhance lactate fermentation so long as anaerobiosis is maintained.

The NDF and ADF were observed to decrease slightly on chopped compared to unchopped napier silage obtained in this study. These results were in line with the findings of Deswysen *et al.* (1978) for the crude fibre contents between chopped and long temperate grass silages. These authors reported CF values of 330 and 332 g kg^{-1} DM in short chopped and long rye grass silages respectively. Otieno *et al.* (1990) obtained the NDF of 594.6 g kg^{-1} DM in chopped bana silage, the value which was lower than the one reported in the present study for 5cm chopped napier silage. However, from their findings, the ADF of 405.4 g kg^{-1} DM was nearly the same as

402.6 g kg^{-1} DM obtained in this study, but yet, both the NDF and ADF values reported by Otieno *et al.* (1990), were lower than those observed for unchopped napier silage in the present work.

According to McDonald *et al.* (1991) up to 50% of hemicellulose may be broken down during fermentation as a result of activities of plants and bacterial enzymes. Therefore from this view, its possible that more of the hemicellulose and slightly cellulose present in the ensiled forage were fermented in chopped compared to unchopped silage since chopping expose more surfaces of the plant for enzymatic hydrolysis of the linked sugar molecules in hemicellulose. Chopping also might have facilitates rapid multiplication of lactic acid fermenters leading to increased acidity for further hydrolysis of hemicellulose.

Under normal circumstances the lignin part of forage is not utilized as a substrate for microbial fermentation in the silo (McDonald *et al.,* 1960; Van Soest, 1982). But significantly higher ADL observed for unchopped compared to chopped napier silage was probably due to unavoidable sampling error as there was high probability of collecting more stemmy part in unchopped silage compared with the chopped one. Generally the NDF, ADF and ADL components for both chopped and unchopped silage obtained in this study, were higher compared with the original forage. This agrees with the findings obtained by Sarwatt (1995). The reason could be due to losses of cell contents in ensiled material leaving larger proportion of cell walls in the total

DM of the silage recovered.

The WSC in both chopped and unchopped silage were much lower than those of the pre-ensiled forage. This should be expected since during the process of fermentation part of WSC present in forages would be used up. Nevertheless, the higher amount of WSC's retained in chopped napier silage compared with the unchopped silage coincides with the findings of McCullough (1976) and Panditharatne *et al.* (1986), that short chopping of forages prior to ensiling restricts further losses of carbohydrates due to aerobic deterioration.

In vitro DM and OM digestibilities of napier silage were improved by chopping of forage prior to ensiling as more than 50% of the organic matter in the chopped silage was digested compared with only 41.4% in unchopped napier silage. This was contributed by better fermentation qualities and more nutrients retention especially protein and energy in chopped silage compared to unchopped one. Observed DM and OM digestibilities could have improved further if the silage obtained were high in protein content above the maintenance level of 7 percent, as supported by findings of Otieno *et al.* (1990) who reported *in vitro* DMD of 56.3 percent from chopped bana silage with the CP value of 10.4 percent of the total DM obtained.

5.3.2 Fermentation and sensoric qualities of napier silage as influenced by chopping

Chopping prior to ensilage, produced silage with lower pH of 3.99 which was 0.66 units lower than that observed on unchopped silage. Such lower pH value obtained on chopped napier silage is closely related with the findings of several workers for well preserved high moistured temperate and tropical grass silages (Catchpoole and Henzell, 1971; Deswysen *et al.,* 1973; Ojala *et al.,* 1988; Yokota *et al.*, 1990; Faisal and El - Hag, 1992). Panditharatne *et al.* (1986) reported lower pH by about 0.2 units less in 1.5 cm chopped *Panicum maximum* silage compared with it's corresponding silage ensiled at about 15 cm lengths. The observed lower pH in chopped napier silage could be a result of increased affinity of the forage tissues for multiplication of lactic acid bacteria and rapid achievement of optimum anaerobic condition which induced lactate fermentation of the available soluble sugars ending up with silage which is more acidic.

During silage fermentation, plants proteases and microbial enzymes degrade a substantial portion of true proteins into NPN including ammonia - N. Under high pH between 5 to 8 inside the silo, extensive proteolysis might occur, resulting into conversion of 56% of total nitrogen to ammonia-N (McKersie, 1983; Fairbain *et al.,* 1988; McDonald *et al.,* 1991). Therefore, the observed lower levels of ammonia - N in chopped napier silage compared to unchopped silage was probably caused by minimum degradation of proteins within the chopped materials facilitated by total exclusion of air. But yet the concentration of ammonia - N in unchopped napier silage was within the acceptable standards for a well preserved silage (below 8%) as reported by Catchpoole and Henzell (1971) and Breirem and Saue (1973).

Higher lactic acid concentration observed for 5cm chopped napier silage was within the standard range of 3 to 13% of DM set by Catchpoole and Henzell (1971) for a good quality unwilted tropical silage. Yokota *et al.* (1990) reported higher lactic acid about 7% from 3cm chopped napier silage. Machado and Muhlbach (1986) obtained almost similar lactic acid (3.03% of DM) concentration in napier silage cultivar Cameroon wilted prior to ensilage, thus indicating no differences in lactic acid concentration between pre chopped or pre wilted napier silage. Present observations conform with the argument of Gibson *et al.* (1961) that, chopping increases lactic acid fermentation as it enhances multiplication of homo and heterolactic fermenters in ensiled material leading to higher production of lactic acid in the resulting silage. The extent of lactic acid production however vary greatly depending on WSC content of the ensiled forage. This is supported by the findings of Tosi (1973) who reported higher lactic acid concentration about 50g kg^{-1} DM on chopped napier silage obtained from fresh forage with a percentage WSC of 3.67.

Acetic acid concentration was also increased by chopping. The trend was in agreement with the observations made by Panditharatne *et al.* (1986) who obtained 40.0 and 37.3g kg^{-1} DM of acetic acid on 7.5 and 15 cm chopped napier silages respectively.

Similar trend was observed on temperate grass silages where rye grass chopped at 1.8cm produced silage with an average of 46.2g kg^{-1} DM acetic acid, compared with only 29.7 g kg^{-1} DM obtained on unchopped silages (Deswysen *et al.*, 1978). Reasons for this could be in line with those explained in the previous paragraph for lactic acid, but in this case, the heterofermentative lactic acid bacteria are more concerned. These bacteria multiply rapidly, owing to more rapid establishment of anaerobic conditions within the chopped materials and utilize the available WSC to produce Co_2, mannitol, ethanol and larger amounts of acetic acid in addition to lactic acid (Woolford, 1972). The acetic acid so produced has been reported to maintain stability of most tropical grass silages even without addition of silage preservatives (Catchpoole and Williams, 1970; Aguilera, 1975).

Observed lower concentrations of butyric acid in pre-chopped napier silage compared with unchopped silage are supported by the findings of Deswysen *et al.* (1978) and Panditharatne *et al.* (1986) who reported a negative correlation between fine chopping and butyric acid production in both temperate and tropical grass silages. These observations were also in agreement with the standard set by several authors who reported a range of between 0 to 0.3% butyric acid in silage as optimum on a well preserved grass silage (Catchpoole and Henzell, 1971; Breirem and saue, 1973). The reason could be due to achievement of optimum anaerobiosis, in the well consolidated chopped materials inside the silos, which lower the silage pH and inhibit butyric acid formation. The reverse is true for unchopped napier silage in which larger amount of entrapped air within the poorly consolidated material might have caused a rise in temperature and pH inside the silo ending up with secondary fermentation of sugars and lactic acid to large quantities of butyric acid. Also some traces of overheating were evident on unchopped napier silages as indicated by growth of mould on the uppermost layer and corners of the silos.

The present differences observed on patterns of fermentation in chopped and unchopped napier silages were more supported by the scores given on the sensoric evaluation of the silages. Whereby the overall higher total score observed for the chopped napier silage was probably caused by good fermentation of the respective silage. On the other hand, the slimy texture and slight foul smell sensed in unchopped napier silage might have been due to increased extent of degradation of true proteins to ammonia, owing to clostridial fermentation which was developing in that silage.

5.3.3 Dry matter losses

Higher DM losses observed in long napier silage compared to chopped silage were probably due to poor fermentation of the silages owing to increased aerobic deterioration and putrefaction in inefficient consolidated material. Whereas slight dry matter losses also occurred in the well preserved chopped napier silage, these losses were probably caused by some effluent losses as the forage had a high moisture content and may be the heterolactic type of fermentation which was responsible for acetic acid production in the silage. This is supported by McDonald *et al.* (1991) who noted that oxidation of soluble sugars present in ensiled forage by the action of heterolactic bacteria, result into losses of some organic constituents of the plants through the carbon dioxide produced. The present findings were in the same trend as those of Panditharatne *et al.* (1986) who reported slightly higher DM losses from unchopped *Panicum maximum* silage about 11.8% compared with 11.0% obtained on chopped silage. The DM losses reported by above workers were however lower than those obtained in the present study since, the authors used *Panicum maximum* with slightly higher DM content averaging 18.6% compared with an average of 17.2% DM for napier hybrid (bana) used in this study. But still the DM losses observed for chopped napier silage were within the optimum level suggested by Webster and wilson (1980) for a well preserved napier silage which should not exceed 20 percent of the weight of ensiled forage .

5.3.4 Degradability and intake rate of napier silage as influenced by chopping

Generally the dry matter in chopped napier silage was more degradable than in unchopped napier silage. This was possibly caused by significantly higher ratio of soluble materials to insoluble degradable materials found in the chopped silage. The findings which agrees with the argument of Ørskov, *et al.* (1980) and Orskov and Ryle (1990) that water soluble fraction form major part of the total DM which is rapidly lost during the first hours of incubation, thereby influencing the potential degradability of dry matter present in feedstuff. From the above argument, it might be possible that, higher proportion of solubles to insoluble materials in chopped napier silage was responsible for observed higher rate of fibre degradation in chopped napier silage owing to it's lower proportion of insoluble actual rumen degradable materials.

The effective DM degradability and 48h DM degradation of napier grass were considerably reduced by ensilage, hence it's overall digestibility. This was caused by the decline in true proteins and energy, coupled with increased cellwall materials in silage. However the apparently higher 48h DM degradability and effective DM degradability percentages for chopped napier silage, further reflected it's better digestibility and improved intake compared with unchopped napier silages.

The observed DM disappearance after 48 hours for chopped and unchopped napier silages were lower by approximately 2 and 8% units respectively, compared with *in vitro* DM digestibility of chopped bana silage reported by Otieno *et al.* (1990). The observed bigger difference between unchopped napier silage and that reported by Otieno *et al.* (1990), could be associated with the much lower protein value and higher ADF present in unchopped napier silage obtained in the present work. In the present study, chopped napier silage offered more protein and energy substrate for activities of cellulolytic microbes. This could be the case since the CP values were 61.1 and 54.9g kg^{-1} DM, and ME values were 8.6 and 7.9MJ/kg DM in chopped and unchopped napier silages respectively. This also contributed to increased rate of fibres degradation in chopped napier silage thereby promise more nutrients consumption when offered to dairy animals.

These findings were also supported by results of DM intake rate experiment conducted with heifers, whereby the chopped napier silage resulted in more DM consumption per minute, that was approximately 21.9% above that of unchopped napier silage. These results agree with those of Dulphy and Demarquilly (1973), Deswysen *et al.* (1978) and Panditharatne *et al.* (1986). Deswysen *et al.* (1978) working on sheep showed that pre chopping at 1.8cm length improved intake of grass silage by 20.6% above that of silage chopped at 5.3cm. In another experiment Panditharatne *et al.* (1986) reported increased DM intake of chopped bana silage by about 17% units above that of long silage. In addition to energy and protein values the higher intake rate of the pre chopped silage compared to unchopped one probably was indirectly influenced by it's good smell, texture as well as low levels of ammonia and butyric acid concentrations. This may imply that higher levels of ammonia and butyric acid concentrations in unchopped silage delineated it unpalatable.

5.4 Effects of additive (molasses) on quality of napier silage

Addition of molasses to napier grass at ensiling was generally noticed to have improved fermentation, hence the overall quality of napier silage obtained in the present study.

5.4.1 Effects of addition of molasses on chemical composition and *in vitro* DM and OM digestibilities of napier silage

Results in section 4.3.2 revealed very minor increase in DM content of napier silage without additive above that of original ensiled forage (by approximately 1%). Probably this was caused by a slight increase in proportion of structural carbohydrates in the silage, which formed the larger part of the total silage dry matter. The same trend was reported by Otieno *et al.* (1990) who observed DM values of 16.9 and 15.9% for bana silages without additive and it's corresponding ensiled forage respectively. Nevertheless, in the present work, napier silage with molasses exhibited higher DM content of about 2.6% above that found in freshly harvested forage. This was possibly contributed by some soluble sugars and trace minerals from molasses added as this was found to contain about 412.5 and 9.5g kg^{-1} DM of WSC and ash respectively (Appendix 2). Alternatively, the greater part of effluent losses from molasses treated silage, might comprise of water and sugars mainly from the molasses added, leaving more organic constituents of the forage material intact, while in untreated silage effluent losses incorporate nutrients which originate from the ensiled forage.

Augmentation of silage DM content when forages are mixed with molasses have been documented by several workers (Ojala *et al.*, 1988; Otieno *et al.*, 1990; Sarwatt, 1995). Ojala *et al.* (1988) and Otieno *et al.* (1990) reported silage dry matter with excess of 3 and 3.9 percentages respectively above that of fresh napier grass when the forage was mixed with about 5% molasses at ensiling. On the other hand, Sarwatt (1995) reported an increase of about 2% DM only, above that of untreated silage when rhodes grass was mixed with 3% molasses at ensiling.

Significantly ($P < 0.01$) higher CP value in molasses treated napier silage compared with untreated ones could possibly be due to rapid achievement of low pH in molassesed silage which might have stabilized the silage early thereby inhibiting further microbial degradation of proteins. These findings were in line with the argument of Crowder and Chheda (1982) that, microbial activities ceases inside the silo when the high moistured tropical grass silages attain a pH ranging between 3.5 to 4.2 so long as anaerobiosis is maintained. The present observations, agrees with those of Otieno *et al.* (1990) who reported slightly higher CP value in 5% molasses treated than untreated bana silages. But, it should be noted that the CP values obtained for silage cannot give a clear picture of the true protein contents since it combines both true protein nitrogen and non protein nitrogen. Yet, it can be concluded that molasses treated napier silages have more protein value since as suggested by Van soest (1982), chances of recovery of amino acids especially methionine, cystine and tyrosine in silages decline as the pH rises above 4.2.

Although, differences in ash contents between molasses treated and untreated napier silage were not statistically significant, observed higher ash in molasses treated silage was probably caused by the excess minerals from added molasses. This might be the case, since Preston and Leng (1987) notified presence of an appreciable amount of trace minerals and some macro elements such as sulphur, calcium and potassium in molasses.

The WSC content in molasses treated and untreated napier silage were lower than that of ensiled forage due to similar reason as that explained previously on the effect of chopping that; an appreciable amount of WSC's present in ensiled material are being utilized during fermentation. Working with temperate forages Henderson *et al.* (1972) reported that very little sugars usually less than 20g kg^{-1} DM remains after silage fermentation leaving aside starch which is generally not acted upon by majority of lactic acid bacteria. However, WSC reserved in molasses treated silage obtained in this study was higher by 7.6 g kg^{-1} DM above that remained in untreated silage. This might be due to additional soluble sugars from molasses.

Higher EE values obtained on molasses treated compared with untreated napier silage reflects the higher concentration of total organic acids present in the silage mixed with molasses with a total of about 82.8 vs 44.7g kg^{-1} DM present in untreated napier silage. This should be anticipated since excess soluble sugars from molasses might have induced homolactic and heterolactic fermentation ending up in large amount of lactic and acetic acids in the silage.

Slight higher NDF and ADF in unmolassesed napier silage compared to molasses treated silage was likely caused by more seepage losses of the cell contents of forage in untreated silage, leaving aside higher percentage of cell wall contents in the total dry matter. Alternatively, the increased acidity in molasses treated napier silage might have stimulated further hydrolysis of linked sugar molecules in the cellwall, causing further breakdown of hemicellulose. Breakdown of up to 50% of hemicelluloses during silage fermentation process has been documented by McDonald *et al.* (1991). The present findings are also supported by Otieno *et al.* (1990) who reported lower NDF, ADF and ADL values for 5% molasses added bana silage than in it's corresponding untreated silage.

In addition, the IVDMD and IVOMD of napier silage was improved by addition of molasses, since nutrient additives such as molasses have been reported to be useful energy substrate for ruminal microbes (McDonald *et al.*, 1973). Though, silage digestibility could have been ameliorated further if the protein content of ensiled forage was above maintenance protein requirement of the animals.

5.4.2 Effects of addition of molasses on fermentation and sensoric qualities of napier silage

Fermentation of napier silage obtained in the present study was also improved by addition of molasses at the time of ensiling. Without additional source of water soluble carbohydrates, the high moisture content in napier grass counteracts the preservative action of the primary fermentation acids and allow extensive microbial degradation of proteins to yield large quantities of ammonia. This also allows secondary fermentation of lactic acid to butyric acid which in turn reduce the lactic and acetic acid concentrations in the resulting silage as observed in untreated napier silage.

The observed fermentation pattern of molasses treated napier silage however agrees with the standards set by Catchpoole and Henzell (1971) for a well preserved tropical grass silage though the butyric acid concentration was found to be slightly above the maximum level of 0.3% of the silage dry matter. These findings are in line with those reported by various people working on ensilage of tropical grass species (Catchpoole, 1966, 1970; Medling, 1972; Wilkinson, 1983a; Ojala *et al.*, 1988; Otieno *et al.*, 1990; Sarwatt, 1995; Sunarso *et al.*, 1995). This was possibly caused by additional WSC content in the herbage from the molasses added, which in turn was fermented by the lactic acid bacteria ending up with large quantities of lactic and acetic acid in the total acidity. This acidity stabilized the silage at a pH of 4.21 thereby inhibiting the wasteful activities of clostridial bacteria which was indicated by lower levels of ammonia - N and butyric acid (4.09% and 3.8gkg-1 DM respectively) and higher concentrations of lactic and acetic acids (36.8 and 40.3 g kg^{-1} DM respectively), the fermentation qualities which were in contrary from those observed for untreated napier silage.

Furthermore, addition of molasses produced silage with high total sensoric score value in comparison with the silage without molasses. These findings are in agreement with those of Otieno *et al.* (1990) and Sarwatt (1995). This was manifested by the good appearance and a pleasant fruity smell sensed just on opening the silo, while foul smell of ammonia was sensed from untreated silage, the scent which was more conspicuous on long untreated napier silage. In addition to unpleasant smell, unmolassesed napier silage was found to have patches of mould growth almost around the whole surface layer coupled with a slimy texture. This gives clear signs of putrefaction in the course of fermentation of untreated silage, although, acetic acid produced might have helped to maintain it's stability thereby preventing the silage from total spoilage.

5.4.3 Effects of addition of molasses on dry matter losses of napier silage

Lower DM losses observed in molasses treated napier silage compared with untreated silage were within the normal range of 10 to 20 percent reported by Crowder and Chheda (1982) and Lampila *et al.* (1988) from the well preserved unwilted tropical grasses. Possibly because, the excess WSC from molasses might have compensated for the nutrients losses which could have occurred from ensiled forage. Additionally, the soluble sugars from molasses which stimulate lactic acid fermentation might have allowed rapid achievement of stable acidity in the silage hence reduce further nutrients losses in molasses treated silage. Whereas, the untreated silage requires more time to attain the stability. This agrees with Catchpoole (1970) who reported reduced hydrolytic activities associated with increased acidity in ensiled crops with high moisture content when molasses is added. According to the author, such acidity prevent clostridial fermentation in molasses treated silages hence, minimize further nutrients losses.

5.4.4 Dry matter degradability and rate of intake of napier silage as influenced by addition of molasses

The results from this study (section 4.3.2) showed that, addition of 3 percent molasses apparently increase the proportion of soluble materials in napier silage while the actual degradable fraction may slightly be altered. Probably this was caused by improved fermentation of carbohydrates which might have yielded more concentration of organic acids that form part of the soluble materials which disappears immediately in the rumen leaving slightly lower portion of actual degradable fibres. In contrast, lesser amount of organic acids produced during fermentation of untreated napier silage, was evident by reduced proportion of soluble matter in the silage while the total amount of degradable materials remained high. Based on this counterbalancing effect between solubles and insoluble materials in the silages the potential degradability was not altered much even when the silage was treated with molasses. Also the rate of degradation of the actual rumen degradable fraction was not affected much, since their proportion in untreated and molasses treated napier silages showed minor differences.

Basing on the degradability characteristics discussed above, the digestibility of napier silages estimated from the 48 hours *in sacco* DM degradability showed a slight improvement with addition of 3% molasses, however the effect was not significant. Ojala *et al.* (1990) reported slightly higher OM digestibility on molasses treated napier silages however these workers applied slightly higher level of molasses (5%) than the one used in this study. Sarwatt (1995) narrated a slight increase of *in vivo* DM digestibility of maize, sorghum and rhodes grass silages when the forage were treated with 3% molasses at the time of ensiling, though the differences were not significant from that of untreated silages. The trend which was closely related with 48 hours DMD of molasses treated and untreated napier silages obtained in the present study. Inspite of this, significant improvement was visible for effective DM degradability of napier silage treated with 3% molasses in comparison with the untreated silage. The reason could be similar as that explained on molasses effects on *in vitro* DM and OM digestibilities that this additive provide excess energy to cellulolytic microbes (from the fermentable sugars and lactic acid) which improve their ability to attack digestible fibrous material present in the silage. The DM intake rate was significantly improved in molasses treated napier silage compared with untreated one; since addition of molasses at ensiling produced a well fermented silage with a nice aroma and texture which might have arouse appetite of the heifers thereby increase it's acceptance to the animals. Apart from that, Carpintero *et al.* (1969) argued that, improved fermentation in molasses treated silages results into high levels of organic acids. These acids were noted to induce negative effects on intake (Rogers *et al.*, 1979; Forbes, 1986). This could be the case where higher levels of organic acids are produced. In the present study however, addition of molasses at the time of ensiling had greater positive effects on acceptability which masked the negative effects of concentration of organic acids. These findings are in agreement with those of Sarwatt (1995) who reported higher DM intake of maize, sorghum and rhodes grass silages treated with 3% molasses than the untreated silages when they were fed to sheep.

5.5 Effects of chopping and addition of molasses on quality of napier silage

Further analysis revealed that, good fermentation of napier silage was an attribute of both chopping and addition of molasses at the time of ensiling. This was confirmed by observed significant interaction effect between chopping and additive on pH, EE, lactic, acetic and butyric acids concentrations of napier silage clarified on section 4.4.1. Without pre - chopping, addition of 3% molasses had minor effects on silage pH (4.63 vs 4.67) and insignificant effects on butyric acid concentration (7.0 vs 8.1 g kg^{-1} DM). Perhaps because, the little amount of molasses added could not get enough space to penetrate within the plant tissue, an effect which restricts lactic acid bacteria surrounding surfaces of unchopped fodder to utilize soluble sugars present in molasses and fail to effectively attack the soluble carbohydrates found within the ensiled forage. Consequently, lactate fermenters fail to procure stable low pH in the silage and inhibit butyric acid production by putrefying activities of clostridial microbes.

Chopping along with molasses treatment however, induced rapid multiplication of lactic acid bacteria which were activated to ferment the soluble carbohydrates available in the forage as well as from molasses into a stable low pH, higher lactic acid and lower butyric acid (3.79, 56.2 and 0.7 g kg^{-1} DM respectively) containing napier silage. The findings which were in close relationship with those reported by other workers for a well preserved high moistured tropical grass silage (Catchpoole and Henzell, 1971; Breirem and Saue, 1973; Ojala *et al.*, 1988).

5.6 Effect of type of silo on chemical composition, fermentation and sensoric qualities, dry matter losses, degradability and rate of intake of napier silage

The overall quality of napier silages recovered from the earth pit silos was slightly better than that obtained from the concrete silos. This was shown by the slightly higher percentages of dry matter, as well as crude protein and ash in the total DM; associated with reasonable fermentation certified by significantly lower pH and higher total sensoric score from silages recovered from the earth pit silos compared with that obtained from the concrete silos. Besides that, napier silage recovered from the earth pits was more digestible in comparison with that from the concrete silos. This was confirmed by observed significantly higher *in vitro* DM and OM digestibilities coupled with higher effective DM degradability and 48 hours percentage DM degradability of napier silage recovered from the earth pits than in the concrete silos. Nevertheless the differences in rate of DM intake between napier silage recovered from the two types of silos was negligible. This was probably attributed by the constant environment which was maintained within the underground earth pits, whereas the concrete silos which were built above the ground, were more exposed to direct changes in ambient temperatures thereby increasing chances of the walls of the silos to absorb the excess heat which might have intervened the normal microbial fermentation and even increase the amount of DM losses.

The present findings do therefore agree with those of Pizarro and Vera (1980) who observed higher total DM losses on forage maize ensiled in concrete bunker and clamp silos than in trench silo with averages of 25, 35 and 9 percent, respectively. Thus suggesting the need of insulating the properly sealed concrete silos. This can be achieved by construction of a thatched roof to minimize absorption of extra heat and rain water into the silo during sunny and rain days respectively.

Furthermore, it could be possible that the fermentation of napier silage within the concrete silos was more dominated by heterolactic fermenters than in the earth pits. This is indicated by the slightly higher pH value and acetic acid concentration coupled with more though insignificant DM losses from the silage recovered in the concrete silos, the distinctive features of the fermentation dominated by heterolactic bacteria (Bousset *et al.*, 1972; Woolford, 1972; McDonald *et al.*, 1973). McDonald *et al.* (1973) documented that, DM losses as high as 24% may occur in silage fermentation dominated by heterolactic bacteria. Whereas Bousset *et al.* (1972) and Woolford (1972) went further by noting maintenance of a slight higher pH and production of larger quantities of acetic acid in heterolactic fermentation of forages with WSC content below 6 percent.

Further analysis on interaction between silo structure and pre chopping revealed that, quality of napier silage made in the earth pits and or concrete silos was improved more when the forages were chopped than if they were not chopped prior to ensilage. This was confirmed by the significantly lower pH, associated with rather better smell, texture and overall quality scores coupled with more soluble materials retained in the chopped compared with unchopped napier silage obtained in the earth pits and concrete silos. Apparently because chopping facilitate better package and consolidation of forage material inside the silos. This consequently minimized aerobic respiration and allowed better fermentation which resulted into more production of lactic and acetic acid in the total acidity which together with the soluble nutrients increased the amount of soluble materials disappearing immediately when the silage is incubated within the rumen of fistulated animals.

Besides that, addition of 3 percent molasses contributed significantly to slow down the pH of napier silage to 4.18 vs 4.33 and 4.24 vs 4.53 from silages recovered in the earth pits and concrete silos, respectively. Likewise this maintained fairly good aroma within the silages as evident by the interaction effect between silo structure and addition of molasses on pH and smell of napier silage. In spite of above findings the effects of molasses upon silage pH were more markedly on napier silage preserved in the concrete silos than the earth pits though the pH values of the silages from concrete silos were maintained at higher levels throughout. Probably because the additional WSC's from molasses might have counterbalanced the spoilage effects caused by instability of the temperature within the concrete walls. This might also be the reason for improved effective rumen DM degradation of 3% molasses treated napier silage from the concrete silos by approximately 5.3% above that of untreated silage. In addition to above findings, significant interaction effects between silo type, chopping and molasses treatment on silage pH, smell and proportion of soluble materials as reported in section 4.4.4. This gives more merits to earth pits as the most suitable structures for preservation of napier grass silage so long as the inside of it's walls are covered by plastic sheets to prevent contamination of ensiled material with soil and the material are completely sealed.

5.7 Comparison of economic suitability of the various methods applied for preservation of napier grass as silage

By using simple estimations, the act of chopping and addition of molasses to napier grass during ensilage seems to increase the ensiling costs. However, in this study, this method of treatment of the forage material for ensilage has proved to be most technical and economical feasible especially when applied to material ensiled in the underground pit silos covered with plastic sheet. Apparently because, this treatment method allowed recovery of larger quantity of well preserved napier silage which was found to compensate the costs incurred, thereby producing silage at a reasonably least cost compared with other techniques applied. Lower cost per kgDM of silage produced observed for unchopped, molasses treated napier silage (T3) from the pit silo does not conform the method to be economical feasible, since it allowed recovery of smaller amount of useful silage compared with chopped, molasses treated silage (T1).

Furthermore during the first year of production, the estimated costs of producing 1kg DM of useful napier silage from the earth pits was just one third of that spent for the concrete silos. This was mainly created by high initial costs of constructing the concrete silos when compared with the earth pit silos which used local available natural materials. However in the preceeding years, the use of concrete walled silo could eliminate the costs of constructing a new silo. Therefore, by omitting 42,942.80 Tsh., the concrete silo construction cost (Appendices 4.5 - 4.8) in the second year of silage production, one can produce 1kg DM of useful napier silage at an estimated cost of 215.17, 238.30, 190.66 and 229.10 Tsh. for T1, T2, T3 and T4 respectively. This cost is slightly lower than 221.15, 255.30, 202.80 and 232.88 Tsh. indicated in the results for producing 1kg DM of T1, T2, T3 and T4 respectively, in earth pit silos which need to be reconstructed each year.

In most villages of Tanzania and other developing countries, building materials for making concrete silos are usually expensive thus cannot be afforded by most small scale farmers. On that basis, the use of underground pit silos, can still be useful and more economical than the concrete silos if the surrounding walls of these silos are being reinforced by the use of burnt earth bricks that can be easily made by cooperation among farmers. This technique will maintain the permanent underground silo structures, thus avoiding costs of making the silos every year and minimize extensive land degradation, bearing in mind that most small scale farmers are in land shortages.

6. CONCLUSIONS AND RECOMMENDATIONS

This study aimed at investigating the possibility of preserving napier grass as silage by small scale dairy farmers of Tanzania using various methods which can facilitate it's conservation as silage.

The results obtained indicate that, napier grass, can be conserved as a silage feed with minimum loss of essential nutrients if all the precautions to avoid losses are followed during ensiling and for the whole period of storage. This confirms the earlier observations cited in the literature.

Chopping of the forage material prior to ensiling maintained the preservation quality of napier silage. This was indicated by more retention of DM, crude proteins and soluble carbohydrates which were supported by the minimum level of dry matter losses in 5cm chopped silage when compared with unchopped napier silage.

Besides that, chopping of napier grass at ensiling time, lowered the pH, butyric acid concentration and ammonia - N levels of the resulting silage; a situation which was influenced by more exclusion of air from ensiled material associated with minimum protein degradation as well as increased affinity of the plant tissues for lactate fermentation. As a result of better fermentation, pre chopped napier silage was observed to maintain higher rate of dry matter intake and nutrients digestibility as compared to the intact silage.

Addition of 3% molasses to napier grass at ensiling time, decreased the silage pH, ammonia - N and butyric acid production while lactic acid and acetic acid concentrations increased. The condition which was more prominent on chopped, molasses treated napier silage.

Furthermore, addition of molasses at ensiling improved acceptance, palatability and digestibility of napier silage. This was confirmed by the higher rate of dry matter intake, *in vitro* DM and OM digestibility as well as *in sacco* DM degradability percentages of 3% molasses treated silage compared with untreated silage with less than 50% of digestible nutrients.

Sometimes napier silage may be of lower protein value as revealed in this study. This situation can be overcomed by further improvement of the nitrogen status of the soil. Alternatively, fodder harvested for silage making can be supplemented with the cheap available protein sources such as urea or protein enriched leguminous pastures like leucaena leaves at the time of ensiling.

Ensiling of napier grass in plastic sheets covered earth pit silos produced a slightly better silage than in the concrete silos. This was mainly caused by a stabilized environment maintained within the underground pits coupled with total protection of ensiled material from soil contamination. In concrete silos however, the ensiled forage was presumably more subjected to rapid changes in temperatures as heat may be absorbed through the concrete wall during sunny days.

Additionally, lower cost can be incurred to produce well preserved napier silage from the chopped, molasses treated napier grass ensiled in the plastic sheet covered underground pit silos compared with the concrete silos This is because, the initial cost of constructing the concrete silo was higher than for the earth pit silo. However, use of earth pit silos for silage making should be undertaken with the caution, because these silo structures need to be remade every year due to expansion of the dimensions of the silo walls caused by erosion on their surfaces. Therefore, in order to maintain the size of the pit silo and avoid the cost of making new pits every year it has been suggested to strengthen the walls and floor of the silo by using burnt earth blocks which can be easily made by the small scale dairy farmers living in villages. This suggestion therefore provide more room for further studies on suitability of such a type of silo for small scale silage production.

This study also provide the basis for further research on voluntary intake and performance of dairy animals fed napier silage based diets during the dry season.

The work also provide more area for further studies on the effects of different chopping lengths and inclusion of various levels of molasses on preservation of napier grass as silage. Apart from that this study give the hint on the necessity of conducting researches on effects of inclusion of various locally available protein sources as additives to napier silage in orders to improve it's protein status and meet both maintenance and production protein requirements of dairy animals.

Most small scale dairy farmers are not aware of the knowledge and technology of silage making. Therefore, there is an urgent need to link research work with extension work to ensure rapid adoption of technologies that are likely to improve milk production and the welfare of small scale dairy farmers.

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8. APPENDICES

Appendix 1. Meteorological data for the whole season of establishment of napier regrowth and preservation of the forage as silage. November, 1994 - April, 1995

Parameter	Nov	Dec	Jan	Feb	March	April
Total rainfall (mm)	43.5	49.2	142.2	98.5	202.0	246.9
Total sunshine (hrs)	219.1	225.7	217.8	185.1	192.0	162.4
Total radiation (MJM^{-2})	543.9	565.0	581.8	511.5	544.9	486.6
Mean max. Temp. (^0C)	31.3	32.0	31.6	31.7	30.8	29.1
Mean min. Temp. (^0C)	19.5	20.5	21.0	20.6	20.5	20.3

Appendix 2. Chemical composition of molasses and other feeds used to formulate rations for heifers on intake rate experiment and fistulated steers on degradability study (as percent of dry matter)

Feed ingredient	DM (%)	CP	CF	EE	Ash	NFE	WSC	Ca	P
Molasses	65.1	2.9	0.0	0.0	9.5	52.7	41.2	-	-
Napier silage	19.2	6.3	38.8	3.2	12.4	39.3	-	-	-
Brachiaria spp. grass	29.4	5.9	27.6	1.0	8.8	56.7	-	0.48	0.20
Mixed grass hay	88.2	7.0	28.5	0.9	9.7	42.1	-	0.35	0.18
Maize bran	90.9	11.4	11.0	8.3	3.8	56.4	-	1.09	0.60
Sunflower cake	91.0	26.4	21.5	4.0	4.5	34.6	-	0.24	0.41

Appendix 3.1 Dry matter degradability for the pre -ensiled treatments of napier grass in the rumen of steers fed a "standard" diet

Treat	Steer No	Incubation time in hours 0	12	24	48	72	96	120
T1.CM	1	30.54	48.27	58.49	67.78	70.88	71.91	72.26
	2	31.28	47.82	57.83	67.57	71.18	72.52	73.03
Mean		30.91	48.05	58.16	67.68	71.18	72.52	73.03
T2.CW	1	23.13	37.26	47.08	58.74	64.51	67.40	68.88
	2	23.65	37.44	47.15	58.87	64.76	67.75	69.27
Mean		23.39	37.35	47.12	58.81	64.64	67.58	69.08
T3.UM	1	30.08	47.73	57.92	67.24	70.38	71.45	71.81
	2	31.25	48.24	58.30	67.84	71.24	72.45	72.89
Mean		30.67	47.99	58.11	67.54	70.81	71.95	72.35
T4.UW	1	23.16	37.17	47.01	58.82	64.74	67.73	69.26
	2	23.33	37.47	47.35	59.12	64.97	67.91	69.41
Mean		23.25	37.32	47.18	58.97	64.86	67.82	69.34

Appendix 3.2 Dry matter degradability of chopped and unchopped napier silage in the rumen of steers fed a "standard" diet

Treat	Steer No	Incubation time in hours 0	12	24	48	72	96	120
Chopped	1	17.97	32.67	42.55	53.89	59.35	62.07	63.47
	2	17.04	33.79	44.55	56.26	61.54	64.00	65.18
Mean		17.51	33.23	43.55	55.08	60.45	63.04	64.33
Unchopped	1	14.09	27.36	36.88	48.85	55.41	59.14	61.34
	2	14.18	27.80	37.81	50.63	57.60	61.42	63.52
Mean		14.14	27.58	37.35	49.74	56.51	60.28	62.43

Appendix 3.3 Dry matter degradability for 3% molasses treated and untreated napier silage in the rumen of steers fed a "standard" diet

Treat	Steer No	Incubation time in hours 0	12	24	48	72	96	120
3% Molasses	1	17.48	32.20	42.06	53.40	58.96	61.84	63.41
	2	18.09	33.28	43.31	54.77	60.33	63.13	64.58
Mean		17.79	32.74	42.69	54.09	59.65	62.49	63.99
0% Molasses	1	14.58	27.83	37.38	49.34	55.79	59.37	61.41
	2	13.13	28.31	39.05	52.12	58.81	62.29	64.12
Mean		13.86	28.07	38.21	50.73	57.30	60.83	62.77

Appendix 3.4 Rumen dry matter degradability of napier silage recovered from the earth pits and concrete silos

Treat	Steer No	Incubation time in hours 0	12	24	48	72	96	120
Earth pit	1	17.30	32.62	42.82	54.34	59.71	62.30	63.57
	2	16.84	31.33	41.65	54.30	60.82	64.21	65.78
Mean		17.07	31.98	42.24	54.32	60.27	63.26	64.68
Concrete	1	13.50	24.81	29.04	45.44	52.71	57.23	60.08
	2	13.14	29.71	40.24	51.72	57.07	59.72	61.07
Mean		13.32	27.26	34.64	48.58	54.89	58.48	60.58

Appendix 4.1 Estimated costs of producing napier silage from forage treatment (T1 - CM) in earth pit silo

Component	Cost (Tsh.)
Pit preparation:	
Labour (digging) 18 man hours @ 43.60, 18 * 43.60	784.80
Plastic sheet 10 metres @ 520.00, 10 * 520.00	5200.00
Grass bedding (cutting and placing labour) 1 man hour @ 43.60	43.60
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/60	5350.00
Chopping:	
Chopper operating time 22 minutes, 1 forage chopper operating hour = 10,000/= (Hatibu and Simalenga, 1989) 22 * 10,000/60	3666.70
Labour for 22 minutes, 22 * 43.60/60	16.00
Molasses 15 litres, @ 29.00 15 * 29/=	435.00
1 watering can	1500.00
Ensiling process:	
Labour;	
Molasses solution preparation 10 minutes, 10 * 43.60/60	7.30
Ensiling and compaction 8 man hours and 2 minutes 8 * 43.60 + 2 * 43.60/60	350.30
Sealing 4 man hours, 4 * 43.60	174.40
Total cost	**17,731.50**

Average amount of useful napier silage obtained = 80.18 kgDM
Therefore total cost per kgDM of napier silage recovered = 17,731.50/80.18 = <u>221.15 Tsh./kg DM.</u>

Appendix 4.2 Estimated costs of producing napier silage from forage treatment (T2 - CW) in earth pit silo

Component	Cost (Tsh.)
Pit preparation:	
Labour (digging) 18 man hours @ 43.60,18 * 43.60	784.80
Plastic sheet 10 metres @ 520.00, 10 * 520.00	5200.00
Grass bedding (cutting and placing labour) 1 man hour @ 43.60	43.60
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/60	5350.00
Chopping:	
Chopper operating time 22 minutes, 1 forage chopper operating hour = 10,000/= (Hatibu and Simalenga, 1989) 22 * 10,000/60	3666.70
Labour for 22 minutes, 22 * 43.60/60	16.00
Ensiling process:	
Labour; Ensiling and compaction 7 man hours and 39 minutes 7 * 43.60 + 39 * 43.60/60	333.54
Sealing 4 man hours 4 * 43.60	174.40
Total cost	**15,772.44**

Average amount of useful napier silage obtained = 61.80 kgDM
Therefore total cost per kgDM of napier silage recovered = 15,772.44/61.8 = <u>255.22 Tsh/kgDM.</u>

Appendix 4.3 Estimated costs of producing napier silage from forage treatment (T3 - UM) in earth pit silo

Component	Cost (Tsh.)
Pit preparation:	
Labour (digging) 18 man hours @ 43.60,18 * 43.60	784.80
Plastic sheet 10 metres @ 520.00, 10 * 520.00	5200.00
Grass bedding (cutting and placing labour) 1 man hour @ 43.60	43.60
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/60	5350.00
Molasses 15 litres, @ 29.00 15 * 29/=	435.00
1 watering can	1500.00
Ensiling process:	
Labour; Molasses solution preparation 10 minutes, 10 * 43.60/60	7.30
Ensiling and compaction 8 man hours and 15 minutes 8 * 43.60 + 15 * 43.60/60	359.70
Sealing 3 man hours and 46 minutes, 3 * 43.60 + 46 * 43.60/60	164.20
Total cost	**14,048.00**

Average amount of useful napier silage obtained = 69.38 kgDM
Therefore total cost per kgDM of napier silage recovered = 14,048.00/69.38 = 202.50 Tsh./kgDM

Appendix 4.4 Estimated costs of producing napier silage from forage treatment (T4 - UW) in earth pit silo

Component	Cost (Tsh.)
Pit preparation:	
Labour (digging) 18 man hours @ 43.60,18 * 43.60	784.80
Plastic sheet 10 metres @ 520.00, 10 * 520.00	5200.00
Grass bedding (cutting and placing labour) 1 man hour @ 43.60	43.60
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40

Appendix 4.4 continue

Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/603.60	5350.00
Ensiling process:	
Labour;	
Ensiling and compaction 8 man hours and 4 minutes 8 * 43.60 + 4 * 43.60/60	351.50
Sealing 3 man hours and 40 minutes, 3 * 43.60 + 40 * 43.60/60	159.90
Total cost	12,093.50

Average amount of useful napier silage obtained = 51.95 kgDM
Therefore total cost per kgDM of napier silage recovered = 12,093.50/51.95 = 232.80 Tsh./kgDM

Appendix 4.5 Estimated costs of producing napier silage from forage treatment (T1 - CM) in the concrete silo

Component	Cost (Tsh.)
Preparation of concrete silo:	
Concrete silo construction	42,942.80
Plastic sheet 10 metres @ 520/= 10 * 520	5200.00
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/60	5350.00
Chopping:	
Chopper operating time 22 minutes, 1 forage chopper operating hour = 10,000/= (Hatibu and Simalenga, 1989) 22 * 10,000/60	3666.70
Labour for 22 minutes, 22 * 43.60/60	16.00
Molasses 15 litres, @ 29.00 15 * 29/=	435.00
1 watering can	1500.00

Appendix 4.5 continue

Ensiling process:

Labour;	
Molasses solution preparation 10 minutes,	
10 * 43.60/60	7.30
Ensiling and compaction 8 man hours and 15 minutes	
8 * 43.60 + 15 * 43.60/60	359.70
Sealing 3 man hours and 30 minutes,	
3 * 43.60 + 30 * 43.60/60	152.60
Total cost	**59,833.50**

Average amount of useful napier silage obtained = 78.50 kgDM
Total cost per kg DM of silage recovered = 59,833.50/78.50 = 762.20 Tsh./kgDM

Appendix 4.6 Estimated costs of producing napier silage from forage treatment (T2 - CW) in the concrete silo

Component	Cost (Tsh.)
Preparation of concrete silo:	
Concrete silo construction	42,942.80
Plastic sheet 10 metres @ 520/= 10 * 520	5200.00
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60,	
4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes,	
40 * 43.60/60	29.00
Tractor hours 30 minutes,	
1tractor hour = 10,700/= (Hatibu and Simalenga, 1989)	
30 * 10,700/60	5350.00
Chopping:	
Chopper operating time 22 minutes,	
1 forage chopper operating hour = 10,000/= (Hatibu and Simalenga, 1989)	
22 * 10,000/60	3666.70
Labour for 22 minutes, 22 * 43.60/60	16.00
Ensiling process:	
Labour;	
Ensiling and compaction 8 man hours, 8 * 43.60	348.80
Sealing 3 man hours and 35 minutes,	
3 * 43.60 + 35 * 43.60/60	156.20
Total cost	**57,883.90**

Average amount of useful napier silage obtained = 62.73 kgDM
Total cost per kgDM of napier silage recovered = 57,883.90/62.73 = 922.75 Tsh./kgDM

Appendix 4.7 Estimated costs of producing napicr silage from forage treatment (T3 - UM) in the concrete silo

Component	Cost (Tsh.)
Preparation of concrete silo:	
Concrete silo construction	42,942.80
Plastic sheet 10 metres @ 520/= 10 * 520	5200.00
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/60	5350.00
Molasses 15 litres, @ 29.00 15 * 29/=	435.00
1 watering can	1500.00
Ensiling process:	
Labour;	
Molasses solution preparation 10 minutes, 10 * 43.60/60	7.30
Ensiling and compaction 8 man hours and 25 minutes 8 * 43.60 + 25 * 43.60/60	367.00
Sealing 3 man hours, 3 * 43.60	130.80
Total cost	56,136.30

Average amount of useful napier silage obtained = 69.20 kgDM
Total cost per kgDM of napier silage recovered = 56,136.30/69.20 = 810 Tsh./kgDM

Appendix 4.8 Estimated costs of producing napier silage from forage treatment (T4 - UW) in the concrete silo

Component	Cost (Tsh.)
Preparation of concrete silo:	
Concrete silo construction	42,942.80
Plastic sheet 10 metres @ 520/= 10 * 520	5200.00
Forage harvesting:	
Harvesting (500 kg), labour 4 man hours @ 43.60, 4 * 43.60	174.40
Forage transportation (from field - silo):	
Labour (loading and unloading trailer) 40 minutes, 40 * 43.60/60	29.00
Tractor hours 30 minutes, 1tractor hour = 10,700/= (Hatibu and Simalenga, 1989) 30 * 10,700/60	5350.00

Appendix 4.8 continue

Ensiling process:

Labour;	
Ensiling and compaction 8 man hours and 20 minutes	
8 * 43.60 + 20 * 43.60/60	363.30
Sealing 3 man hours, 3 * 43.60	130.80
Total cost	54,190.30

Average amount of useful napier silage obtained = 49.10 kgDM
Total cost per kgDM of napier silage recovered = 54,190.30/49.10 = 1103.20 Tsh./kgDM

Appendix 5.1 ANOVA for the effect of pre ensiling physical preparation (chopping) and additive (molasses) on chemical composition and *in vitro* DM and OM digestibility of napier grass before ensiling

Dependent Variable: DM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	0.34320417	0.34320417	2.49	0.1304
ADD	1	22.48470417	22.48470417	163.03	0.0001
PHT*ADD	1	0.39270417	0.39270417	2.85	0.1071
Error	20	2.75828333	0.13791417		
Corrected Total	23	25.97889583			

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	1.60166667	1.60166667	0.31	0.5848
ADD	1	0.00000000	0.00000000	0.00	1.0000
PHT*ADD	1	0.06000000	0.06000000	0.01	0.9155
Error	20	103.86333333	5.19316667		
Corrected Total	23	105.52500000			

Dependent Variable: ASH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	48.7350000	48.7350000	0.53	0.4753
ADD	1	154.0266667	154.0266667	1.67	0.2106
PHT*ADD	1	11.4816667	11.4816667	0.12	0.7277
Error	20	1841.2166667	92.0608333		
Corrected Total	23	2055.4600000			

Dependent Variable: EE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	0.15041667	0.15041667	0.07	0.7951
ADD	1	8.05041667	8.05041667	3.71	0.0686
PHT*ADD	1	1.00041667	1.00041667	0.46	0.5052
Error	20	43.44833333	2.17241667		
Corrected Total	23	52.64958333			

Appendix 5.1 continue

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	338.2504167	338.2504167	0.45	0.5119
ADD	1	10.0104167	10.0104167	0.01	0.9097
PHT*ADD	1	176.5837500	176.5837500	0.23	0.6347
Error	20	15170.0316667	758.5015833		
Corrected Total	23	15694.8762500			

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	5.60666667	5.60666667	0.03	0.8710
ADD	1	0.16666667	0.16666667	0.00	0.9777
PHT*ADD	1	9.62666667	9.62666667	0.05	0.8316
Error	20	4147.48000000	207.37400000		
Corrected Total	23	4162.88000000			

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	0.70041667	0.70041667	0.24	0.6299
ADD	1	0.12041667	0.12041667	0.04	0.8413
PHT*ADD	1	8.05041667	8.05041667	2.75	0.1127
Error	20	58.49833333	2.92491667		
Corrected Total	23	67.36958333			

Dependent Variable: WSC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	168.010417	168.010417	1.50	0.2344
ADD	1	2390.010417	2390.010417	21.39	0.0002
PHT*ADD	1	173.343750	173.343750	1.55	0.2274
Error	20	2235.121667	111.756083		
Corrected Total	23	4966.486250			

Dependent Variable: IVDMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	14.0913375	14.0913375	0.54	0.4727
ADD	1	228.1050042	228.1050042	8.67	0.0080
PHT*ADD	1	19.6747042	19.6747042	0.75	0.3974
Error	20	526.0446500	26.3022325		
Corrected Total	23	787.9156958			

Dependent Variable: IVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
PHT	1	0.6048375	0.6048375	0.03	0.8637
ADD	1	254.2155042	254.2155042	12.71	0.0019
PHT*ADD	1	5.3298375	5.3298375	0.27	0.6113
Error	20	399.8855833	19.9942792		
Corrected Total	23	660.0357625			

Appendix 5.2 ANOVA for the effect of pre - ensiling physical preparation (chopping) and additive (molasses) on degradability of napier grass before ensiling

Dependent Variable: A

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
ADD	1	334.7307042	334.7307042	51.86	0.0001
PHT	1	0.2185042	0.2185042	0.03	0.8559
ADD*PHT	1	0.0135375	0.0135375	0.00	0.9639
Error	20	129.0861167	6.4543058		
Corrected Total	23	464.0488625			

Dependent Variable: B

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
ADD	1	188.0480167	188.0480167	33.86	0.0001
PHT	1	0.2204167	0.2204167	0.04	0.8441
ADD*PHT	1	0.3700167	0.3700167	0.07	0.7990
Error	20	111.0787333	5.5539367		
Corrected Total	23	299.7171833			

Dependent Variable: C

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
ADD	1	0.00136504	0.00136504	63.91	0.0001
PHT	1	0.00000038	0.00000038	0.02	0.8959
ADD*PHT	1	0.00000037	0.00000037	0.02	0.8959
Error	20	0.00042717	0.00002136		
Corrected Total	23	0.00179296			

Dependent Variable: POT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
ADD	1	21.00010417	21.00010417	5.44	0.0303
PHT	1	0.00000417	0.00000417	0.00	0.9992
ADD*PHT	1	0.52510417	0.52510417	0.14	0.7162
Error	20	77.26568333	3.86328417		
Corrected Total	23	98.79089583			

Dependent Variable: D48

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
ADD	1	454.2270042	454.2270042	70.97	0.0001
PHT	1	0.0001042	0.0001042	0.00	0.9968
ADD*PHT	1	0.1053375	0.1053375	0.02	0.8992
Error	20	127.9977167	6.3998858		
Corrected Total	23	582.3301625			

Dependent Variable: EFFD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
ADD	1	244.4816667	244.4816667	61.71	0.0001
PHT	1	0.0000000	0.0000000	0.00	1.0000
ADD*PHT	1	0.2016667	0.2016667	0.05	0.8238
Error	20	79.2300000	3.9615000		
Corrected Total	23	323.9133333			

Appendix 5.3 ANOVA for the effect of pre - ensiling physical preparation (chopping), additive (molasses) and silo type on chemical composition of napier silage.

Dependent Variable: DM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	33.70737500	4.81533929	6.29	0.0094
Error	8	6.12040000	0.76505000		
Corrected Total	15	39.82777500			

R-Square	C.V.	Root MSE	DM Mean
0.846328	4.925298	0.874671	17.7587500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	13.06822500	13.06822500	17.08	0.0033
PHT	1	6.57922500	6.57922500	8.60	0.0189
ADD	1	12.00622500	12.00622500	15.69	0.0042
SILO*PHT	1	1.70302500	1.70302500	2.23	0.1740
PHT*ADD	1	0.18922500	0.18922500	0.25	0.6323
SILO*ADD	1	0.01322500	0.01322500	0.02	0.8986
SILO*PHT*ADD	1	0.14822500	0.14822500	0.19	0.6715

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	401.0675000	57.2953571	22.07	0.0001
Error	8	20.7700000	2.5962500		
Corrected Total	15	421.8375000			

R-Square	C.V.	Root MSE	CP Mean
0.950763	2.778682	1.611288	57.9875000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	207.3600000	207.3600000	79.87	0.0001
PHT	1	152.5225000	152.5225000	58.75	0.0001
ADD	1	36.6025000	36.6025000	14.10	0.0056
SILO*PHT	1	0.6400000	0.6400000	0.25	0.6329
PHT*ADD	1	3.4225000	3.4225000	1.32	0.2841
SILO*ADD	1	0.1600000	0.1600000	0.06	0.8102
SILO*PHT*ADD	1	0.3600000	0.3600000	0.14	0.7193

Dependent Variable: ASH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	595.3800000	85.0542857	1.90	0.1945
Error	8	358.7300000	44.8412500		
Corrected Total	15	954.1100000			

R-Square	C.V.	Root MSE	ASH Mean
0.624016	5.544493	6.696361	120.775000

Appendix 5.3 continue

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	470.8900000	470.8900000	10.50	0.0119
PHT	1	16.0000000	16.0000000	0.36	0.5668
ADD	1	51.1225000	51.1225000	1.14	0.3168
SILO*PHT	1	33.6400000	33.6400000	0.75	0.4116
PHT*ADD	1	0.3025000	0.3025000	0.01	0.9366
SILO*ADD	1	2.7225000	2.7225000	0.06	0.8116
SILO*PHT*ADD	1	20.7025000	20.7025000	0.46	0.5160

Dependent Variable: EE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	267.4393750	38.2056250	50.31	0.0001
Error	8	6.0750000	0.7593750		
Corrected Total	15	273.5143750			

R-Square	C.V.	Root MSE	EE Mean
0.977789	3.334786	0.871421	26.1312500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	7.9806250	7.9806250	10.51	0.0118
PHT	1	118.2656250	118.2656250	155.74	0.0001
ADD	1	131.6756250	131.6756250	173.40	0.0001
SILO*PHT	1	0.6806250	0.6806250	0.90	0.3715
PHT*ADD	1	6.8906250	6.8906250	9.07	0.0168
SILO*ADD	1	0.6806250	0.6806250	0.90	0.3715
SILO*PHT*ADD	1	1.2656250	1.2656250	1.67	0.2328

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	12876.97437	1839.56777	2.00	0.1768
Error	8	7376.48500	922.06063		
Corrected Total	15	20253.45938			

R-Square	C.V.	Root MSE	NDF Mean
0.635791	4.651971	30.36545	652.743750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	346.890625	346.890625	0.38	0.5567
PHT	1	7625.655625	7625.655625	8.27	0.0206
ADD	1	1154.300625	1154.300625	1.25	0.2957
SILO*PHT	1	137.475625	137.475625	0.15	0.7095
PHT*ADD	1	3246.150625	3246.150625	3.52	0.0975
SILO*ADD	1	281.400625	281.400625	0.31	0.5957
SILO*PHT*ADD	1	85.100625	85.100625	0.09	0.7690

Appendix 5.3 continue

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	29179.97938	4168.56848	1.90	0.1933
Error	8	17523.14500	2190.39313		
Corrected Total	15	46703.12438			

R-Square	C.V.	Root MSE	ADF Mean
0.624797	10.79669	46.80164	433.481250

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	4241.26562	4241.26562	1.94	0.2015
PHT	1	15233.73063	15233.73063	6.95	0.0298
ADD	1	8167.64062	8167.64062	3.73	0.0896
SILO*PHT	1	45.90063	45.90063	0.02	0.8885
PHT*ADD	1	904.50563	904.50563	0.41	0.5385
SILO*ADD	1	393.03063	393.03063	0.18	0.6830
SILO*PHT*ADD	1	193.90563	193.90563	0.09	0.7736

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1236.834375	176.690625	4.64	0.0233
Error	8	304.565000	38.070625		
Corrected Total	15	1541.399375			

R-Square	C.V.	Root MSE	ADL Mean
0.802410	11.14876	6.170140	55.3437500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	156.8756250	156.8756250	4.12	0.0769
PHT	1	500.6406250	500.6406250	13.15	0.0067
ADD	1	459.0306250	459.0306250	12.06	0.0084
SILO*PHT	1	45.2256250	45.2256250	1.19	0.3075
PHT*ADD	1	21.8556250	21.8556250	0.57	0.4704
SILO*ADD	1	50.0556250	50.0556250	1.31	0.2847
SILO*PHT*ADD	1	3.1506250	3.1506250	0.08	0.7809

Dependent Variable: WSC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	323.8475000	46.2639286	11.33	0.0014
Error	8	32.6700000	4.0837500		
Corrected Total	15	356.5175000			

R-Square	C.V.	Root MSE	WSC Mean
0.908364	13.02710	2.020829	15.5125000

Appendix 5.3 continue

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	2.2500000	2.2500000	0.55	0.4791
PHT	1	85.5625000	85.5625000	20.95	0.0015
ADD	1	229.5225000	229.5225000	56.20	0.0001
SILO*PHT	1	1.9600000	1.9600000	0.48	0.5081
PHT*ADD	1	3.0625000	3.0625000	0.75	0.4117
SILO*ADD	1	0.4900000	0.4900000	0.12	0.7380
SILO*PHT*ADD	1	1.0000000	1.0000000	0.24	0.6340

Dependent Variable: IVDMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	931.7270437	133.1038634	14.69	0.0005
Error	8	72.4764500	9.0595562		
Corrected Total	15	1004.2034937			

R-Square	C.V.	Root MSE	IVDMD Mean
0.927827	6.526168	3.009910	46.1206250

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	106.6572562	106.6572562	11.77	0.0089
PHT	1	520.8665062	520.8665062	57.49	0.0001
ADD	1	253.0485562	253.0485562	27.93	0.0007
SILO*PHT	1	0.2185563	0.2185563	0.02	0.8804
PHT*ADD	1	13.3407562	13.3407562	1.47	0.2596
SILO*ADD	1	8.5702562	8.5702562	0.95	0.3592
SILO*PHT*ADD	1	29.0251563	29.0251563	3.20	0.1113

Dependent Variable: IVOMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	822.1731438	117.4533063	17.09	0.0002
Error	8	54.9918500	6.8739812		
Corrected Total	15	877.1649937			

R-Square	C.V.	Root MSE	IVOMD Mean
0.937307	5.594501	2.621828	46.8643750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	67.1990062	67.1990062	9.78	0.0141
PHT	1	471.2155563	471.2155563	68.55	0.0001
ADD	1	235.2389063	235.2389063	34.22	0.0004
SILO*PHT	1	1.3167563	1.3167563	0.19	0.6732
PHT*ADD	1	6.5152562	6.5152562	0.95	0.3588
SILO*ADD	1	9.0751562	9.0751562	1.32	0.2837
SILO*PHT*ADD	1	31.6125063	31.6125063	4.60	0.0643

Appendix 5.4 ANOVA for the effect of pre - ensiling physical preparation (chopping), additive (molasses) and type of silo on the fermentation product of napier silage.

Dependent Variable: PH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	6.88895833	0.98413690	644.98	0.0001
Error	40	0.06103333	0.00152583		
Corrected Total	47	6.94999167			

R-Square	C.V.	Root MSE	PH Mean
0.991218	0.904124	0.039062	4.32041667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	0.05467500	0.05467500	35.83	0.0001
PHT	1	5.30670000	5.30670000	3477.90	0.0001
ADD	1	0.55900833	0.55900833	366.36	0.0001
PHT*ADD	1	0.38163333	0.38163333	250.11	0.0001
SILO*PHT	1	0.22413333	0.22413333	146.89	0.0001
SILO*ADD	1	0.19000833	0.19000833	124.53	0.0001
SILO*PHT*ADD	1	0.17280000	0.17280000	113.25	0.0001

Dependent Variable: ACET

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3126.960175	446.708596	104.92	0.0001
Error	8	34.060000	4.257500		
Corrected Total	15	3161.020175			

R-Square	C.V.	Root MSE	ACET Mean
0.989225	6.842267	2.063371	30.1562500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	243.204025	243.204025	57.12	0.0001
PHT	1	1113.223225	1113.223225	261.47	0.0001
ADD	1	1633.372225	1633.372225	383.65	0.0001
PHT*ADD	1	51.912025	51.912025	12.19	0.0082
SILO*PHT	1	0.000025	0.000025	0.00	0.9981
SILO*ADD	1	30.858025	30.858025	7.25	0.0274
SILO*PHT*ADD	1	54.390625	54.390625	12.78	0.0072

Dependent Variable: PROP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	28.59734375	4.08533482	9.50	0.0025
Error	8	3.43865000	0.42983125		
Corrected Total	15	32.03599375			

R-Square	C.V.	Root MSE	PROP Mean
0.892663	24.14233	0.655615	2.71562500

Appendix 5.4 continue

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	0.63600625	0.63600625	1.48	0.2585
PHT	1	16.14030625	16.14030625	37.55	0.0003
ADD	1	10.90650625	10.90650625	25.37	0.0010
PHT*ADD	1	0.33350625	0.33350625	0.78	0.4041
SILO*PHT	1	0.00050625	0.00050625	0.00	0.9735
SILO*ADD	1	0.02175625	0.02175625	0.05	0.8276
SILO*PHT*ADD	1	0.55875625	0.55875625	1.30	0.2872

Dependent Variable: BUTYR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	132.0649438	18.8664205	27.63	0.0001
Error	8	5.4618500	0.6827312		
Corrected Total	15	137.5267937			

R-Square	C.V.	Root MSE	BUTYR Mean
0.960285	16.24728	0.826276	5.08562500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	1.01505625	1.01505625	1.49	0.2574
PHT	1	96.08900625	96.08900625	140.74	0.0001
ADD	1	25.57830625	25.57830625	37.46	0.0003
PHT*ADD	1	8.19390625	8.19390625	12.00	0.0085
SILO*PHT	1	0.05880625	0.05880625	0.09	0.7766
SILO*ADD	1	0.09455625	0.09455625	0.14	0.7194
SILO*PHT*ADD	1	1.03530625	1.03530625	1.52	0.2531

Dependent Variable: LACT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	5061.564444	723.080635	153.63	0.0001
Error	8	37.653450	4.706681		
Corrected Total	15	5099.217894			

R-Square	C.V.	Root MSE	LACT Mean
0.992616	8.422133	2.169489	25.7593750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	0.701406	0.701406	0.15	0.7095
PHT	1	2123.136006	2123.136006	451.09	0.0001
ADD	1	1965.370556	1965.370556	417.57	0.0001
PHT*ADD	1	971.101406	971.101406	206.32	0.0001
SILO*PHT	1	0.278256	0.278256	0.06	0.8140
SILO*ADD	1	0.888306	0.888306	0.19	0.6755
SILO*PHT*ADD	1	0.088506	0.088506	0.02	0.8943

Appendix 5.4 continue

Dependent Variable: NH_3N

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	45.53119375	6.50445625	9.50	0.0025
Error	8	5.47695000	0.68461875		
Corrected Total	15	51.00814375			

R-Square	C.V.	Root MSE	NH3N Mean
0.892626	15.92143	0.827417	5.19687500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	0.09150625	0.09150625	0.13	0.7241
PHT	1	21.92580625	21.92580625	32.03	0.0005
ADD	1	19.64705625	19.64705625	28.70	0.0007
PHT*ADD	1	3.30330625	3.30330625	4.83	0.0593
SILO*PHT	1	0.06890625	0.06890625	0.10	0.7592
SILO*ADD	1	0.09455625	0.09455625	0.14	0.7198
SILO*PHT*ADD	1	0.40005625	0.40005625	0.58	0.4666

Appendix 5.5 ANOVA for the effect of pre - ensiling physical preparation, additive (molasses) and type of silo on sensoric quality of napier silage.

Dependent Variable: APP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	28.12187500	4.01741071	29.14	0.0001
Error	72	9.92500000	0.13784722		
Corrected Total	79	38.04687500			

R-Square	C.V.	Root MSE	APP Mean
0.739138	12.77515	0.371278	2.90625000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	4.27812500	4.27812500	31.04	0.0001
PHT	1	9.45312500	9.45312500	68.58	0.0001
ADD	1	14.02812500	14.02812500	101.77	0.0001
SILO*PHT	1	0.02812500	0.02812500	0.20	0.6528
PHT*ADD	1	0.02812500	0.02812500	0.20	0.6528
SILO*ADD	1	0.15312500	0.15312500	1.11	0.2954
SILO*PHT*ADD	1	0.15312500	0.15312500	1.11	0.2954

Appendix 5.5 continue

Dependent Variable: SME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	26.15000000	3.73571429	25.26	0.0001
Error	72	10.65000000	0.14791667		
Corrected Total	79	36.80000000			

R-Square	C.V.	Root MSE	SME Mean
0.710598	15.08233	0.384599	2.55000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	2.45000000	2.45000000	16.56	0.0001
PHT	1	13.61250000	13.61250000	92.03	0.0001
ADD	1	7.20000000	7.20000000	48.68	0.0001
SILO*PHT	1	1.01250000	1.01250000	6.85	0.0108
PHT*ADD	1	0.01250000	0.01250000	0.08	0.7721
SILO*ADD	1	1.25000000	1.25000000	8.45	0.0048
SILO*PHT*ADD	1	0.61250000	0.61250000	4.14	0.0455

Dependent Variable: TEXT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	30.50000000	4.35714286	34.66	0.0001
Error	72	9.05000000	0.12569444		
Corrected Total	79	39.55000000			

R-Square	C.V.	Root MSE	TEXT Mean
0.771176	16.30042	0.354534	2.17500000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	5.00000000	5.00000000	39.78	0.0001
PHT	1	19.01250000	19.01250000	151.26	0.0001
ADD	1	5.51250000	5.51250000	43.86	0.0001
SILO*PHT	1	0.61250000	0.61250000	4.87	0.0305
PHT*ADD	1	0.05000000	0.05000000	0.40	0.5302
SILO*ADD	1	0.31250000	0.31250000	2.49	0.1192
SILO*PHT*ADD	1	0.00000000	0.00000000	0.00	1.0000

Dependent Variable: TOTSCORE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	238.9968750	34.1424107	64.06	0.0001
Error	72	38.3750000	0.5329861		
Corrected Total	79	277.3718750			

R-Square	C.V.	Root MSE	TOTSCORE Mean
0.861648	9.566702	0.730059	7.63125000

Appendix 5.5 continue

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	34.4531250	34.4531250	64.64	0.0001
PHT	1	123.7531250	123.7531250	232.19	0.0001
ADD	1	77.0281250	77.0281250	144.52	0.0001
SILO*PHT	1	2.6281250	2.6281250	4.93	0.0295
PHT*ADD	1	0.0781250	0.0781250	0.15	0.7030
SILO*ADD	1	0.9031250	0.9031250	1.69	0.1972
SILO*PHT*ADD	1	0.1531250	0.1531250	0.29	0.5936

Appendix 5.6 ANOVA for the effect of pre - ensiling physical preparation, additive (molasses) and type of silo on DM losses in napier silage.

Dependent Variable: DML

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	294.4400417	42.0628631	10.06	0.0208
Error	4	16.7280500	4.1820125		
Corrected Total	11	311.1680917			

R-Square	C.V.	Root MSE	DML Mean
0.946241	9.710721	2.044997	21.0591667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	22.6010042	22.6010042	5.40	0.0807
PHT	1	177.1776750	177.1776750	42.37	0.0029
ADD	1	62.9750083	62.9750083	15.06	0.0178
SILO*PHT	1	7.3593375	7.3593375	1.76	0.2553
PHT*ADD	1	8.4840083	8.4840083	2.03	0.2275
SILO*ADD	1	3.9285042	3.9285042	0.94	0.3873
SILO*PHT*ADD	1	11.9145042	11.9145042	2.85	0.1667

Dependent Variable: DMUS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	162.5786417	23.2255202	7.22	0.0373
Error	4	12.8586500	3.2146625		
Corrected Total	11	175.4372917			

R-Square	C.V.	Root MSE	DMUS Mean
0.926705	1.917369	1.792948	93.5108333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	12.08420417	12.08420417	3.76	0.1245
PHT	1	80.44540833	80.44540833	25.02	0.0075
ADD	1	54.65600833	54.65600833	17.00	0.0146
SILO*PHT	1	2.60700417	2.60700417	0.81	0.4188
PHT*ADD	1	7.56840833	7.56840833	2.35	0.1997
SILO*ADD	1	4.37760417	4.37760417	1.36	0.3081
SILO*PHT*ADD	1	0.84000417	0.84000417	0.26	0.6361

Appendix 5.7 ANOVA for the effect of pre - ensiling physical preparation, additive (molasses) and type of silo on rate of intake and degrability of napier silage.

Dependent Variable: GIN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	58161.91667	4846.82639	5.61	0.0001
Error	35	30249.06250	864.25893		
Corrected Total	47	88410.97917			

R-Square	C.V.	Root MSE	GIN Mean
0.657859	20.22528	29.39828	145.354167

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HEIF	5	39112.10417	7822.42083	9.05	0.0001
SILO	1	3553.52083	3553.52083	4.11	0.0503
PHT	1	3056.02083	3056.02083	3.54	0.0684
ADD	1	5874.18750	5874.18750	6.80	0.0133
PHT*SILO	1	2715.02083	2715.02083	3.14	0.0850
ADD*SILO	1	1250.52083	1250.52083	1.45	0.2371
ADD*PHT	1	713.02083	713.02083	0.83	0.3699
ADD*PHT*SILO	1	1887.52083	1887.52083	2.18	0.1484
					1351

Dependent Variable: GDMI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	2175.051325	181.254277	6.87	0.0001
Error	35	923.339575	26.381131		
Corrected Total	47	3098.390900			

R-Square	C.V.	Root MSE	GDMI Mean
0.701994	19.87908	5.136256	25.8375000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
HEIF	5	1199.519125	239.903825	9.09	0.0001
SILO	1	1.020833	1.020833	0.04	0.8452
PHT	1	305.424300	305.424300	11.58	0.0017
ADD	1	533.466675	533.466675	20.22	0.0001
PHT*SILO	1	37.807500	37.807500	1.43	0.2393
ADD*SILO	1	42.978675	42.978675	1.63	0.2102
ADD*PHT	1	12.834008	12.834008	0.49	0.4901
ADD*PHT*SILO	1	42.000208	42.000208	1.59	0.2154

Appendix 5.7 continue

Dependent Variable: A

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	234.1507000	33.4501000	30.41	0.0001
Error	8	8.7999000	1.0999875		
Corrected Total	15	242.9506000			

R-Square	C.V.	Root MSE	A Mean
0.963779	6.902289	1.048803	15.1950000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	56.32502500	56.32502500	51.21	0.0001
PHT	1	62.48902500	62.48902500	56.81	0.0001
ADD	1	67.48622500	67.48622500	61.35	0.0001
SILO*PHT	1	12.11040000	12.11040000	11.01	0.0106
PHT*ADD	1	0.96040000	0.96040000	0.87	0.3774
SILO*ADD	1	1.08160000	1.08160000	0.98	0.3504
SILO*PHT*ADD	1	33.69802500	33.69802500	30.63	0.0006

Dependent Variable: B

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	142.7173938	20.3881991	2.49	0.1121
Error	8	65.4419500	8.1802437		
Corrected Total	15	208.1593437			

R-Square	C.V.	Root MSE	B Mean
0.685616	5.694387	2.860113	50.2268750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	10.35230625	10.35230625	1.27	0.2932
PHT	1	56.96475625	56.96475625	6.96	0.0298
ADD	1	38.03805625	38.03805625	4.65	0.0631
SILO*PHT	1	22.72905625	22.72905625	2.78	0.1341
PHT*ADD	1	0.02030625	0.02030625	0.00	0.9615
SILO*ADD	1	14.61150625	14.61150625	1.79	0.2182
SILO*PHT*ADD	1	0.00140625	0.00140625	0.00	0.9899

Dependent Variable: C

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.00059075	0.00008439	0.68	0.6906
Error	8	0.00099900	0.00012487		
Corrected Total	15	0.00158975			

R-Square	C.V.	Root MSE	C Mean
0.371599	38.70043	0.011175	0.02887500

Appendix 5.7 continue

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	0.00003600	0.00003600	0.29	0.6059
PHT	1	0.00028900	0.00028900	2.31	0.1667
ADD	1	0.00015625	0.00015625	1.25	0.2958
SILO*PHT	1	0.00007225	0.00007225	0.58	0.4687
PHT*ADD	1	0.00000900	0.00000900	0.07	0.7951
SILO*ADD	1	0.00001600	0.00001600	0.13	0.7296
SILO*PHT*ADD	1	0.00001225	0.00001225	0.10	0.7621

Dependent Variable: POT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	82.77177500	11.82453929	1.54	0.2778
Error	8	61.35340000	7.66917500		
Corrected Total	15	144.12517500			

R-Square	C.V.	Root MSE	POT Mean
0.574305	4.233070	2.769328	65.4212500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	18.36122500	18.36122500	2.39	0.1604
PHT	1	0.12602500	0.12602500	0.02	0.9012
ADD	1	4.20250000	4.20250000	0.55	0.4803
SILO*PHT	1	1.65122500	1.65122500	0.22	0.6550
PHT*ADD	1	0.70560000	0.70560000	0.09	0.7694
SILO*ADD	1	23.61960000	23.61960000	3.08	0.1173
SILO*PHT*ADD	1	34.10560000	34.10560000	4.45	0.0680

Dependent Variable: D48

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	416.5562437	59.5080348	4.93	0.0196
Error	8	96.5614500	12.0701812		
Corrected Total	15	513.1176937			

R-Square	C.V.	Root MSE	D48 Mean
0.811814	6.752526	3.474217	51.4506250

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	131.8478062	131.8478062	10.92	0.0108
PHT	1	155.3139063	155.3139063	12.87	0.0071
ADD	1	63.6405062	63.6405062	5.27	0.0508
SILO*PHT	1	28.7028062	28.7028062	2.38	0.1616
PHT*ADD	1	4.0905063	4.0905063	0.34	0.5765
SILO*ADD	1	14.5351563	14.5351563	1.20	0.3044
SILO*PHT*ADD	1	18.4255562	18.4255562	1.53	0.2517

Appendix 5.7 continue

Dependent Variable: EFFD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	241.7243750	34.5320536	13.12	0.0008
Error	8	21.0500000	2.6312500		
Corrected Total	15	262.7743750			

R-Square	C.V.	Root MSE	EFFD Mean
0.919893	3.143249	1.622113	51.6062500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	82.35562500	82.35562500	31.30	0.0005
PHT	1	64.40062500	64.40062500	24.48	0.0011
ADD	1	41.92562500	41.92562500	15.93	0.0040
SILO*PHT	1	8.55562500	8.55562500	3.25	0.1090
PHT*ADD	1	0.27562500	0.27562500	0.10	0.7545
SILO*ADD	1	17.43062500	17.43062500	6.62	0.0329
SILO*PHT*ADD	1	26.78062500	26.78062500	10.18	0.0128

Appendix 5.8 ANOVA for the effect of various ensiling techniques studies on the cost of producing a useful Napier silage.

Dependent Variable: TCOST

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	4778567937	682652562	99999.99	0.0
Error	4	331	83		
Corrected Total	11	4778568268			

R-Square	C.V.	Root MSE	TCOST Mean
1.000000	0.031426	9.096102	28944.5292

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	4726360710	4726360710	99999.99	0.0
PHT	1	40756286	40756286	99999.99	0.0
ADD	1	11450733	11450733	99999.99	0.0
SILO*PHT	1	137	137	1.66	0.2675
PHT*ADD	1	17	17	0.21	0.6703
SILO*ADD	1	52	52	0.63	0.4720
SILO*PHT*ADD	1	1	1	0.01	0.9387

Dependent Variable: DMUSEF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1314.391467	187.770210	32.78	0.0022
Error	4	22.911300	5.727825		
Corrected Total	11	1337.302767			

R-Square	C.V.	Root MSE	DMUSEF Mean
0.982868	3.652852	2.393287	65.5183333

Appendix 5.8 continue

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	2.3312667	2.3312667	0.41	0.5582
PHT	1	343.0421333	343.0421333	59.89	0.0015
ADD	1	963.0208333	963.0208333	168.13	0.0002
SILO*PHT	1	0.8362667	0.8362667	0.15	0.7218
PHT*ADD	1	0.4961333	0.4961333	0.09	0.7832
SILO*ADD	1	0.0008167	0.0008167	0.00	0.9910
SILO*PHT*ADD	1	4.6640167	4.6640167	0.81	0.4179

Dependent Variable: COSTDMUS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1274869.533	182124.219	2959.97	0.0001
Error	4	246.116	61.529		
Corrected Total	11	1275115.649			

R-Square	C.V.	Root MSE	COSTDMUS Mean
0.999807	1.735645	7.844046	451.938333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SILO	1	1203225.167	1203225.167	19555.40	0.0001
PHT	1	1814.496	1814.496	29.49	0.0056
ADD	1	28163.016	28163.016	457.72	0.0001
SILO*PHT	1	12139.652	12139.652	197.30	0.0001
PHT*ADD	1	1273.904	1273.904	20.70	0.0104
SILO*ADD	1	25176.747	25176.747	409.18	0.0001
SILO*PHT*ADD	1	3076.550	3076.550	50.00	0.0021

Appendix 6. An arbitrary organoleptic test chart used for sensoric evaluation of napier silage recovered from the silos.

Date................
Assesor No..........
Silo type...........

Treatment number	Condition score			
	Appearance			
	1	2	3	4
T1				
T2				
T3				
T4				
	Smell			
	1	2	3	4
T1				
T2				
T3				
T4				
	Touch			
	1	2	3	
T1				
T2				
T3				
T4				

Score grades:

Appearance:
1 = Poor - Spoiled silage, dark brown in colour with mould growth
2 = Moderate - Greenish, with some mould growth
3 = Good - Yellowish green to brown colour
4 = Very good - Well pickled silage, yellowish green to light brown colour

Smell:
1 = Poor - Foul smell associated with putrefaction
2 = Moderate - Moderate pungent smell of ammonia
3 = Good - Moderate pleasant aroma
4 = Very good - Pleasant estery aroma (typical silage smell)

Touch:
1 = Poor - Slimy and watery
2 = Satisfactory - Less slimy and wet
3 = Good - Non - slippery and slightly wet

NB: Tick the appropriate score.