USE OF FRESH SUGAR CANE CRUSH AS AN ADDITIVE FOR GRASS SILAGE

BY

PIUS YORAM KAVANA

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE

1998

ABSTRACT

A study comprising of two experiments was conducted to investigate the effectiveness of Fresh Sugar Cane Crush (FSCC) as water soluble carbohydrate (WSC) additive for napier (*Pennisetum purpureum*) and guatemala (*Tripsacum laxum*) grasses silage making.

Polyvinyl chloride (PVC) pipes of average 1.9 X $10^{-2}M^3$ were used as laboratory silos for experiment I and earth pit silos (7.5 x $10^{-1}M^3$) for experiment II. The second experiment was conducted so as to mimic the field condition as well as to produce enough silage for acceptability test by dairy heifers.

The effect of grass species and additives were observed in both experiments while the effect of wilting was observed in the first experiment only. In both experiments five treatments comprised of T1 - no additive (control), T2 - 5 % molasses, T3 - 5 % FSCC, T4 - 10 % FSCC, T5 - 15 % FSCC were used to test the effectiveness of FSCC as a WSC additive in grass silage making. Parameters observed were chemical composition, fermentation products, sensoric tests and *in- vitro* dry matter digestibility (IVDMD). Dry matter losses and acceptability test were observed in the second experiment. The data were analyzed by General linear model system of SAS (1988). In the first experiment, there was no significant ($P > 0.05$) difference between unwilted and wilted napier silages in terms of DM contents. Wilted guatemala silage had significantly ($P < 0.05$) higher DM contents than unwilted guatemala silage. In

napier silage, wilting resulted into higher WSC (16.7 vs 15.0 $gkg^{-1}DM$), IVDMD (59.9 vs 58.7 %), pH (4.02 vs 3.89), ammonia nitrogen (3.4 vs 2.5 %) and lower lactic acid (15.3 vs 17.5 $gkg^{-1}DM$). In guatemala grass silage,wilting resulted into higher WSC (20.4 vs 14.2 $gkg^{-1}DM$), ammonia nitrogen (3.8 vs 2.9 %), lactic acid (18.4 vs 13.5 gkg-1DM), butyric acid (1.2 vs 0.6 $gkg^{-1}DM$) and lower IVDMD (60.7 vs 62.2).The pH between wilted and unwilted guatemala grass silages were not significantly different ($P > 0.05$).

The DM contents were significantly different ($P < 0.05$) between treatments in unwilted napier and wilted guatemala grass silages. For both napier and guatemala grass silages, pH ranged from 3.78 in T5 for unwilted guatemala to 4.5 in T1 for wilted napier. Lactic acid ranged from 3.6 in T1 wilted guatemala to 27.4 $gkg^{-1}DM$ in T5 unwilted napier. Ammonia nitrogen was lowest (2.3 %) in T5 wilted guatemala and highest (4.6 %) in T1 wilted guatemala.

Regardless of wilting DM, WSC, IVDMD, ammonia nitrogen, and butyric acid were significantly ($P < 0.05$) higher in guatemala silage than in napier silage. The pH and lactic acid contents of napier and guatemala silages were not significantly ($P > 0.05$) different.

In experiment two, the DM contents were significantly ($P < 0.001$) different between treatments in guatemala silage and the percentage DM loss ranged from 16.1 in T5 to

39.1 % in T1. In napier silage the DM loss was highest (32.9 %) in T2 and lowest (13.7 %) in T3. In guatemala silage the intake rate between treatments ranged from 14.6 in T4 to 31.2 gDM/min in T2. In napier silage the intake rate ranged from 29.1 in T2 to 41.6 gDM/min in T4. Both napier and guatemala silages showed significant ($P < 0.05$) difference between treatments in terms of WSC and IVDMD. In napier silage, the control treatment had highest pH (4.34), ammonia nitrogen (3.9 %) and lower lactic acid (7.9 $gkg^{-1}DM$).Butyric acid was not detected in napier silages. In guatemala silage, the control treatment showed the highest pH (4.54), Ammonia nitrogen (3.1 %), butyric acid (3.0 $gkg^{-1}DM$) and lowest lactic acid (7.3 $gkg^{-1}DM$).

There were no significant differences between napier and guatemala silages in terms of DM, IVDMD and ammonia nitrogen. The WSC contents and intake rate were higher in napier than in guatemala silage.The percentage DM loss, pH, lactic acid and acetic acid content were significantly ($P < 0.05$) higher in guatemala than in napier silage.

It was concluded that 5% FSCC and 10% FSCC could be used to conserve well silages of guatemala and napier grasses, respectively. Further findings are required to establish the levels of inclusion of FSCC in other common grasses such as *Panicum maximum* and *Setaria splendida.*

DECLARATION

I, PIUS YORAM KAVANA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and that it has never been submitted for a degree in any other University.

Signature.....

Date.....10/11/1998

COPYRIGHT

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the Norwegian Agency for International Development Cooperation (NORAD) for financial support granted to me. I would like to thank the Ministry of Agriculture, Livestock and Cooperatives for offering the study leave that enabled me to perform this work.

I wish to express my deepest appreciation to my supervisors Dr. E.J. Mtengeti and Prof. N.A. Urio for their guidance and constructive criticism when conducting this study. Special thanks to Mr. Protas, Mrs. Mbwana, Mr. Alute, Mr. Haji, Mr. John, and Mr. Moses for the assistance they provided me during data collection and laboratory work.

Special thanks to Mr. Palangyo who assisted me during VFA and lactic acid determination at the University of Dar-es-salaam. Lastly but not least I would like to thank my brothers, sisters and class mates for their contribution in one way or another during the whole period of my stay at Sokoine University of Agriculture. May God bless you all.

DEDICATION

To my parents, Rev. Yoram and Mrs. Josephine Kavana, for their efforts and sacrifices to make sure that I get education at a higher level.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS

% = Percent

ADF = Acid detergent fibre

ANOVA = Analysis of variance

AOAC = Association of official analytical chemists

CP = Crude protein

DM = Dry matter

FSCC = Fresh sugar cane crush

g = gram

g/min = Gram per minute

GLM = General Linear Model

HEM = Hemicellulose

IVDMD = in vitro dry matter digestibility

kg = Kilogram

LA = Lactic acid

LAB = Lactic acid bacteria

m = Metre

μL = Microlitre

ml = Millilitre

mm = Millimetre

N = Nitrogen

NDF = Neutral detergent fibre

NH_3N = Ammonia nitrogen

SAS = Statistical analysis system

SEM = Standard error of the means

SS1 = Sum of square type 1

T1 = Treatment 1. (No additive used)

T2 = Treatment 2. (5 % molasses included)

T3 = Treatment 3. (5 % FSCC included)

T4 = Treatment 4. (10 % FSCC included)

T5 = Treatment 5. (15 % FSCC included)

TN = Total nitrogen

VFA = Volatile fatty acid

vs = Versus

WSC = Water soluble carbohydrates

1.0 INTRODUCTION

Pasture and forage whether grazed or cut and carried to the animals, are the basis for ruminant production in the tropics. The improvement of ruminant production through breeding and disease control cannot be of high value if forage supply remains the first limit to animal output in a particular area. In the tropics forage availability during the wet season often exceeds the animal requirement while in the dry season the forage availability is scarce.

Inadequate supply of forage during the dry season has been recorded to last for about 6 to 7 months per year in some places of Tanzania (Mbwile and Madata, 1984). It has been documented by Crowder and Chedda (1982) that the productivity and chemical composition of tropical grassland vary depending on the length and intensity of wet and dry seasons. The authors revealed further that herbage quality is generally satisfactory during 3 to 6 months of the growing season. Therefore dairy animals are supplied with low quality forage during the dry season. From such poor supply of feed the overall performance of the animal can be greatly reduced.

Fluctuation in terms of quantity and quality of feed can be reduced by conserving the surplus forage that is available during the wet season. Mtengeti *et al* (1989) indicated that elephant and guatemala grasses are high yielding fodders which small scale dairy farmers are encouraged to grow. Like other tropical grasses, elephant and guatemala

grasses grow fast and produce high dry matter in the rainy season that could be wasted if not conserved. Productivity of elephant grass for example may be up to 7 tons of DM/cut/ha (Otieno *et al*,1990). On the other hand, Mtengeti *et al.* (1989) observed higher dry matter in guatemala grass than napier grass at all stages of growth. It is therefore, important to develop conservation methods that will enable small holder dairy farmers to conserve the surplus forage obtained from these grasses and thereby ensuring availability of good quality forage for feeding dairy animals during the dry season.

Hay and silage making can be appropriate methods of forage conservation. Hay making in the tropics is however difficult because in most cases the optimal hay making periods are attained at the mid of the rainy season which limits the drying process. Fine weather for hay making can be towards the end of the rain season when the grasses are overgrown resulting into low nitrogen content, high crude fibre and low digestibility (Humphreys, 1978). Silage making could therefore be appropriate because the technique is less weather dependent (Wilson and Bringstock,1981).

Conservation of forage in form of silage is not common to small holder dairy farmers in Tanzania (Maeda, 1996). The reason for such a situation could be lack of simple methods of silage making that can be easily adopted by farmers. Tropical grasses are generally coarse and stemmy, high in crude fibre and low in water soluble carbohydrates (Crowder and Chedda, 1982). A combination of these factors result in

delayed fermentation and proliferation of clostridia organisms during fermentation process. To alleviate the limitation of low water soluble carbohydrates, additives that stimulate fermentation process (e.g.molasses) are added in pre-ensiled forage. Recently, molasses has gained popularity over chemical additives as a cheap and non toxic silage preservative in tropical countries where sugar cane and sugar beets are grown (Maeda, 1996). However its availability for small holder dairy farmers is hampered by high transportation costs. It is therefore, plausible to consider other alternative sources that could be within reach to small holder dairy farmers. An example of such alternatives include fresh sugar cane crush which was used in this study. Sugar cane is widely grown in different areas of Tanzania by small scale farmers for chewing, and for making local brew.

The main objective of this study was therefore to establish the effectiveness of fresh sugar cane crush as a water soluble carbohydrate additive for grass silage making. The specific objectives were:

(a) To determine the quality of napier and guatemala grass silages prepared with fresh sugar cane crush as water soluble carbohydrates additive.

(b) To test the acceptability by cattle of napier and guatemala grass silages prepared by using fresh sugar cane crush as an additive.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Principles of ensilage

Ensilage involves all physical and chemical changes that take place when forage with sufficient moisture is stored in a silo in the absence of air (Banerjee, 1991). Storage of forage in airtight structures known as silo, result in fermented feed which is commonly known as silage.

The conservation of crop silage depends upon the natural fermentation of sugars by Lactic Acid Bacteria (LAB) under anaerobic condition. Generally, achieving and maintaining anaerobic conditions are the most important tasks in making silage.

Anaerobic conditions limits the plant tissue respiration, clostridial activity and aerobic microbial growth. All these can increase wasteful utilization of plant tissue nutrients and result into poor quality silage.

2.2 The ensiling process

For good quality silage, dry Matter (DM) content of the materials to be ensiled should be between 30 to 45 % (Banerjee, 1991). This is essential because high moisture content of the material increase effluent production. On the other hand, materials with high DM content are difficult to compress and therefore, liable to aerobic losses.

Succulent forage can be wilted before ensiling so as to raise the DM content but, wilting does not improve silage quality significantly. Martinsson (1991) observed minor differences in chemical composition between wilted and un-wilted silages dominated with *Phleum pratense* and *Festuca pratensis*. Both pH, ammonia nitrogen per total Nitrogen and fatty acids contents were almost identical. But, the difference could be significant in some grass species probably in the tropics because high ambient temperatures could favour high rate of aerobic respiration during the wilting period and consequently, high DM losses that could affect fermentation product and therefore the quality could be affected. Also, tough stemmy tropical grasses are difficult to compress resulting into entrapping of air that could cause losses of DM due to aerobic respiration.

2.3 The fermentation process

Silage is always made from living plants and the cells live for some time after the plants are put into the silo. The respiration processes can continue in the silo although they can be modified by the absence of air i.e, anaerobic respiration can take place in the silo, but the photosynthesis processes which depend on light and air are stopped. Therefore anaerobic processes that take place during fermentation of ensiled plant materials involve utilization of plant cells protoplasm by anaerobic bacteria.

The major changes which occur during ensiling are the fermentation of sugars to form acids and the breakdown of some of the protein in the forage to simpler compounds,

including ammonia (Wilkins and Wilson, 1970).

Fermentation processes results in an increase of heat in the silo because the silo is sealed and therefore heat is not dissipated through evapotranspiration as it could be done in living plants. Elevated heat in the silo, accelerates the anaerobic respiration but, as long as the synthesis processes are not taking place the process finally comes to halt because of depletion of substrate to break down.

2.3.1 Role of microorganisms in silage making

Aerobic fungi and bacteria are the dominant microorganisms on fresh herbage, but as anaerobic conditions develop in the silo they are replaced by bacteria able to grow in the absence of oxygen such as Escherichia, Klebsiella, Bacillus, Clostridium, Streptococcus, Leuconostoc, Lactobacillus and Pediococcus (McDonald, *et al*,1988). The potential microorganisms for silage making are the Lactic Acid Bacteria (LAB) which are facultative anaerobes. They are normally present on growing crops in small numbers but usually multiply rapidly after harvesting, particularly if the crop is chopped or lacerated (McDonald *et al*, 1988). These bacteria are of two types, homofermentative and heterofermentative. The homofermentative LAB convert glucose and fructose to lactic acid only while the heterofermentative LAB convert sugars to a range of products.

Henderson (1993) noted that, when there is no more carbohydrate available in the

silage, the LAB can do secondary fermentation of Lactic Acid (LA) to Acetic Acid. Some bacteria compete with LAB for available carbohydrates. For example Enterobacteria can be active at the initial stages of ensilage but they are readily inhibited by anaerobiosis and acidification. Failure to establish anaerobic conditions in the silo might result into the establishment of Enterobacteria and consequently lower the quality of silage. This is because the bacteria can utilize some of amino acids available and produce ammonia as a by product. Both saccharolytic and proteolytic clostridia can be present in silage as contaminants derived from soil particles. Clostridia are particularly sensitive to water availability and their growth cannot be inhibited even at pH below 4.0 if the crop is very wet (McDonald *et al.*, 1995). Wilting of succulent forage is important so as to limit the growth of these microorganisms.

Yeasts and mould are dependent on oxygen for their growth and they have significant role in the aerobic deterioration of silage. Opening of silo at the time of feeding enables entry of oxygen which can support growth of these microorganisms.

2.3.2 Effect of wilting in silage making

Water loss from the plant takes place at the leaf surface and it is estimated that 5 - 10 % of water loss in plant is through the cuticle while the greater part is throughstomata or from wet surface of mesophyll cells opening to substomatal cavities (Sullivan, 1973). Control of water loss through stomata is significant when the plant is intact

because stomata are open if the guard cells have a great turgor than adjacent epidermal cells. This may occur from the presence of organic solutes produced by photosynthesis or from reception of ions from adjacent cells. In prolonged draught the stomata may remain closed and therefore water loss through epidermal cells becomes the major route. Plants with different epidermal thickness could therefore differ in extent to which they dry when wilted. Plants which have thick cuticle layer could impose high resistant to water loss than plants with thin cuticle layer. Moisture content of the air could determine the rate at which the plants lose moisture to the surrounding. Dry air could allow large amount of water to escape from the plants than humid air.

Wilting of plants before ensiling is intended to increase the proportion of the dry matter in ensiled materials. However, there are controversial observations on the benefits of wilting to the nutritive value of silage prepared from wilted forage. Many authors reported that wilting of plants before ensiling is beneficial in reduction of effluent production (Henderson, 1993; McDonald, 1995; Crowder and Chheda, 1982). Other benefits of wilting forages before ensiling were noted by Crowder and Chheda (1982) as production of more palatable silage with higher pH and higher concentration of sugar and increased stability of silage due to higher osmotic pressure which suppress the growth of Clostridia. However, very dry silages (above 50 % DM) are associated with difficult in anaerobic storage due to difficult in compaction. In comparing unwilted and wilted silages, Teller and Vanbelle (1991) reported improvement in digestibility and protein content in wilted silage than unwilted silage.

Further, the authors reported a reduced live weight losses of cows after calving, improvement in fertility, increase in milk yield and protein content of milk for cows fed wilted silage than cows fed unwilted silage. However, Martinsson (1991) reported minor differences in chemical composition between unwilted and wilted silages. On the other hand, Michelena and Molina (1990) reported lower nitrogen content, pH, lactic acid and higher volatile acids (VFA) in unwilted silage than wilted silage. The differences observed by different authors could be associated with species difference. Martinsson (1991) was dealing with silage prepared from grasses dominated by *Phleum pratense* and *Festuca pratensis* (temperate grasses). While Michelena and Molina (1990) did their observation in *Pennisetum purpureum* silage (tropical grass). Further, the differences between unwilted and wilted could depend on the extent to which wilted forage is dried because McDonald (1995) noted that fermentation is restricted as dry matter content increases which is reflected in higher pH and WSC values. Teller *et al.* (1990) reported greater protein intake in wilted silage than unwilted silage and concurrently efficiency of bacteria protein synthesis in the rumen was improved as well as energy supply when wilted silage was fed instead of unwilted silage. The literature indicated controversy between characteristics of unwilted and wilted silages. It can be concluded that good quality silages can be prepared from both wilted and unwilted forages provided that anaerobic conditions in silos are ensured and the forages are harvested within a reasonable time of growth.

2.3.3 Forage components contributing to fermentation

Carbohydrates are the major component of plant tissues and they comprise 50 % or more of dry matter of forages. This component can be classified into two main categories, structural and non structural carbohydrates. Structural carbohydrates are not readily soluble in water therefore their contribution to fermentation is limited. Non structural carbohydrates comprise starch (which is sparingly soluble in water) and the Water Soluble Carbohydrates (WSC). The WSC includes fructans, glucose, fructose, sucrose, raffinose and stachose (McDonald *et al.*, 1995). Water soluble carbohydrates play a major role in fermentation because they provide readily available energy to LAB which in turn produce lactic acid as a by product. Grasses of tropical and sub tropical origin accumulate starches instead of fructans in their vegetative tissue (McDonald, 1995). Starch is not a water soluble carbohydrate therefore cannot be utilized efficiently by lactic acid bacteria.

Ensilage process has an influence on protein content of silage. When oxygen is present in the silo the rate of proteolysis is rapid. Plant proteases are most active between pH 6 and 7 but, activity continue at reduced rate at values below pH 4 (Heron *et al*, 1989). Thus the higher the rate of drop of pH in the silo, the less extensive is the degradation of protein. Protein and amino acid degradation are also less extensive as DM of herbage increases (Charmley and Veira, 1990). High DM content signify low moisture content which has a negative effect on microbial activities. According to Rechcigl (1975) the amount of moisture available to various microorganisms determines whether they can grow or not. The same author indicated that mould

require less moisture than yeast and yeast in turn are less moisture demanding than bacteria. According to Henderson (1993), the important factors which influence the extent of degradation of protein by plant enzymes are DM content, the presence of oxygen, pH and temperature.

2.3.3.1 Water Soluble Carbohydrates

Glucose and fructose are the two most important monosaccharides occurring in grasses, concentrations being of the order of 10 to 30 g/kgDM (Waite and Gorrod, 1959). Disaccharides normally sucrose occurs in amounts ranging from 20 to 80 g/kg DM (McDonald, 1981). Tropical grasses are considered to be lower in WSC than temperate grass species. Crowder and Chheda (1982) reported that the WSC contents of tropical grasses is often less than 6 % of DM. Dale (1973) reviewed some literatures which indicated that early maturing cultivars of cocksfoot (*Dactylis glomerata*) showed higher WSC contents than late maturing cultivars. The same author noted a diurnal variation in WSC in perennial ryegrass. This could be a result of photosynthetic activities during the day. Again, the author noted that light intensity and ambient temperature influence WSC content. Highest level of WSC was observed in plants grown at high light intensities and low temperature condition while lowest WSC level was observed in plants grown in shade and low temperature condition. High levels of N-fertilizer has been shown to reduce WSC in plants (McIlroy, 1967). Probably, N-fertilizers promote rapid vegetative growth which result in low deposition of carbohydrates because growth is energy requiring process.

2.3.4 Silage quality

Silage quality is the term generally used to denote the extent to which silage fermentation has been successful (Sarwatt, 1995). There are different methods that can be used to determine quality of silage. For example simple organoleptic tests (Amos and Woodman, 1930) as cited by Sarwatt (1995) or use of modern equipments which enable automatic recording of the important parameters during the fermentation process (Selma-Olsen, 1990). Well preserved silage is indicated by low pH (below 4.2), low ammonia nitrogen (below 8 % TN), high lactic acid content (above 3 %) and absence of butyric acid (Jones, 1970). Low pH is required to limit growth of microorganisms that can spoil silage. Low pH in silage can be achieved by ensiling forage containing high WSC provided that anaerobic conditions are maintained in the silo. Tropical grasses have low concentration of WSC often below 6 % (Crowder and Chheda, 1982). It is therefore difficult to achieve low pH when ensiling tropical grasses without additive that can increase the level of WSC. Forage crops such as maize and sorghum however, have higher sugar contents and therefore produce good lactic acid silage in tropical environment (Miller *et al.*, 1964). The demand of maize and sorghum as food for human being is high in Tanzania. This makes rather difficult to depend on maize and sorghum as appropriate forages for silage making. Therefore alternative forages for silage making have to be used. High ammonia nitrogen result from proteolytic activities of plant enzymes and proteolytic microbes. Proteolysis reduces the protein content of silage due to degradation of proteins and putrefaction of amino acids such as lysine and arginine. The extent of proteolysis varies

depending on the silage condition for example McPherson and Violante (1966) reported that a high final pH of silage entail severe proteolysis and massive deamination because slow and limited fall in pH had little inhibitory effect either on plant or bacterial enzymic action. High and rapid production of acid in ensiled materials could be important in limiting loss of proteins due to proteolysis. Organic acids like lactic acid produced during fermentation play a role in conservation of silage by limiting development of clostridia. The inhibition of clostridia is caused by hydrogen ion concentration and undissociated acid (McDonald and Whittenbury, 1973). The same authors stated that it is difficult to state an exact `critical pH value' for silage because it depends not only on pH but also on moisture content and temperature. Clostridia are not desirable in silage because they can cause secondary fermentation of organic acids (eg. *Clostridium butyricum*) to form butyric acid and other group for example *Clostridium sporogenes* can putrefy proteins. These activities of Clostridia result in increase in pH of silage which consequently enables growth of other microorganisms like fungi which spoil the silage. It is clear that rapid lowering of pH result in production of good quality silage due to limitation of proteolysis as well as growth of microbes that can produce undesirable products. The key factor apart from maintaining anaerobic condition in silo is the WSC content of ensiled material because it enables production of acids which lower the pH. Therefore, in order to produce silage of good quality from tropical grasses, methods to improve WSC content of ensiled material should be given priority.

In order to classify silage with respect to fermentation quality, different indices have been developed and used. For example, concentration of volatile fatty acids (Flieg, 1938), pH values (Virtanen, 1952) and ammonia nitrogen content (Nilson *et al*, 1956) or a combination of these and other criteria (Langston *et al*, 1958).

2.3.4.1 Physical assessment of silage

Based on silage temperature, appearance, smell, texture and taste, McCullough (1975) identified three distinct types of silage. He described good quality silage as one which maintain temperature between 26.7 to 37.8 °C, having a light green to yellow colour with pleasant aroma, firm tissue and sharp acid taste. Poor silage was described to be 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. Over heated silage described as the one maintained at high temperature above 40 °C and having a brown to blackish colour. This technique of evaluating silage quality can be useful by farmers because it does not involve sophisticated measurements which require modern laboratories and equipments.

2.3.4.2 pH value

Well preserved silages are characterized by having low pH values between 3.7 to 4.2 and containing high concentration of lactic acid generally between 80 to 120 g/kg DM (McDonald *et al.*, 1995). The pH alone is not a determinant of good quality silage because low pH could have resulted from organic acids other than lactic acid.

Generally, a decrease in pH reflects an increase in lactic acid, total acidity and amino acids while denoting a decrease in volatile acids content (McCullough, 1975).

2.3.4.3 Flieg index

Flieg (1938) developed an index based on proportions of lactic acid, acetic acid and butyric acids (expressed in milliequivalents). It was observed that the higher the proportions of lactic acid and acetic acid to butyric acid, the higher the scores and the better the quality. This index was modified by Zimmer (1966) who based the index on the percent of lactic acid in total acids and classified the silage as very bad (0-20), bad(21-40), medium(41-60), good (61-80) and very good (81-100).

2.3.4.4 Ammonia nitrogen

Ammonia nitrogen level indicates the extent by which protein has been degraded or lost during fermentation (Maeda, 1996). Ammonia production in silages result from proteolytic activities of microbes on the amino acids. Lactic acid bacteria are virtually non proteolytic, their ability to ferment amino acids appears to be restricted and thought to be limited to serine and arginine. More over, it is only some lactic acid bacteria which can attack those amino acids (McDonald, 1981).

Clostridia are the main proteolytic bacteria in silage. The amount of ammonia present in the silage is therefore a reliable indicator of the extent of proteolytic clostridia activity. Ammonia is however produced in small amount by other microorganisms and

plant enzymes (McDonald, 1981). It is therefore plausible to consider the production of ammonia nitrogen in silage as one of the indicators of the quality of silage because production of ammonia nitrogen occurs at the expense of protein degradation. Breirem and Saue (1973) made an arbitrary classification of the silage quality based on the percentage of butyric acid and ammonia nitrogen as shown in table 1.

Table 1: Silage quality based on some important fermentation products

Silage quality	Butyric acid concentration (%)	Ammonia nitrogen as % of total nitrogen
Good	maximum 0.1	maximum 8
Acceptable	0.1 to 0.3	8.1 to 12
Poor	0.3 to 0.6	12.1 to 18
Not acceptable	above 0.6	above 18

Source: Breirem and Saue (1973)

2.4 Nutritive value of silage

The nutritive value of forage can be defined as the concentration of the nutrient in the herbage or can be defined in terms of the animal production response per unit of forage consumed (Pathak and Jakhmola,1983). The nutritive value of silage is influenced by the nature of the crop at the time of harvest and the changes which occur as a result of plant enzyme and microbial activities in the silo (McDonald, 1981). Generally, nutrients are maximum in the forage at the critical point of heading or incipient flowering (Van Soest, 1982). Variation in nutrient content of forages do

occur depending on the environmental condition (mainly edaphic factors), the forage species and stage of maturity of the plants. It is therefore important to consider the agronomic principles required for good quality forage production and optimum time of harvest so as to ensile forage of high nutrient content.

2.4.1 Chemical composition of silage

The amount of nutrients in a well preserved silage may be almost similar to the amount of nutrients found in fresh herbage from which the silage was made (Woolford, 1984). However, Catchpoole and Henzell (1971) reported great variations in chemical composition of silage particularly in energy and protein. The reason for the variations were due to the breakdown of soluble carbohydrates in the ensiled forage material followed by increase in concentration of organic acids and structural carbohydrates together with transformation of nitrogenous components. The nutrient contents of silage are expressed relative to the total dry matter because they are components of the dry matter. It is therefore important to know the dry matter content of the silage because it determines the amount of nutrients that can be consumed by the animal when fed silage.

2.4.1.1 Dry matter content of silage

Dry matter content of silage is an indication of the amount of nutrients available that can be subjected to digestibility and utilization by the animal. Dry matter content of silage also includes the volatile fatty acids. Therefore, dry matter determination of

silage should be in such a way that losses of volatile fatty acids are avoided or the losses be taken into account when the calculation of dry matter is done. Reliable data on dry matter of silage can be obtained by using results from either toluene distillation or freeze dried samples (Larsen and Jones, 1975).

Dry matter of the silage is the outcome of the dry matter retained after losses that ensiled forage had encountered during fermentation as a result of effluent loss and biochemical changes of nutrients. Nutrient losses are inevitable during ensilage though they can be minimized. It was indicated by McCullough (1983) and Woolford (1984) that forages low in dry matter contents are prone to clostridial fermentation and increased effluent losses resulting in low dry matter content of silage. Wilting or addition of preservatives were suggested by Machado and Muhlbach (1986) as the prerequisite for improvement of dry matter content of silage made from high moisture forage. However, Robles and Ordoveza (1971) found that wilting of forage can cause difficult in compaction of the ensiled materials and therefore result into poor quality silage due to aerobic fermentation.

2.4.1.2 Crude protein content of silage

The amount of protein in the silage vary depending on the protein content of the ensiled forage and the degree of protein degradation that occur during fermentation. The growing condition and stage of growth of the plant have a significant influence on the nutrient content of the forage. Bosch *et al* (1992) indicated an increase in cell wall

and lignin contents and a decrease in crude protein content with plant maturity. Silages prepared from grasses of the same species but cut at different stages of growth can therefore differ in crude protein contents. The decrease in crude protein content of hybrid napier (*Pennisetum purpureum x Pennisetum americanum*) from 10.9 to 7.12 % was reported by Randhawa and Gill (1992) when the third year regrowth were cut at 75 and 125 cm height, respectively.

2.4.2 Digestibility of silage

The purpose of ensiling forage in the tropics is to conserve the excess forage that is available in the rainy eason so that it can be utilized in the dry season when forage is scarce. The conservation method is intended to provide hay or silage of minimum nutrient losses relative to the fresh forage material before ensiling. It is therefore expected that organic matter digestibility of properly ensiled forages be very similar to that of fresh forage. Losses before and during ensiling are however, inevitable owing to respiration, fermentation and effluent. These losses contribute to the decrease in nutritive value of the conserved material. The most digestible components of the forage, especially water soluble carbohydrates and proteins decrease while there is an increase in fibre content, a reduction in organic matter and nitrogen digestibility, and reduced dry matter intake. *Sarwatt et al.* (1992) reported a slightly higher *in-vitro* dry matter digestibilities in fresh forages ranging between 59.7 to 70.4 % compared with 56.4 to 64.1 % in their respective silage.

Poorly preserved silage as indicated by high content of ammonia nitrogen and butyric acid is normally low in digestibility as compared to its respective fresh forage. Givens *et al.* (1993) indicated that *in- vitro* dry matter digestibility of the badly preserved *Lolium perenne* (with butyric acid and ammonia nitrogen averaging 35 g/kg DM and 36.4 % of total nitrogen, respectively) was lower (64.5 % of dry matter) than the expected temperate standards (ranging from 70 to 75 % of dry matter). It is therefore plausible to consider stage of maturity to be among the factors which affect the digestibility of ensiled materials.

2.5 Silage additives

Silage additives have been developed over the years to lower the risks which occur with the ensiling process and to improve the nutritive value of silage. According to Merensalmi and Virkki (1991), a silage additive should be safe to handle, reduce dry matter losses, improve the hygienic quality of the silage, limit secondary fermentation and increase the nutritive value by increasing the efficiency of utilization of the silage.

Silage additives can be chemicals or biological substances that can either be stimulants, inhibitors, nutrients or adsorbents (McDonald *et al*, 1991). Chemical additives such as mineral acids and organic acids were the most widely researched and used in Europe and North America (Henderson, 1993). The acid lowers the pH of the herbage and therefore inhibits the activities of the respiratory and proteolytic enzymes. Whether acid additives act as stimulants or inhibitors of Lactic Acid Bacteria depends

upon the concentration of the active ingredients and the rate at which the product is applied to the crop. Chemicals such as mineral acids cannot be used by small holder dairy farmers in Tanzania because they are difficult to handle since they are corrosive in nature and not readily available.

Biological additives like *Lactobacillus plantarum* and *Streptococcus faecalis* which are inoculated in ensiled forage are said to be safe to handle (Henderson, 1993). They either provide additional substrate for the indigenous population of microorganisms or increase the population of homofermentative LAB. In some products the LAB are added with enzymes or with substrate to provide additional substrate. Cellulolytic and hemicellulolytic enzymes can be used as silage additives. The use of these enzymes has been considered from two points of view; first as a means of increasing the soluble carbohydrates required as substrates for Lactic Acid Bacteria (LAB) through break up of polysaccharides and second as a method of improving the degradability of the Organic Matter (OM) of the crop (McDonald *et al.*, 1991). Although cell wall degrading enzymes do increase the Water Soluble Carbohydrate (WSC) content and lower the fibre content during ensilage, Jacobs and McAllan (1990) indicated non significant improvement in digestibility with cell wall degrading enzymes treatment.

Carbohydrate rich materials such as sugar, molasses, whey, citrus pulp and potatoes are also added to silage crops to increase the supply of substrate for the LAB. Molasses is a carbohydrate source used most frequently, and is of particular benefit

when applied to crops low in soluble carbohydrates such as legumes and tropical grasses (Henderson, 1993). Apart from molasses, little if any has been done in Tanzania to consider the use of the above mentioned materials as additives in silage making. Sugar and whey cannot be used easily because their demand for human consumption is high and are rather expensive to obtain. Citrus pulp and potatoes can be used to some extent because in few cases there is seasonal surplus production . As an alternative to sugar, fresh sugar cane crush can be used as additive because chewing sugar canes are grown in almost all areas of Tanzania.

2.6 Voluntary intake

Ruminants tend to adjust voluntary feed intake to their energy requirements (Baile and Forbs, 1974). Thus over longer periods animals can keep net energy intake almost in balance with energy output, if the amount of feed consumed and its energy contents are not limiting factors (Baumgart, 1970). The brain and hypothalamus are said to be the ultimate regulatory centres in the control of food intake (Forbes, 1986). Baile and McLaughlin (1987) proposed that there are two centres of activity, the lateral hypothalamus which causes the animal to eat (the hunger centre) and the ventromedial hypothalamus which causes the animal to stop eating (satiety centre) (Baile and Forbes, 1974; Baile and McLaughlin, 1987).

It is believed that there are two groups of intrinsic stimuli that may provide feed back signals to the control system to limit feed intake. The stimuli arise from the process

of absorption and feed metabolism (Conrad, 1966;Baile and Mayer, 1970 and Baumgardt, 1970). Another stimuli is said to arise from distention of the alimentary canal due to physical presence of feed (physical control) (Balch and Campling, 1962; Conrad, 1966; Campling, 1970 and Grovum,1984).

2.6.1 Stimulation factors

Feed characteristics such as palatability and physical state influence the feed intake. Palatability has an influence to some extent if the animal has not been starved. For a starved animal palatability could not limit the intake to a great extent because the animal could feed non selectively with intention of satisfying hunger. Van Soest (1982) indicated that palatability is the major factor in selection of feed by ruminants when they are grazing, browsing or when they are fed hay made up of high quality leaves and poor quality stems.

2.6.2 Gut fill

It has been suggested that ruminants fed bulky forages may stop eating before they have consumed enough feed to meet their nutrient requirements for maximum production (Balch and Campling, 1962; Campling, 1970 and Bines, 1971). Physical distention of the reticulo-rumen has been proposed to be the main factor limiting intake of the roughage even before the energy requirement of the animal has been satisfied (Baile and Forbes, 1974). Campling and Balch (1961) found that removing swallowed hay as it entered the reticulo-rumen made the animal able to eat longer than normal

periods.

However, physical distention is not the only factor that determine intake. It has been indicated by Weston (1989) that ruminants do not eat to a constant rumen fill on certain diets. Doyle (1984) observed that sheep ate to a constant level of fill which was not consistent between different roughages, and did not always approach the maximum capacity of the rumen. He therefore concluded that gut fill as a factor that determines feed intake should not be over emphasized.

2.6.3 Feed factors

Gastrointestinal factors and factors associated with chemical and physical properties of feed are interrelated in their effects on voluntary intake (Mbwile, 1990). Bines (1971) found that the rate of disappearance of digesta from the reticulo-rumen depends on the rate at which the feed is broken down chemically by the process of digestion and on the rate at which the undigested residues of the feed are broken down physically. The plant cell wall content (CWC) was shown to be the primary restrictive determinant of intake (Osbourn *et al.*, 1974). The CWC not only dilutes the digestible energy content of the diet but also requires time for rumination and microbial attack in order to change the size and density of the feed particles sufficiently to allow passage through the reticulo-omasal orifice (Van Soest, 1982).

2.6.4 Ability to feed

Ingestive ability of the animal depends on the species, sex, physiological state of the animal such as growth, pregnancy and lactation. The environmental factors such as temperature and diseases can also influence the ingestive capacity of the animal. Changes in the animal due to any of these factors may obscure the forage characteristics as a factor that limiting intake (Campling and Lean, 1983). Changes in voluntary intake are largely determined by changes in physiological requirements of the animal. During pregnancy for example, physical and physiological changes in the animal occur and these alterations have been associated with the greater demand for nutrients, space in the abdomen and increase in endocrine secretions (Forbes, 1971). The most significant factor is lactation because it has been observed that cows and ewes eat considerably more when lactating than when dry (Hutton, 1963 and Anold, 1975).

2.6.5 Forage intake rate

The rate at which a forage can be eaten is an important factor influencing animal preference (Kenney and Black, 1984) and voluntary intake (Forbes *et al.*, 1972; McLeod and Smith, 1984). There are several factors which are said to affect the rate at which a forage can be eaten. These factors include the following÷

Physical characteristics of the forage such as its ease to fracture during chewing (Vincent, 1990), size of particles in the diet (Kenney and Black, 1984;Minson, 1990),

moisture content (Suzuki, 1969; Kenney *et al.*, 1984; John and Ulyatt, 1987) and cell content (McLeod and Smith, 1989). Mtengeti (1993) found that there was a great variation in dry matter intake rate within grasses and within legumes. This could be attributed to differences in NDF contents between species and at different stage of growth. The same author observed a negative correlation -0.688 ($p < 0.05$) between the rate of forage intake and NDF. When comparing intake rate in tropical grasses and temperate grasses, the author suggested that the relatively low intake rate in tropical grasses could be due to solid stems of tropical grasses which take time in prehension and as compared to hollow stems of temperate grasses.

Accessibility of the forage or pasture component, is considered to affect the rate of forage intake in grazing animals depending upon tiller height and size of the plant parts (Stobbs, 1973; Black and Kenney, 1984). The taste, odour and texture of the forage could also affect the rate of forage intake (Arnold *et al.*, 1980; Grovum, 1984). Other findings have shown that the intake rate of low quality roughages can be increased by promoting their acceptability through taste and texture. Arnold *et al.* (1980) found that the voluntary intake of some forages were increased by adding the odour of butyric acid and amyl acetate. It is therefore possible to use some additives in forage materials so as to promote acceptability of the forage than when the forage is fed alone. The additives could contribute to the complementary effect by filling up the nutrient deficit of the basal ration.

2.5.6 Intake rate of silage

Silage intake has been documented to be lower than that of fresh forage or hay made from respective forage species (Wilkins, 1974; Rogers *et al.*, 1979; Forbes, 1986). Many authors associated low intake of silage with the fermentation products. Thomas and Wilkins (1975) suggested that a low pH lactate silage could result in alteration of normal rumen pH which consequently lower the voluntary intake of silage. Crude protein content of silage has been observed to have an influence on intake, for example Thomas *et al.* (1975) found low intake in silages containing less than 9 gkg^{-1}DM. The author suggested that, the low CP supplied insufficient amount of nitrogen for effective microbial fermentation in rumen.

A negative correlation between intake and total organic acids and ammonia in silage has been reported by Thomas and Chamberlain (1983). However, they reported relatively higher voluntary intake in silage with higher proportion of lactic acid in the total acidity than silage with higher acetic acid in total acidity.

Physical characteristics of the herbage prior to ensiling is known to influence the voluntary intake of silage. Panditharatne (1985) reported a 17 % unit increase in DM intake of *Panicum maximum* silage by sheep when the grass was chopped. Chopping could improve fermentation and reduced nutrient loss as well as increase the passage rate of particles through the gut, resulting in high voluntary intake.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experiment I: Laboratory silos

Forage materials were ensiled in miniature silos as a preliminary study. The objective of the study was to determine the quality of napier and guatemala grass silages prepared with fresh sugar cane crush as water soluble carbohydrates additive.

3.1.1 Forage material used

Napier (*Pennisetum purpureum*) and guatemala (*Tripsacum laxum*) grasses were used in this experiment because they are commonly abundant in almost all potential areas for dairy production in Tanzania. These fodder grasses were already established at Magadu dairy farm of the Department of Animal Science at Sokoine University of Agriculture.

The sugar cane used in this experiment was purchased from local farmers around the University campus. It was a local sugar cane variety commonly known as ``Albino'' and characterized by a reddish rind (plate 1). This variety is normally established for chewing and not for sugar production.

3.1.2 Management of fodder grasses used

Weeding of the plots was done in late September and the forages were cut to enable uniform regrowth. Cutting was done at 15 cm above the ground by using bush knives.

Farm yard manure was applied at a rate of 10 tonsDM/ha. Irrigation using hose pipe was applied occasionally because the expected short rains were not available. The forage materials was harvested at 8 weeks of age for ensilage. Their heights were 0.8 - 1.0 m and 1 - 1.2 m for guatemala and napier grasses, respectively.

3.1.3 Additives used

Molasses and Fresh Sugar Cane Crush (FSCC) were used. Molasses was obtained from Mtibwa sugar factory which is about 50 km from Morogoro town. Molasses was applied at a rate of 5 % of the total weight of the forage material ensiled. Dilution of molasses with water at a ratio of 1:1 was done so as to facilitate spraying over ensiled forage materials.

Fresh Sugar Cane Crush (FSCC) was prepared by using 8-10 internodes of derinded sugar canes. The internodes were counted from the base of the sugar cane. It is known heuristically that the concentration of sugar declines towards the top of sugar cane, that is why the upper most internodes were discarded. The fresh sugar cane crush material was obtained by crushing derinded sugar canes over the crusher as shown on plate 3.

Plate 1. Sugar cane variety used

Plate 2. Sugar cane crusher

Plate 3. Sugar cane crushing

3.1.4 Sugar cane crusher

The sugar cane crusher is shown on plate 2. The tool was made of piece of aluminium sheet obtained from empty cooking oil cans. The metal piece was perforated by using a 3 inch nail so as to form an abrasive surface required for crushing of sugar canes. The perforated metal piece was mounted on two pieces of timber which gave support to withstand force during the process of crushing sugar canes.

3.1.5 Laboratory silos

The laboratory silos used were made of PVC pipes open at one end. The mean diameter of the pipes was 17 cm and the average height was 85 cm. The open end of each pipe was sealed by polyethylene sheet held securely by strong rubber bands immediately after ensiling.

3.2 Methods

3.2.1 Ensiling process

The two forages (napier and guatemala grasses) were harvested in november 25th, 1996. The harvested materials were divided into two portions, one portion was chopped and ensiled on the same day while the other portion was pre-wilted by leaving it overnight. The treatments tested were T1 (forage material ensiled without any additive), T2 (forage material treated with 5 % molasses), T3 (forage material treated with 5 % FSCC), T4 (forage material treated with 10 % FSCC) and T5 (forage material treated with 15 % FSCC). The additives were mixed thoroughly with chopped

forage material before ensiling. The number of silos per treatment were two, and about 4 kg of chopped forage material was ensiled in each silo. A polyethylene bag containing 4 kg of sand was inserted in each silo immediately after ensiling so as to exert pressure throughout the experimental period. The experimental period was 45 days.

3.2.2 Experimental set up

The layout of the treatments used in laboratory silos is shown below, in Table 2.

Table 2: Treatment layout for the laboratory silos

Type of forage	T1	T2	T3	T4	T5
Unwilted napier grass	x	x	x	x	x
Wilted napier grass	x	x	x	x	x
Unwilted guatemala grass	x	x	x	x	x
Wilted guatemala grass	x	x	x	x	x

Different levels of FSCC were considered so as to establish an optimum level of inclusion analogous to molassed silage.

3.2.3 Assessment of silage quality

Parameters used to evaluate the quality of silage were sensoric tests, biochemical analyses of the concentration of fermentation products and chemical composition.

3.2.3 Sensoric test

Immediately after opening each silo, the silage material was assessed in terms of appearance, smell and texture. Assessment was done by a panel of 10 individuals, each marked a score grade card for each treatment (appendix 2).

3.2.4 Preparation of silage samples for analysis

The silage from each silo was thoroughly mixed and then a sample of about 400 g was taken. The sample was sufficient to provide enough sub-samples required for chemical analyses and determination of pH, concentration of fermentation products, ammonia nitrogen and invitro dry matter digestibility. The samples were put in polyethylene bags and stored in deep freezer at -10 °C until when they were used for laboratory work.

3.2.5 Determination of pH

Samples of 40 g from each silo were soaked in 200 ml of cool distilled water for 12 hours. The mixture was then filtered and the supernatant divided into 4 aliquots for determination of pH by using a pH meter.

3.2.6 Ammonia nitrogen (NH_3N) determination

Frozen samples were used for determination of ammonia nitrogen. The samples weighing 5 g from each treatment were put in separate digesting tubes followed by addition of 75 ml of cool distilled water.

To determine the amount of free nitrogen contained in silage samples, the digesting tubes with their contents were subjected to steam distillation. The equipment used was Kjeltec system 1002 distilling unit where ammonia nitrogen was collected in boric acid. Titration with hydrochloric acid was done to determine the amount of ammonia nitrogen trapped in boric acid.

The amount of ammonia nitrogen present in silage sample was expressed as the ratio of ammonia nitrogen obtained by steam distillation to total nitrogen content of silage multiplied by 100. Routine Kjeldahl method (AOAC, 1990) was followed in determination of total nitrogen.

3.2.6 Determination of Volatile Fatty Acids (VFA)

3.2.6.1 Principle

The analysis of VFA is based on various acid components which are present in a liquid. Separation occurs by a selective division of the components in a stationary and running phase. The stationary phase carrier in a column is 10 % S - 1000/1 % H_3PO_4 while the running phase is nitrogen gas (N_2). Depending on the properties of the fatty acid, it can leave the column forthwith or later. After leaving the column, fatty acids are detected using a flame ionization detector. The organic matter is ionized in the flame. The event of ionization is expressed in an electric current which can be visualised using a recorder.

3.2.6.2 Preparation of samples

Frozen samples for determination of VFA and Lactic acid were taken to the University of Dar-es-salaam in a cool box. Samples weighing 1 g from each replication were put in separate conical flasks. Then, 5 ml of distilled water was added in each conical flask followed by shaking for 20 minutes.

Silage juice was drawn from conical flasks into test tubes and centrifuged at 3000 revolutions per minute for 5 minutes. Then 0.5 μL of supernatant was drawn and mixed with isobutyric acid (internal standard) and 20 % phosphoric acid as an acidifying agent. The ratio was 8:1:1 (supernatant:internal standard:acid). Then 0.25 μL of the mixture was injected in a gas chromatography (GC) equipment for determination of VFA.

3.2.6.3 Description of the equipment

A Hewlett-Packard model 58090A gas chromatography (GC) with a flame ionization detector coupled with a chart recorder and computing integrator was employed. A glass-lined column (1.83mm x 2 mm internal diameter) packed with porous aromatic polymer chromosorb 101 (Johns Manville) was used.

3.2.6.4 Lactic acid determination

Since Lactic Acid (LA) is not volatile, methylation was done. Centrifuged sample (0.5 ml) was pipetted into a test tube followed by 0.5 ml of 10 mM malonic acid (

internal standard), 0.4 ml of 50 % sulphuric acid (H_2SO_4) and 2.0 ml of ethanol. The contents were mixed well by stirring and incubated in a water bath at 50 °C for 30 minutes. After incubation, 1 ml of distilled water and 1 ml of chloroform were added before meticulous mixing. Then 2 μL of the mixed content was injected into a GC equipment using a wipe syringe for determination of LA. The GC was operated isothermally at 125 °C (column oven), 125 °c (injection or inlet) and 170 °C (detection).

3.2.7 Determination of dry matter

Due to freeze drying equipment perturbation, the dry matter (DM) of samples were determined by oven drying at 60 °c similar to the method done by Doane *et al.*(1997).

3.2.8 Determination of chemical composition of samples

Samples for determination of chemical composition were air dried in a well ventilated room. Dried samples were ground 44to pass through 1 mm screen in a hammer mill. Samples were chemically analyzed for determination of crude protein (CP) and ash according to standard procedures (AOAC, 1990).

Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) of samples were determined as described by Göering and Van Soest (1970). Hemicellulose (HEM) was calculated as the difference between NDF and ADF.

Water soluble carbohydrates (WSC) contents of samples were determined spectrophotometrically according to the method described by Thomas (1977). *In-vitro* dry matter digestibility of samples were determined according to Tilley and Terry (1963).

3.2.9 Experimental design and statistical analysis

3.2.9.1 Experimental design

Data on chemical composition of pre-ensiled treatments of napier and guatemala grasses together with those of fermentation products were statistically analyzed based on effects of species, wilting and additives as 2 x 2 x 5 factorial arrangement of a completely randomized design.

3.2.9.2 Statistical analysis

General Linear Model (GLM) procedures of statistical analysis system (SAS, 1988) with SS1 option for analysis of variance was used in analysis of data. Mathematical model used was as follows:

$$Y_{ijkl} = \mu + A_i + B_j + C_k + AB_{ij} + AC_{ik} + BC_{jk} + e_{ijkl}$$

Where:

Y_{ijkl} = quality attributes of grass species, pre-ensiled process and additive.

μ = fixed general effect.

A_i = effect of ith grass species.

B_j = effect of jth pre-ensiled process (unwilted or wilted)

C_k = effect of kth additive.

AB_{ij} = interaction of ith species and jth pre-ensiling process.

AC_{ik} = interaction of ith species and kth additive.

BC_{jk} = interaction of jth pre-ensiling process and kth additive.

e_{ijkl} = random variation.

3.3 Experiment II: Earth pit silos

Forage materials were ensiled in pit silos capable of holding 100 kg of forage material. The objective of the study was to test acceptability by cattle of napier and guatemala grass silages prepared by using fresh sugar cane crush as an additive.

3.3.1 Forage material used

Napier and guatemala 8 weeks regrowth material in the 1997 rain season were used in this experiment. Weeding was done at the beginning of the rainy season and farmyard manure applied at a rate of 10 tonsDM/ha. Equipments for harvesting were the same as those described in experiment I.

3.3.2 Pit silos

The dimensions of pit silos were 1 x 1 x 0.75 m^3 capable of holding up to 200 kg of forage material. Two silos were prepared for each treatment thus the total number of silos were 20. The silos were lined with polyethylene sheet in all sides so as to prevent soil contamination and seepage of rain water into the ensiled forage material.

3.4 Methods

3.4.1 Method of ensiling

The forage materials (napier and guatemala grasses) were harvested and chopped to 2 cm length by a tractor driven chopper. Five treatments were tested i.e. T1 (forage materials ensiled without any additive), T2 (forage material treated with 5 % molasses), T3 (forage material treated with of 5 % FSCC), T4 (forage material treated with 10 % FSCC) and T5 (forage treated with 15 % FSCC). The additives were mixed thoroughly with chopped forage material before ensiling. There were two replications for each treatment resulting into a total number of twenty silos. The total weight of ensiled material in each silo was 100 kg. Filling of forage materials in silos was conducted in layers of about 20 cm each. Each layer was compacted thoroughly by using 50 kg concrete block with handle so as to expel entrapped air. After filling 100 kg of forage material, the upper surface of ensiled material was covered by polyethelene sheet followed by a heap of soil about 500 kg which exerted pressure throughout the experimental period (i.e.45 days).

3.4.2 Dry matter and chemical composition

Dry matter, chemical composition and *In-vitro* dry matter digestibility of pre-ensiled materials, silages and fermentation products in silage were determined in the manner described in experiment I.

3.4.3 Determination of dry matter loss

The amount of dry matter lost from the silos was calculated by considering the difference between the DM contained in the original ensiled material and the DM of silage recovered. The DM losses were calculated as follows:

KgDM loss = kgDM of ensiled forage - kgDM of recovered silage

Whereby:

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

The DM losses were finally expressed as percentage of DM present in the original forage material to be ensiled.

3.4.4 Silage acceptability test

The acceptability of the silage by the animals was evaluated in terms of intake rate.

3.4.4.1 Experimental animals and their management

Eight dairy heifers (Friesian x Ayrshire) were selected from Magadu dairy farm herd of the Department of Animal Science and Production at Sokoine University of agriculture. The body weights of heifers were between 163 to 190 kg. The experiment was conducted in August 1997 when the heifers were 14 months of age. Prior to experimental period, the animals were dewormed using "Nilzan".

The animals were allowed to graze in paddocks during the day and were confined at the night. In the morning the animals were confined in individual stalls where they

were supplied with the silage to be tested.

3.4.4.2 Feeding of silage

The silos were opened at 0800 hours. Well preserved silage from each treatment was weighed to provide two meals weighing 3000 g each from each treatment. The animals were divided into two permanent groups of four animals where one group was fed napier silage and the other group fed guatemala silage. The animals were allocated to the groups at random. The animals were subjected to silage similar to the experimental silage for seven days so as to acclimatize the animals to the feed before the experimental period. After the preliminary period the animals were provided with experimental silage. Each treatment from napier and guatemala silages was fed to the animals for three days. The feeding commenced at 0900 hours where one person was monitoring the time allowed for animals to feed and recording the weight of silage remaining after ten minutes for each animal.The other eight men fed the animals and collected the feed that remained after ten minutes. Each animal was given access to silage for ten minutes per meal. Two meals per animal were provided consecutively.

The intake rate of silage was calculated as follows:

$$\text{Intake rate (g/min.)} = \frac{\text{grams eaten (for ten minutes)}}{\text{10 minutes}}$$

Finally the intake rate was expressed in terms of DM (gDM/minute) by multiplying

the grams of fresh silage eaten by the corresponding DM content of each treatment.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment I: Laboratory silos

4.1.1 Dry matter and chemical composition of fresh forage at the time of ensiling

Results of DM, chemical composition and *in-vitro* digestibility of fresh napier grass are shown in table 3. Guatemala grass had higher DM, WSC, and HEM than napier grass. The CP, Ash and ADF contents were higher in napier grass than guatemala grass. The two grasses did not differ in terms of NDF contents. The IVDMD of guatemala grass was significantly higher ($P<0.001$) than for napier grass.

Table 3: Dry matter, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala grasses before ensiling

Parameter	Napier	Guatemala	SEM
DM (%)	19.9^{b}	29.3^{a}	0.36
In $gkg^{-1}DM$			
CP	100.8^{a}	84.7^{b}	0.05
WSC	31.1^{b}	34.0^{a}	0.30
Ash	128.4^{a}	88.8^{b}	0.08
NDF	722.4	735.3	0.62
ADF	463.5^{a}	409.3^{b}	0.22
HEM	258.9^{b}	325.9^{a}	0.72
IVDMD (%)	57.4^{b}	59.7^{a}	0.13

SEM - Standard error of the means; $^{a, b}$ - Means with different superscripts within a row are significantly different ($P < 0.05$).

The effect of wilting on DM, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala grasses are shown in table 4. Dry matter and CP contents of wilted grasses were significantly higher than unwilted grasses. Wilted guatemala grass had significantly higher ($P<0.05$) WSC than unwilted guatemala but the effect of wilting on WSC was not significant ($P>0.05$) in napier grass.

Table 4: Effect of wilting on DM, chemical composition and *in-vitro* DM digestibility of napier and guatemala grasses before ensiling

	Unwilted		Wilted		
Parameter	Napier	Guatemala	Napier	Guatemala	SEM
DM (%)	19.3^{d}	27.7^{b}	20.6^{c}	30.9^{a}	0.51
In $gkg^{-1}DM$					
CP	95.6^{b}	80.1^{d}	106.1^{a}	89.3^{c}	0.07
WSC	31.2^{c}	32.9^{b}	31.0^{c}	35.0^{a}	0.43
Ash	127.8^{a}	92.0^{b}	129.0^{a}	85.6^{c}	0.11
NDF	745.6^{a}	740.1^{a}	699.3^{b}	730.5^{a}	0.87
ADF	462.7^{a}	412.2^{b}	464.3^{a}	406.5^{b}	0.31
HEM	282.9^{b}	327.9^{a}	235.1^{c}	323.9^{a}	1.02
IVDMD (%)	56.1^{c}	55.7^{c}	58.7^{b}	63.6^{a}	0.18

$^{a, b, c, d}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means.

Ash contents of unwilted guatemala was significantly higher ($P<0.05$) than wilted guatemala grass however, unwilted and wilted napier grass did not differ in terms of ash content. The NDF content of unwilted napier grass was significantly higher ($P<0.01$) than wilted napier grass while the NDF contents of unwilted and wilted guatemala grasses were not significantly ($P>0.05$) different. The ADF contents of unwilted and wilted napier grasses were not significantly ($P>0.05$) different.Similarly, ADF contents of unwilted and wilted guatemala did not differ significantly. The HEM content of unwilted napier grass was higher than wilted napier grass. On the other hand, unwilted and wilted guatemala grasses did not differ in terms of HEM. In both species wilted grasses showed higher IVDMD than their respective unwilted grasses.

The effect of additives on DM, chemical composition and *in-vitro* digestibility of unwilted napier grass are shown in table 5 - 8. There were significant ($P<0.05$) differences between treatments in terms of DM content in unwilted and wilted napier silage but no significant ($P>0.05$) difference observed in unwilted and wilted guatemala grass. The CP contents between treatments were significantly different ($P<0.05$). The CP ranged from 93.9 gkg^{-1}DM for T5 to 98.2 gkg^{-1}DM for T1. The WSC contents between treatments were significantly ($P<0.01$) different in unwilted and wilted napier grass and unwilted guatemala grass but the values were not statistically different in wilted guatemala grass. The ash contents between treatments in unwilted and wilted napier and guatemala grasses were significantly ($P<0.05$)

different. Molasses treated grasses (T2) showed the highest values of ash contents. The NDF contents between treatments in unwilted, wilted napier and guatemala grasses showed significant ($P<0.05$) differences. Molasses treated forage (T2) showed the lowest values of NDF. The ADF contents between treatments in unwilted and wilted napier and guatemala grasses showed significant ($P<0.05$) differences. The HEM contents were significantly ($P<0.01$) different between treatments in unwilted and wilted grasses of both napier and guatemala grasses. Invitro dry matter digestibility showed significant ($P<0.01$) differences between treatments in unwilted and wilted grasses of both napier and guatemala grasses.

Table 5: Effect of additives on DM, chemical composition and *in-vitro* DM digestibility of unwilted napier grass before ensiling

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	18.2^{b}	19.0^{b}	18.3^{b}	19.4^{ab}	21.5^{a}	0.64
In $gkg^{-1}DM$						
CP	98.2^{a}	95.7^{b}	96.0^{ab}	94.3^{b}	93.9^{b}	0.06
WSC	26.4^{c}	34.0^{a}	30.4^{b}	32.0^{b}	33.4^{ab}	0.54
Ash	130.5^{a}	134.0^{a}	129.0^{b}	120.5^{b}	125.0^{b}	0.14
NDF	797.1^{a}	679.9^{d}	780.3^{b}	738.9^{c}	731.8^{c}	0.43
ADF	490.1^{a}	450.5^{d}	445.2^{c}	480.6^{b}	447.4^{c}	0.15
HEM	307.0^{c}	229.5^{e}	335.2^{b}	258.3^{d}	284.4^{c}	0.44
IVDMD (%)	55.4^{c}	54.0^{d}	50.2^{e}	62.4^{a}	58.7^{b}	0.10

$^{a, b, c, d}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means; T1 - No additive included; T2 - 5 % molasses included; T3 - 5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % included.

Table 6: **Effect of additives on DM, chemical composition and *in-vitro* DM digestibility of wilted napier grass before ensiling**

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	19.1^{bc}	21.8^{ab}	18.5^{c}	20.4^{b}	22.9^{a}	0.58
In $gkg^{-1}DM$						
CP	112.2^{a}	97.9^{c}	110.9^{a}	105.9^{ab}	103.5^{b}	0.15
WSC	25.2^{c}	35.8^{a}	27.4^{bc}	30.9^{ab}	35.8^{a}	1.39
Ash	135.0^{b}	144.5^{a}	131.0^{c}	117.0^{d}	117.5^{d}	0.09
NDF	759.1^{a}	549.8^{e}	745.4^{b}	731.9^{c}	710.4^{d}	0.35
ADF	481.3^{a}	474.0^{b}	481.3^{a}	472.0^{b}	465.5^{d}	0.02
HEM	277.8^{a}	121.2^{d}	271.4^{b}	259.9^{c}	245.0^{d}	0.35
IVDMD (%)	51.5^{c}	63.5^{b}	66.3^{a}	54.7^{d}	57.6^{c}	0.39

Table 7: **Effect of additive on DM, chemical composition and *in-vitro* DM digestibility of unwilted guatemala grass before ensiling**

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	29.0	30.7	29.3	29.6	29.3	'1.25
In $gkg^{-1}DM$						
CP	86.5^{a}	75.7^{b}	80.9^{b}	78.1^{b}	79.1^{b}	0.15
WSC	30.6^{d}	36.1^{a}	31.2^{d}	32.3^{c}	34.7^{b}	0.21
Ash	95.5^{a}	98.5^{a}	89.0^{b}	88.0^{b}	89.0^{b}	0.12
NDF	769.2^{a}	657.6^{c}	764.0^{a}	763.4^{a}	728.0^{b}	0.52
ADF	430.3^{a}	397.8^{c}	411.2^{b}	409.2^{b}	412.4^{b}	0.09
HEM	338.9^{b}	277.8^{d}	352.9^{a}	354.2^{a}	315.6^{c}	0.59
IVDMD (%)	58.9^{c}	66.1^{a}	61.5^{b}	61.5^{b}	63.2^{b}	0.57

$^{a, b, c, d}$ - Means with different superscript within a row are significantly different ($P < 0.05$); SEM - Standard error of the means; T1 - No additive included; T2 - 5 % molasses; T3 - 5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % FSCC ..

Table 8: **Effect of additives on DM, chemical composition and *in-vitro* DM digestibility of wilted guatemala grass before ensiling**

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	30.5	31.0	30.6	30.3	30.5	1.02
In $gkg^{-1}DM$						
CP	92.8^{a}	86.3^{b}	92.7^{a}	87.8^{b}	86.9^{b}	0.05
WSC	32.0	37.8	32.8	35.7	37.0	1.05
Ash	88.5^{b}	92.0^{a}	84.0^{c}	84.0^{c}	79.5^{d}	0.10
NDF	747.1^{a}	710.6^{b}	743.6^{a}	738.9^{a}	712.0^{b}	0.05
ADF	440.8^{a}	403.0^{c}	399.9^{d}	370.8^{e}	418.1^{b}	0.05
HEM	306.3^{c}	307.6^{c}	343.7^{b}	368.1^{a}	293.9^{d}	0.20
IVDMD (%)	58.4^{d}	63.5^{c}	64.5^{c}	67.2^{b}	71.6^{a}	0.66

4.1.2 Dry matter, chemical composition and invitro DM digestibility of silages

The results for chemical composition and *in-vitro* dry matter digestibilities of napier and guatemala silages are shown in table 9. Guatemala silage had significantly higher ($P<0.05$) DM, WSC and NDF content than napier silage. The CP and ash contents were however significantly higher ($P<0.001$) in napier than in guatemala silage. The two grass silages did not differ significantly ($P>0.05$) in terms of ADF and HEM contents. Guatemala silage was more digestible than napier silage.

Table 9: Dry matter, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala silages

Parameter	Napier	Guatemala	SEM
DM (%)	17.8^{b}	27.8^{a}	0.39
In $gkg^{-1}DM$			
CP	97.7^{a}	75.0^{b}	0.14
WSC	15.9^{b}	17.3^{a}	0.28
Ash	133.3^{a}	95.2^{b}	0.25
NDF	652.6^{b}	668.2^{a}	0.16
ADF	410.8	413.5	0.45
HEM	249.2	246.9	0.77
IVDMD (%)	59.3^{b}	61.4^{a}	0.16

Results for the effect of wilting on DM, chemical composition and *in-vitro* dry matter digestibility are shown in table 10. Wilted guatemala had the highest DM content. Unwilted and wilted napier silages did not differ significantly ($P>0.05$) in terms of DM contents. The CP content was highest in wilted napier silage and did not differ significantly ($P>0.05$)between unwilted and wilted guatemala silage. In both grass species wilted silages retained higher WSC contents than unwilted silages. Ash content was significantly higher ($P<0.05$) in wilted than unwilted guatemala silage while unwilted and wilted napier silages did not differ significantly ($P>0.05$) in terms of ash contents. Unwilted silages had higher NDF contents than wilted silages. There were no significant differences between unwilted and wilted silages in terms of ADF and

HEM contents. Wilted napier silage was more digestible than unwilted napier silage while unwilted guatemala silage was more digestible than wilted guatemala silage.

Table 10: The effect of wilting on DM, chemical composition and *in-vitro* digestibility of napier and guatemala silages

Parameter	Unwilted		Wilted		SEM
	Napier	Guatemala	Napier	Guatemala	
4DM (%)	17.7^{c}	26.4^{b}	17.8^{c}	29.4^{a}	0.55
In $gkg^{-1}DM$					
CP	92.8^{b}	73.5^{c}	103.0^{a}	76.4^{c}	0.20
WSC	15.0^{c}	14.2^{c}	16.7^{b}	20.4^{a}	0.39
Ash	132.9^{a}	89.2^{c}	133.7^{a}	101.2^{b}	0.33
NDF	665.2^{b}	679.1^{a}	639.9^{d}	657.4^{c}	0.23
ADF	413.3	411.6	408.3	415.3	0.67
HEM	258.7	260.3	239.7	233.5	1.09
IVDMD (%)	58.7^{d}	62.2^{a}	59.9^{c}	60.7^{b}	0.24

$^{a, b, c, d}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means

The effects of additives on DM, chemical composition and *in-vitro* dry matter digestibility are shown in tables 11 -14. The DM contents in unwilted napier and wilted guatemala silages were significantly ($P<0.05$) different while treatments in wilted napier and unwilted guatemala silages were not significantly different. Additives had no significant ($P>0.05$) effect on napier and wilted guatemala silages in terms of CP. The CP content range from 68.0 $gkg^{-1}DM$ for T1 to 77.5 $gkg^{-1}DM$ for

T4. However, in unwilted guatemala silage there were significant differences between treatments in terms of CP. Ash contents in unwilted and wilted napier silages did not differ significantly ($P > 0.05$) between treatments while in unwilted and wilted guatemala silages showed significant ($P < 0.05$) difference between the treatments. The NDF contents between treatments in unwilted and wilted silages of both napier and guatemala grass species were significantly different. Hemicellulose contents between treatments of napier and unwilted guatemala silages were not significantly ($P > 0.05$) different. However hemicellulose contents between treatments in wilted guatemala silage were significantly ($P < 0.05$) different. There were significant ($P < 0.05$) differences between treatments in terms of IVDMD in napier silages as well as in wilted guatemala silage. However, no significant ($P > 0.05$) differences were observed between treatments of unwilted guatemala silage.

Table 11: The effect of additives on DM, chemical composition and *in-vitro* DM digestibility of unwilted napier silage

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	17.2[b]	17.7[b]	16.8[b]	17.9[ab]	18.9[a]	0.32
In gkg^{-1}DM						
CP	95.0	95.5	92.3	89.5	91.5	0.37
WSC	13.5[d]	20.9[a]	8.9[e]	17.9[b]	14.0[c]	0.06
Ash	141.5	142.4	130.8	120.1	142.4	0.46
NDF	702.2[a]	639.8[d]	675.7[b]	663.9[c]	644.6[d]	0.46
ADF	433.3	391.2	408.6	417.2	416.3	1.46
HEM	268.2	242.5	270.3	264.2	248.4	2.29
IVDMD (%)	52.4[e]	59.4[c]	56.5[d]	63.0[a]	62.1[b]	0.07

Table 12: The effect of additives on DM, chemical composition and *in-vitro* dry matter digestibility of wilted napier silage

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	18.1	20.3	18.3	18.8	19.1	0.26
In gkg^{-1}DM						
CP	106.0	97.5	110.0	105.0	92.5	0.32
WSC	12.5[d]	13.8[c]	12.5[d]	20.6[a]	18.6[b]	0.17
Ash	137.5	154.5	131.6	114.1	131.1	1.24
NDF	697.2[a]	556.9[d]	663.0[b]	655.7[b]	626.8[c]	0.61
ADF	437.0	387.0	419.7	402.3	395.8	2.37
HEM	260.0	182.6	239.9	265.5	250.7	3.27
IVDMD (%)	56.5[c]	62.6[b]	66.1[a]	57.6[c]	56.5[c]	0.99

Table 13: The effect of additives on DM, chemical composition and *in-vitro* DM digestibility of unwilted guatemala silage

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	25.8	28.3	26.9	27.1	27.5	0.50
In gkg^{-1}DM						
CP	68.0^{b}	73.0^{ab}	75.0^{ab}	77.5^{a}	74.0^{ab}	0.23
WSC	10.2^{c}	17.5^{a}	10.5^{c}	17.4^{a}	15.3^{b}	0.54
Ash	93.9^{a}	94.5^{a}	89.7^{ab}	87.4^{b}	80.4^{c}	0.17
NDF	702.4^{a}	635.6^{d}	682.9^{c}	694.7^{b}	679.9^{c}	0.21
ADF	425.1	384.4	403.4	422.9	424.4	1.31
HEM	279.3	251.2	279.7	271.8	255.5	2.39
IVDMD (%)	64.0	68.4	65.4	64.6	65.0	3.71

$^{a, b, c}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means; T1 - No additive included; T2 - 5 % molasses included; T3 - 5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % FSCC included.

Table 14: The effect of additives on DM, chemical composition and *in-vitro* DM digestibility of wilted guatemala silage

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	28.6^{b}	28.2^{b}	29.5^{ab}	30.0^{a}	30.2^{a}	0.41
In $gkg^{-1}DM$						
CP	78.0	78.0	75.0	73.0	78.0	0.64
WSC	21.0^{c}	23.9^{a}	17.2^{e}	17.9^{d}	22.1^{b}	0.08
Ash	122.9^{a}	103.7^{ab}	96.3^{ab}	96.4^{ab}	86.9^{b}	0.82
NDF	698.7^{a}	585.1^{c}	668.2^{b}	667.9^{b}	667.2^{b}	0.32
ADF	434.1	389.8	423	413.4	416.4	1.42
HEM	264.6^{a}	195.3^{b}	245.4^{ab}	254.5^{ab}	250.8^{ab}	2.64
IVDMD (%)	50.5^{c}	64.8^{a}	60.0^{b}	64.5^{a}	63.8^{a}	0.66

4.1.3 Fermentation products of silage

The fermentation products of napier and guatemala silages are shown in table 15. The pH and lactic acid contents of napier and guatemala silages were not significantly ($P>0.05$) different. Guatemala silage had higher ammonia nitrogen than napier silage.Acetic and butyric acids were significantly higher ($P<0.01$) in guatemala silage than in napier silage.

Table 15: Fermentation products of napier and guatemala silages

Parameter	Napier	Guatemala	SEM
pH	3.95	3.99	0.026
NH_3-N (% of TN)	2.9^b	3.3^a	0.14
In $gkg^{-1}DM$			
Lactate	16.4	15.9	0.51
Acetate	0.7^b	1.2^a	0.11
Butyrate	0.1^b	0.9^a	0.06

$^{a, b}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means; TN - Total nitrogen.

Results on the effect of wilting on fermentation products of napier and guatemala silages are shown in table 16. The pH of wilted napier silage was significantly higher ($P<0.05$) than unwilted napier silage while the pH of wilted guatemala silage was similar to that of unwilted guatemala silage. Lactic acid content was significantly higher ($P<0.05$) in wilted than unwilted guatemala silages but it was opposite for napier silages. Acetic acid was significantly higher ($P<0.05$) in wilted than unwilted napier grass but did not differ significantly ($P>0.05$) between unwilted and wilted guatemala silages. In both wilted and unwilted silages, butyric acid was higher in guatemala than napier silage, respectively.

Table 16: The effect of wilting on fermentation products of napier and guatemala silages

Parameter	Unwilted		Wilted		SEM
	Napier	Guatemala	Napier	Guatemala	
pH	3.89^{b}	3.95^{ab}	4.02^{a}	4.04^{a}	0.037
NH_3-N	2.5^{c}	2.9^{bc}	3.4^{ab}	3.8^{a}	0.19
In $gkg^{-1}DM$					
Lactate	17.5^{a}	13.5^{b}	15.3^{b}	18.4^{a}	0.72
Acetate	0.5^{b}	1.1^{a}	0.9^{a}	1.3^{a}	0.16
Butyrate	0.1^{c}	0.6^{b}	0^{c}	1.2^{a}	0.09

$^{a, b, c}$, - Means with different superscripts are significantly different ($P < 0.05$); SEM - Standard error of the means.

Results of additives on fermentation products of silages are shown in tables 17 - 20. In both wilted and unwilted guatemala silages T1 had the highest pH. However in all silages pH ranged from 3.8 to 4.5 for T5 and T1, respectively. There were significant differences between treatments in terms of NH_3N except in unwilted napier silage.Relatively higher values of NH_3N were observed in untreated than treated silages. Lactic acid contents were significantly different between treatments in unwilted and wilted silages of both napier and guatemala grass species. Acetic acid contents in unwilted and wilted silages of both napier and guatemala grass species showed significant differences between treatments. The highest values of acetic acid contents were observed in untreated silages (i.e. T1). Butyric acid was not detected in different treatments of unwilted and wilted napier silages except in T1 of unwilted

napier silage. On the other hand, butyric acid was observed in some treatments of unwilted and wilted guatemala silages.

Table 17: The effect of additives on fermentation products of silage prepared from unwilted napier grass

Treatment	pH	NH_3N (% TN)	Lactate	Acetate	Butyrate
			$gkg^{-1}dDM$		
T1	4.00^{a}	2.6	6.8^{d}	1.5^{a}	0.4
T2	3.94^{a}	2.2	20.5^{b}	0.4^{b}	0
T3	3.85^{b}	3.1	10.9^{c}	0.1^{e}	0
T4	3.87^{b}	2.5	21.9^{b}	0.3^{c}	0
T5	3.82^{c}	2.0	27.4^{a}	0.2^{d}	0
SEM	0.021	0.45	0.81	0.01	0.01

Table 18: The effect of additives on fermentation products of silage prepared from wilted napier grass

Treatment	pH	NH_3N %(TN)	Lactate	Acetate	Butyrate
			$gkg^{-1}DM$		
T1	4.50^{a}	4.2^{a}	6.0^{d}	2.8^{a}	0
T2	4.00^{ab}	2.8^{c}	23.7^{a}	0.7^{e}	0
T3	3.40^{b}	3.3^{bc}	10.1^{c}	1.0^{d}	0
T4	3.80^{b}	3.3^{bc}	14.7^{b}	1.6^{c}	0
T5	3.80^{b}	3.3^{bc}	23.9^{a}	2.4^{b}	0
SEM	0.178	0.23	0.71	0.50	0

Table 19: The effect of additives on fermentation products of silage prepared from unwilted guatemala grass

Treatment	pH	NH_3N (% TN)	Lactate	Acetate	Butyrate
				$gkg^{-1}DM$	
T1	4.42^{a}	3.9^{a}	3.6^{e}	2.9^{a}	3.10^{a}
T2	3.89^{b}	2.6^{b}	18.0^{a}	0.3^{d}	0
T3	3.86^{b}	3.0^{b}	11.5^{d}	0.1^{e}	0.03
T4	3.85^{b}	2.7^{b}	16.8^{c}	0.6^{c}	0
T5	3.78^{c}	2.5^{b}	17.8^{b}	1.7^{b}	0
SEM	0.011	0.23	0.03	0.03	0.026

T1- no additive included; T2- 5 % molasses included; T3- 5 % FSCC included; T4- 10 % FSCC included; T5- 15 % FSCC included; $^{a-e}$ Means with different superscripts within a column are significantly different ($P < 0.05$); SEM- standard error of the means.

Table 20: The effect of additives on fermentation products of silage prepared from wilted guatemala grass

Treatment	pH	NH_3N (% TN)	Lactate	Acetate	Butyrate
				$gkg^{-1}DM$	
T1	4.26^{a}	4.6^{a}	4.7^{c}	2.2^{a}	5.0^{a}
T2	3.92^{d}	3.7^{ab}	23.7^{a}	0.7^{bc}	0
T3	4.12^{b}	4.1^{ab}	10.9^{b}	1.3^{ab}	0.6^{b}
T4	4.00^{c}	4.0^{ab}	19.0^{b}	1.8^{a}	0.2^{c}
T5	3.91^{d}	2.3^{b}	23.8^{a}	0.2^{c}	0
SEM	0.011	0.60	0.03	0.25	0.01

T1- no additive included; T2- 5 % molasses included; T3- 5 % FSCC included; T4- 10 % FSCC included; T5- 15 % FSCC included; $^{a-d}$ Means with different superscripts within a column are significantly different ($P < 0.05$); SEM- standard error of the means.

4.1.4 Sensoric tests

Results of sensoric scores of napier and guatemala silages and the effect of wilting on sensoric parameters are shown in table 21 and 22. The results indicated that there were no significant ($P>0.05$) difference between napier and guatemala silages in terms of appearance, smell, and texture. There were also no significant ($P>0.05$) difference between unwilted and wilted silages of both napier and guatemala grasses.

Table 21: Quality evaluation of napier and guatemala silages by sensoric test

Parameter	Napier	Guatemala	SEM
Appearance	3.1	3.2	0.06
Smell	3.0	3.0	0.06
Texture	2.9	2.8	0.04
Total score	9.0	9.0	0.12

The scores used were defined as 1 = poor; 2 = moderate; 3 = good; 4 = very good;
SEM - Standard error of the means

Table 22: The effect of wilting on sensoric parameters of napier and guatemala silages

Parameter	Unwilted		Wilted		SEM
	Napier	Guatemala	Napier	Guatemala	
Appearance	3.0	3.3	3.2	3.2	0.08
Smell	3.0	3.0	3.0	2.9	0.08
Texture	2.8	2.8	2.9	2.9	0.06
Total score	8.9	9.1	9.1	8.9	0.16

The effect of additives on sensoric parameters are shown in tables 23 - 26. The results indicated no significant differences between treatments in terms of appearance, smell and total score for neither wilting nor addition of additives.

Table 23: The effect of additives on sensoric parameters of silage prepared from unwilted napier grass

Treatment	Appearance	Smell	Texture	Total score
T1	3.1	3.0	2.6	8.7
T2	3.0	3.2	2.8	9.0
T3	3.0	3.1	2.8	8.9
T4	3.0	3.1	2.8	8.9
T5	2.9	3.0	3.0	8.9
SEM	0.26	0.39	0.21	1.59

The scores used were 1 = poor; 2 = moderate; 3 = good; 4 = very good; T1 - No additive included; T2 - 5 % molasses included; T3 - 5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % FSCC included; SEM - Standard error of the means

Table 24: The effect of additives on sensoric parameters of silage prepared from wilted napier grass

Treatment	Appearance	Smell	Texture	Total score
T1	3.1	2.7	2.9	8.7
T2	3.1	2.8	2.9	8.8
T3	3.2	2.9	2.7	8.9
T4	3.4	3.2	3.0	9.6
T5	3.2	3.2	3.0	9.4
SEM	0.31	0.56	0.19	1.57

Table 25: **The effect of additives on sensoric parameters of silage prepared from wilted guatemala grass**

Treatment	Appearance	Smell	Texture	Total score
T1	3.3	2.9	2.7	8.9
T2	3.3	2.9	3.0	9.2
T3	3.0	2.8	2.9	9.0
T4	3.3	3.2	2.7	8.9
T5	3.4	3.2	2.9	9.5
SEM	0.22	0.35	0.20	1.12

The scores used were 1 = poor; 2 = moderate; 3 = good; 4 = very good; SEM - Standard error of the means; T1 - No additive included; T2 - 5 % molasses included; T3 - 5 % FSCC included; T4 - 10 FSCC included; T5 - 15 % FSCC included.

Table 26: **The effect of additives on sensoric parameters of silage prepared from wilted guatemala grass**

Parameter	Appearance	Smell	Texture	Total score
T1	2.9	3.0	2.8	8.7
T2	3.2	2.7	2.9	9.1
T3	3.3	3.0	2.6	8.6
T4	3.3	3.0	2.9	8.9
T5	3.1	3.0	2.8	8.9
SEM	0.30	0.35	0.17	1.31

The scores used were defined as 1 = poor; 2 = moderate; 3 = good; 4 = very good; T1 - No additive included; T2 - 5 % molasses included; T3 - 5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % FSCC included

4.2 Experiment II: Earth pit silos

4.2.1 Dry matter, chemical composition and *in-vitro* dry matter digestibility of fresh forage at the time of ensiling

Results for DM,chemical composition and *in-vitro* dry matter digestibility of napier and guatemala are shown in table 27. There were no significant ($P > 0.05$) difference between napier and guatemala grasses in terms of DM, CP, WSC, NDF and HEM and IVDMD. Napier grass had significantly higher ($P < 0.01$) ash content but lower IVDMD than guatemala grass.

Table 27: **Dry matter, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala grasses before ensiling**

Parameter	Napier	Guatemala	SEM
DM (%)	27.8	28.9	0.53
In gkg-1DM			
CP	83.9	77.6	2.68
WSC	38.2	36.8	2.40
Ash	142.2[a]	115.2[b]	4.26
NDF	759.6	762.9	6.73
ADF	481.8	482.2	8.98
HEM	277.9	280.7	11.30
IVDMD (%)	57.4	58.7	0.50

Results of the effects of additives on DM, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala grass before ensiling are shown in tables 28 and 29. The DM contents between treatments in napier and guatemala grasses

showed significant ($P<0.05$) difference. In both napier and guatemala grass, molasses treated grasses (T2) showed the highest DM content. In both napier and guatemala grasses there were significant ($P<0.05$) difference between treatments in terms of CP and NDF contents. Water soluble carbohydrates contents between treatments were significantly ($P<0.05$) different. There were no significant ($P>0.05$) differences between treatments in terms of ADF contents for both napier and guatemala grasses. The results indicated significant ($P<0.05$) differences between treatments in terms of HEM in napier grass as well as in guatemala grass. Napier and guatemala grasses showed significant ($P<0.05$) difference between treatments in terms of IVDMD.

Table 28: The effect of additives on DM, chemical composition and *in-vitro* dry matter digestibility of napier grass before ensiling

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	26.3^{b}	32.8^{a}	24.6^{b}	27.2^{b}	27.9^{b}	1.57
In $gkg^{-1}DM$						
CP	114.2^{a}	68.0^{b}	88.9^{ab}	76.6^{b}	71.9^{b}	7.74
WSC	24.0^{b}	50.0^{a}	31.5^{ab}	40.8^{a}	44.5^{a}	6.99
Ash	149.9^{ab}	169.4^{a}	128.4^{b}	127.9^{b}	135.3^{b}	8.52
NDF	836.1^{a}	551.7^{c}	799.7^{b}	806.0^{b}	804.6^{b}	8.08
ADF	494.3	424.7	493.9	509.4	486.6	24.47
HEM	341.8^{a}	126.9^{c}	305.8^{a}	296.7^{b}	318.1^{a}	25.44
IVDMD (%)	57.7^{ab}	57.8^{ab}	57.0^{b}	56.9^{b}	58.6^{a}	0.23

Table 29: **The effect of additives on DM,chemical composition and *in-vitro* dry matter digestibility of guatemala grass before ensiling**

Parameter	T1	T2	T3	T4	T5	SEM
DM	30.7^{b}	33.6^{a}	28.1^{c}	26.9^{cd}	25.1^{d}	0.58
In $gkg^{-1}DM$						
CP	103.7^{a}	65.5^{c}	82.3^{b}	75.5^{b}	74.3^{b}	3.42
WSC	22.7^{c}	52.0^{a}	27.8^{b}	33.4^{b}	41.3^{a}	2.97
Ash	126.5	127.1	113.2	102.3	106.9	10.43
NDF	816.7^{a}	620.1^{b}	797.8^{a}	789.6^{a}	770.4^{a}	19.68
ADF	484.9	475.2	519.1	463.7	467.9	14.5
HEM	331.8^{a}	144.9^{b}	278.7^{a}	325.9^{a}	302.5^{a}	25.11
IVDMD (%)	59.8^{d}	72.5^{a}	68.4^{c}	70.2^{bc}	70.5^{b}	0.18

4.2.2 Dry matter, chemical composition and *in-vitro* dry matter digestibility of silages

Dry matter, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala silages are shown in table 30. The DM contents of napier and guatemala silages were not significantly($P>0.05$) different. The CP, ash, NDF, and HEM of napier silage were significantly lower ($P<0.01$) than in guatemala silage. However, WSC was higher in napier than in guatemala silage.There was no significant ($P>0.05$) difference in *in-vitro* dry matter digestibility of napier and guatemala silage.

Table 30: Dry matter, chemical composition and *in-vitro* DM digestibility of napier and guatemala silages

Parameter	Napier	Guatemala	SEM
DM (%)	23.0	22.9	0.41
In $gkg^{-1}DM$			
CP	68.6^{b}	77.2^{a}	1.55
WSC	19.3^{a}	18.2^{b}	0.29
Ash	134.6^{a}	110.5^{b}	1.86
NDF	682.3^{b}	723.4^{a}	5.39
ADF	489.8^{b}	500.1^{a}	3.28
HEM	192.5^{b}	224.3^{a}	6.68
IVDMD (%)	60.2	61.9	1.94

$^{a-b}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means

Results of effects of additives on DM, chemical composition and *in-vitro* dry matter digestibility of napier and guatemala silages are shown in tables 31 and 32. There were significant differences in DM contents between treatments in guatemala silage while no significant ($P<0.01$) differences were observed between the treatments in napier silage. The CP contents between treatments were significantly ($P<0.05$) different in napier silage but not in the guatemala silage. Water soluble carbohydrates, NDF and ADF in napier and guatemala silages were significantly ($P<0.05$) different between treatments. There were no significant ($P>0.05$) differences in ash contents between treatments in napier silage but ash contents were different between treatments in guatemala silage. Hemicellulose contents between treatments in napier silage were significantly ($P<0.01$) different. The difference between treatments in terms of HEM

was however not observed in guatemala silage. There were significant ($P<0.001$) differences between treatments in IVDMD of both napier and guatemala silages.

Table 31: The effect of additives on DM, chemical composition and *in-vitro* dry matter digestibility of napier silage

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	21.9	23.2	22.5	24.4	22.8	1.18
In $gkg^{-1}DM$						
CP	69.6^{a}	67.4^{a}	64.4^{b}	70.9^{a}	70.0^{a}	1.04
WSC	17.6^{b}	22.6^{a}	18.1^{b}	18.0^{b}	20.2^{ab}	0.78
Ash	128.4	139.8	132.5	125.3	136.9	5.31
NDF	717.5^{a}	601.5^{c}	681.7^{b}	688.0^{b}	722.9^{a}	6.18
ADF	497.3^{a}	430.8^{b}	515.8^{a}	499.1^{a}	506.3^{a}	6.18
HEM	220.2^{a}	170.7^{c}	165.9^{c}	188.9^{b}	216.7^{a}	4.88
IVDMD (%)	63.9^{c}	65.4^{b}	60.5^{d}	66.9^{a}	63.8^{c}	0.14

Table 32: The effect of additives on DM, chemical composition and *in-vitro* dry matter digestibility of guatemala silage

Parameter	T1	T2	T3	T4	T5	SEM
DM (%)	20.3^{d}	26.5^{a}	23.6^{b}	23.3^{bc}	22.9^{c}	0.53
In gkg^{-1}DM						
CP	70.9	71	74.2	76.5	77.2	4.79
WSC	26.1^{a}	1.c	22.9^{b}	14.7^{c}	13.4^{c}	0.48
Ash	111.2^{ab}	11.a	101.7^{c}	116.9^{a}	105.4^{bc}	2.50
NDF	702.4^{bc}	645	734.9^{ab}	759.7^{a}	764.1^{a}	15.89
ADF	454.6^{c}	450.	504.2^{b}	545.7^{b}	545.7^{a}	7.18
HEM	247.8	195.5	203.7	214.0	218.9	20.55
IVDMD (%)	58.5^{e}	62.8^{b}	68.3^{a}	59.4^{d}	60.6^{c}	0.02

T1 - No additive included; T2 - 5 % mol[illegible]s included; T3 -5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % FSCC[illegible]uded; $^{a-e}$ - Means with different superscripts within a row are significantly[illegible]ferent ($P < 0.05$)

4.2.3 Fermentation products of silages

Results of fermentation products of napier [illegible]uatemala silages are shown in table 33. The pH, lactic acid, acetic acid [illegible] butyric acid were significantly higher($P<0.001$) in guatemala than in nap[illegible]lage. There was no significant ($P>0.05$) difference in ammonia nitrogen co[illegible]between napier and guatemala silage.

Table 33: Fermentation products of napier and guatemala silages

Parameter	Napier	Guatemala	SEM
pH	3.89^{b}	4.01^{a}	0.006
NH_3N	2.9	2.8	0.07
Lactate	23.1^{b}	25.4^{a}	0.02
Acetate	1.1^{b}	1.8^{a}	0.01
Butyrate	0	1.3	0.01

Results of the effect of additives on fermentation products of napier and guatemala silages are shown in tables 34 and 35. The pH was highest in untreated silages (T1). There were significant ($P<0.05$) differences between treatments in ammonia nitrogen contents of both napier and guatemala silages. The lactic acid contents in napier and guatemala silages were significantly ($P<0.05$) different between treatments. The lactic acid contents increased with increase in levels of FSCC (T3 < T4 < T5). There were significant ($P<0.05$) differences in acetic acid contents between treatments of both napier and guatemala silages. Butyric acid was not detected in any treatment of napier silage while in guatemala silage, T1, T2, and T3 contained some amount of butyric acid.

Table 34: The effects of additives on fermentation products of napier silage

Treatment	pH	NH_3N (% TN)	Lactate	Acetate $gkg^{-1}DM$	Butyrate
T1	4.34^a	3.9^a	7.9^e	0.9^d	0
T2	3.77^c	2.5^c	35.2^a	1.3^b	0
T3	3.87^b	3.1^b	13.6^d	0.6^e	0
T4	3.76^c	2.5^c	28.3^c	1.5^a	0
T5	3.71^d	2.5^c	30.4^b	1.2^c	0
SEM	0.014	0.01	0.04	0.02	0

T1- No additive included; T2- 5 % molasses included; T3- 5 % FSCC included; T4- 10 % FSCC included; T5 - 15 % FSCC included; $^{a-e}$ Means with different letters within a column differ significantly ($P < 0.05$); SEM- Standard error of the means.

Table 35: The effect of additives on fermentation products of guatemala silage

Treatment	pH	NH_3N (% TN)	Lactate	Acetate $gkg^{-1}DM$	Butyrate
T1	4.54^a	3.1^a	7.3^e	1.0^e	3.0^a
T2	3.84^c	2.4^d	32.1^a	1.2^c	1.7^c
T3	3.91^b	2.6^c	11.5^d	3.5^a	1.8^b
T4	3.88^b	2.8^b	25.7^c	2.2^b	0
T5	3.86^{bc}	3.1^a	29.7^b	1.1^d	0
SEM	0.014	0.20	0.04	0.01	0.02

4.2.4 Dry matter losses

The results of dry matter losses in napier and guatemala silages are shown in table 36. The kg DM loss in napier and guatemala silages were not significantly ($P>0.05$) different. However, guatemala silage had higher dry matter loss than napier silage when the DM loss was expressed as percent of DM ensiled.

Table 36: Dry matter losses in napier and guatemala silages

Parameter	Napier	Guatemala	SEM
DM ensiled	27.8	28.9	0.53
DM recovered	23.0	22.9	0.41
DM loss (kg)	4.8	6.0	0.52
DM loss (as % of ensiled forage)	17.3^{b}	20.8^{a}	1.34

$^{a, b}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of means.

The results of the effect of additives on DM losses of napier and guatemala silages are shown in tables 37 and 38. The kgDM loss, % DM loss and DM of useful silage expressed as % of silage recovered did not show significant (P.0.05) differences between treatments in napier silage. On the other hand, kgDM loss, % DM loss and DM of useful silage expressed as % of silage recovered, showed significant (P,0.05) differences between treatments in guatemala silage.

Table 37: Effects of additives on DM losses of napier silage

Parameter	T1	T2	T3	T4	T5	SEM
In kg:						
DM ensiled	26.3	32.8	24.6	27.2	27.9	1.57
DM of silage recovered	21.0	21.8	21.2	23.2	20.6	1.07
DM loss	5.3	11.0	3.4	4.0	7.3	1.53
% DM loss	20.2	32.9	13.7	14.8	26.1	3.72
Spoiled silage	ND	0.1	0.5	0.04	ND	ND
Useful silage	21.0	21.7	20.7	23.2	20.6	1.05
% DM useful	100.0	99.7	97.7	99.8	100.0	0.45

ND - Not detected; T1 - No additive included; T2 - 5 % molasses included; T3 - 5 % FSCC included; T4 - 10 % FSCC included; T5 - 15 % FSCC included; SEM - Standard error of the means.

Table 38: Effect of additives on DM loss of guatemala silage

Parameter	T1	T2	T3	T4	T5	SEM
In kg:						
DM ensiled	30.6^{b}	33.6^{a}	28.1^{c}	27.0^{cd}	25.1^{d}	0.58
DM silage recovered	18.6^{c}	24.2^{a}	21.9^{b}	19.9^{bc}	21.0^{b}	0.57
DM loss	12.0^{a}	9.4^{b}	6.2^{cd}	7.1^{c}	4.1^{d}	0.58
% DM loss	39.1^{a}	27.8^{b}	22.0^{bc}	26.3^{b}	16.1^{c}	1.99
Spoiled silage	0.1	0.5	0.1	ND	ND	ND
Useful silage	18.5^{b}	23.7^{a}	21.8^{b}	19.9^{b}	21.0^{ab}	0.60
% DM useful	99.7^{a}	97.9^{b}	99.7^{a}	100.0^{a}	100.0^{a}	0.41

4.2.5 Sensoric test

The results of sensoric scores of napier and guatemala silages in terms of appearance, smell and texture are shown in table 39. Napier silage had high scores in terms of appearance, smell and the total score than guatemala silage. There was no difference between napier and guatemala silages in terms of texture.

Table 39: Quality evaluation of napier and guatemala silages

Parameter	Napier	Guatemala	SEM
Appearance	3.5^{a}	3.2^{b}	0.41
Smell	3.3^{a}	2.9^{b}	0.25
Texture	2.9	2.7	0.25
Total score	9.7^{a}	8.9^{b}	0.54

$^{a, b}$ - Means with different superscripts within a row are significantly different ($P < 0.05$); SEM - Standard error of the means.

The results of effects of additives on sensoric parameters of napier and guatemala silages are shown on tables 40 and 41. Napier and guatemala silages did not show significant (P.0.05) difference between treatments in appearance. The texture of napier silage showed significant ($P<0.001$) difference between treatments but, guatemala silage did not show significant ($P>0.05$) difference between treatments in terms of texture. The overall scores showed significant ($P<0.05$) differences between treatments for both napier and guatemala silages.

Table 40: Sensoric evaluation of silage prepared from napier grass

Treatment	Appearance	Smell	Texture	Total score
T1	3.5	3.1^{b}	2.8^{bc}	9.4^{b}
T2	3.2	3.1^{b}	2.4^{c}	8.7^{b}
T3	3.5	3.4^{ab}	3.1^{ab}	10.0^{ab}
T4	3.8	3.7^{a}	3.5^{a}	11.0^{a}
T5	3.7	3.0^{b}	2.7^{bc}	9.4^{b}
SEM	0.4	0.6	0.5	1.9

T1 = No additive included; T2 = 5 % molasses included
T3 = 5 % FSCC included; T4 = 10 % FSCC included; T5 = 15 % FSCC included;
SEM = Standard error of the means; $^{a-c}$ Means with different letters within the column differ significantly ($P < 0.05$)

Table 41: Sensoric evaluation of silage prepared from guatemala grass

Treatment	Appearance	Smell	Texture	Total score
T1	3.0	2.8^{ab}	2.6	8.5^{ab}
T2	3.0	2.9^{ab}	2.4	8.3^{b}
T3	3.4	3.2^{a}	3.1	9.7^{ab}
T4	3.0	2.4^{b}	2.6	8.0^{b}
T5	3.7	3.3^{a}	3.0	10.1^{a}
SEM	0.5	0.5	0.6	3.1

T1 = No additive included; T2 = 5 % molasses included
T3 = 5 % FSCC included; T4 = 10 % FSCC included; T5 = 15 % FSCC included;
SEM = Standard error of the means; $^{a-b}$ Mean with different letters within a column differ significantly ($P < 0.05$).

4.2.6 The rate of intake of silages

The results of rate of intake of napier and guatemala silages are shown in table 42. The

rate of intake of fresh silage as well as silage dry matter was higher for napier than guatemala silage.

Table 42: The rate of intake of napier and guatemala silages by dairy heifers

Silage eaten	Napier	Guatemala	SEM
Fresh silage ($gmin.^{-1}$)	147.6^{a}	99.2^{b}	5.62
DM intake/min.	34.1^{a}	23.0^{b}	1.29

The results of the effect of additives on rate of intake of napier and guatemala silages are shown in table 4.41. Napier silage showed no significant ($P>0.05$) differences between treatments in terms of rate of intake while significant ($P<0.001$) differences in rate of intake of silage between treatments were observed in guatemala silage.

Table 43: Effect of additives on intake rate of napier and guatemala silages

Parameter	T1	T2	T3	T4	T5	SEM
In gDM/min.						
Napier	29.7	29.1	34.9	41.6	35.1	3.77
Guatemala	20.9^{c}	31.5^{a}	26.1^{b}	14.6^{d}	21.6^{c}	1.65

$^{a-d}$ - Means with different superscripts within a row are significantly different ($P < 0.05$)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Experiment I: Laboratory silos

5.1.1 Dry matter, chemical composition and in-vitro dry matter digestibility of forage material before ensiling

Dry matter of napier grass obtained in this study was similar to the one reported by *Brown et al.* (1984) (i.e. 19.2 %) while the DM of guatemala grass was within the range (19 - 30) reported by Göhl (1975). Guatemala grass had higher DM content than napier grass. Similar results were reported by Mtengeti *et al.* (1989) in the same area. The CP content of napier grass observed in this study was similar to the one reported by Brown *et al.*(1984). However, Tisian (1994) reported lower CP (81 gkg^{-1}DM)from the same variety harvested at vegetative stage of growth. Mtengeti *et al.* (1989) reported high CP content of 129 gkg^{-1}DM from napier grass harvested at vegetative stage. Variation in CP contents between different researchers could be attributed to differences in stage of cut and agronomic practices. In the present study, farmyard manure was applied at a rate of 10 tons DM/ha while Mtengeti *et al.* (1989) applied sulphate of ammonia at a rate of 200 kg N/ha. Tisian (1994) harvested the grass at a height of 1.5 m while in this study the grass was harvested when it was 1 m tall. The CP content of guatemala grass was lower than 115.8 gkg^{-1}DM reported by Mtengeti *et al.* (1989). Again, this difference could be due to differences in management applied to the grass. The WSC content of napier grass was within the range of 26.2 - 83.7 gkg^{-1}DM reported by Woodard *et al.* (1991). The authors pointed out that the WSC

contents of napier grass can increase with increase in number of cut of regrowth. However, the forage used in this study was of the first cut.

Water soluble carbohydrate content was higher in guatemala than in napier grass. Differences in physiological maturity could be attributed to the difference in WSC contents between the two grasses. Dale (1973) reviewed higher WSC content in fast growing cooksfoot (*Dactylis glomerata*) than in late maturing variety of cooksfoot.

The ash contents of napier and guatemala grasses were within the range of 12.4 - 14.8 % and 5.3 - 16.4 % respectively, reported by Göhl (1975). The results indicated higher ash content in napier grass than in guatemala grass, this could be attributed by long and tough internodes as well as hairy leaf sheaths of napier grass as compared to soft internodes and smooth leaf sheaths of guatemala grass. The NDF, ADF and HEM values of napier grass observed in the present study were lower than those reported by Otieno *et al.* (1990) (i.e. 784.8, 471.9 and 312.9 $gkg^{-1}DM$) respectively. The difference could be due to difference in locality, environmental condition and/or management applied to the grass.

The NDF contents of napier and guatemala grasses were not significantly different but, ADF content in napier grass was higher than in guatemala grass. Crowder and Chheda (1982) noted the percentage increase in DM of tropical grasses to be associated with increase in cell wall components especially ADF and lignin. The authors observed an

increase in cell wall components to be downward along the stem axis, however the extent of deposition can differ between different genotypes. In the present study napier grass was stemmy as compared to guatemala grass, which could have resulted into higher ADF content in napier grass than in guatemala grass.

In-vitro DM digestibility of guatemala grass was higher than IVDMD of napier grass. The difference in ADF contents between the two grasses could have attributed to the difference in digestibility.

Wilting resulted into an increase in DM contents of both napier and guatemala grasses as compared to their respective unwilted grasses. The results comply with the observations made by Henderson (1993) on a review of several works on silage. The author noted that under good weather conditions the DM and sugars are concentrated by wilting. Further observations indicated that under poor rainy conditions the DM content may increase very little and if the wilting period is extended over several days, the soluble carbohydrates may be lost together with protein. The CP contents of wilted grasses were higher than unwilted grasses. Similar results were reported by Martinsson (1991) when dealing with unwilted and wilted grasses dominated with *Phleum pratense* and *Festuca pratensis*.

Wilted and unwilted grasses did not show significant difference in WSC while wilted guatemala had higher WSC content than unwilted guatemala grass. Sullivan (1973)

reviewed several works on the behaviour of soluble carbohydrates during wilting of forages. A decrease from 7.0 % to 3.7 % of total sugar was observed in alfalfa (*Medicago sativa*) maintained at 27 °C until air dried; the greatest losses were in glucose and fructose with some decrease in sucrose. Another study showed little change in the hexose after wilting of ryegrass (*Lolium perene*) for 24 hours but significant losses in sucrose and fructosan. The same author noted a report which showed a decrease of fructosan in ryegrass while hexose did not show loss and sucrose showed an increase. The increase in sucrose was described as the synthesis during wilting period. These observations were based on temperate grasses so synthesis during wilting could also happen in tropical grasses resulting in unexpected results like the higher WSC in wilted guatemala than unwilted guatemala grasses which was observed in the present study.

The NDF, ADF and HEM contents between unwilted and wilted guatemala grass were not significantly different. The results indicated no significant difference between ADF contents of unwilted and wilted napier grass while unwilted napier grass showed higher NDF and HEM contents than wilted. Variations in structural carbohydrates contents between different parts of the plant have been documented by Sullivan (1973). Stem tissues showed to be higher in levels of cellulose and hemicellulose than the leaf tissue which implies that sampling error can result into differences in fibre fractions determined between the samples. However , the ADF contents between unwilted and wilted napier grass were not different as it was expected because structural

carbohydrates cannot be depleted during wilting due to respiration. The difference in NDF content between unwilted and wilted napier could be caused by analytical error in determination of NDF which consequently affected the HEM contents as HEM was calculated as the difference between NDF and ADF.

In-vitro DM digestibility of wilted grasses were higher than unwilted grasses. This observation is in agreement with Robles and Ordoveza (1971) who observed significantly higher digestion coefficient in wilted napier grass than unwilted napier grass (64.8 and 57.9 %, respectively). The difference observed in this study could be attributed to high CP content in wilted grasses which provided substrate required for rapid multiplication of cellulolytic microbes.

Addition of FSCC (i.e. T3 - T5) slightly improved the DM contents of both unwilted and wilted napier grass while no significant improvement was observed in unwilted and wilted guatemala grasses. Improvement in DM contents in unwilted and wilted napier grass could be caused by high DM content of FSCC (24.7 %). No improvement in DM content was observed in unwilted and wilted guatemala grasses because the DM content in FSCC was lower than in guatemala grasses. Literature on use of fresh sugar canes in mixture with grasses is scarce thus limiting the scope of comparison of the present study with other findings.

The CP contents of additive treated materials (T2 - T5) were lower than in untreated

materials (T1). Low CP contents in additive treated materials could have been caused by the dilution effect resulted from low CP contents of molasses and FSCC (Appendix 1) which were used as additives. Addition of FSCC improved the WSC contents (T3 -T5) in unwilted and wilted napier grass as well as in unwilted guatemala grass. Water soluble carbohydrate values increased slightly with increase in FSCC in unwilted guatemala grass. Improvement in WSC due to addition of FSCC is caused by high WSC content of FSCC (appendix 1) as compared to grasses. High WSC of molasses caused even higher values of WSC in T2.

Fresh sugar cane treated forages (T3 - T5) were lower in ash content than untreated forages. The difference could be attributed to low ash content in FSCC (appendix 1) which caused dilution effect when mixed with forages. Addition of molasses and FSCC lowered the NDF content of the mixture. Molasses used was in fluid form while FSCC was low in fibre content so, these additives were expected to cause dilution effect when mixed with grasses.

The ADF contents of FSCC treated forages (T3 - T5) were lower than untreated forages (T1). The reason for lower values of ADF content in FSCC treated forages could be due to low ADF content of fresh sugar cane crush which was used as additive. Hemicellulose component form an important structural carbohydrate in forage which is used as a substrate for silage fermentation (McDonald *et al.*, 1960). The hemicellulose components in different treatments were therefore expected to

contribute in fermentation process in addition to the additive used. The HEM contents in molasses treated forages (T2) and FSCC treated forages (T3 - T5) were lower than in untreated forage except in wilted guatemala where T4 had the highest value of HEM. The highest value of HEM in T4 in wilted guatemala grass could be caused by analytical error during determination of ADF content. Low HEM in additive treated (T2 - T5) forages could be caused by low HEM content of the additive used (appendix 1).

5.1.2 Dry matter, chemical composition and *in-vitro* dry matter digestibility of silages

The DM of guatemala silage was higher than napier silage, this was expected because guatemala grass showed higher DM content than napier grass before ensiling. The results indicated higher CP content in napier silage than in guatemala silage. The same trend was shown before ensiling. The trend was not reversed because the silages fermented well with minimum loss of protein as revealed by low ammonia nitrogen produced.

The WSC in guatemala silage was higher than in napier silage possibly due to high WSC and HEM in guatemala grass before ensiling which could have contributed excessive substrates to fermentative bacteria in the silos. McDonald *et al.* (1966) noted multiplication of anaerobes and facultative anaerobes between two to three days within temperature range of 20 - 40 °C followed by period of decline count. Therefore,

forage materials with high WSC content before ensiling have high chance of producing silage with high WSC content.

Ash content in napier silage was higher than in guatemala silage, indicating an insignificant change in ash content occurred during fermentation period. Guatemala silage had higher NDF value (about 15.6 $gkg^{-1}DM$) than napier silage. Since napier and guatemala grasses were not significantly different in terms of NDF contents before ensiling, the difference in silages' NDF suggests that the fibre components in napier grass contributed substrates for fermentation to a great extent as compared to guatemala grass.

The ADF and HEM contents between napier and guatemala silages were not significantly different. *In-vitro* dry matter digestibility of guatemala silage was higher than the IVDMD of napier silage by 2.1 %. High digestibility of guatemala silage could be attributed to high WSC content which provided readily available energy for survival and multiplication of rumen cellulolytic microbes responsible for degradation of fibre.

Wilting resulted into silage of high DM content in guatemala silage but there was no significant difference between DM content of unwilted and wilted napier silage. There was a slight difference of about 1.3 % in DM contents between unwilted and wilted napier grass before ensiling so, it was possible for wilted napier grass to lose more

than 1.3 % DM through effluent together with oxidation losses due to entrapped air during filling of silos. Crowder and Chheda (1982) noted that wilting of napier grass may create difficulties in compaction of forage and thus allowing retention of air.

The results indicated higher CP content in wilted napier silage than unwilted napier silage while no significant difference was observed between unwilted and wilted guatemala silages. The results of forage materials before ensiling indicated higher CP content in wilted guatemala than unwilted guatemala. Thus, non significant difference observed in silage could be attributed to high CP loss in wilted silage due to difficult in compaction of wilted guatemala grass. Difficult in compaction result in entrapped oxygen which consequently favour tissue respiration and increase in temperature in silo. High temperature increase enzyme activities including proteases which break down the proteins. It has been documented that when herbage is ensiled, proteolysis continues and within 12 to 24 hours the non protein nitrogen (NPN) can increase from 200 gkg^{-1} TN to 400 gkg^{-1} TN (McDonald, 1981).

The results indicated higher WSC contents in wilted silages than in unwilted silages. High WSC contents in wilted silage could be attributed to low moisture content in ensiled material which limits the efficiency of utilization of available soluble carbohydrates by microbes relative to unwilted ensiled materials. On the other hand, high WSC content in wilted guatemala grass together with low moisture content could have provided excess soluble carbohydrates to the existing microbes population as

compared to unwilted guatemala grasses ensiled.

Ash content of unwilted and wilted napier silages were not significantly different while the ash content of wilted guatemala silage was 12.0 gkg^{-1}DM higher than unwilted guatemala silage. High ash content in wilted guatemala silage could have been caused by concentration of minerals due to decrease in fibre content particularly NDF of wilted guatemala silage as compared to unwilted guatemala silage. The NDF contents of unwilted napier and guatemala silages were higher than their respective wilted napier and guatemala silages. Much consideration has not been put on the effect of wilting on the fibre components of silages.

The results indicated no significant difference between unwilted and wilted silages of both napier and guatemala silages in terms of ADF and HEM. Results of forages before ensiling also indicated no significant difference between unwilted and wilted grasses in terms of ADF. Therefore, regardless of species difference, the results indicated that the effect of ensiling on ADF in unwilted and wilted materials were the same.

In-vitro DM digestibility of wilted napier silage was 1.2 % higher than in unwilted napier silage while unwilted guatemala silage was 1.5 % higher than wilted guatemala silage. Regardless of statistical insignificance, the ADF contents of wilted napier silage was slightly lower than unwilted napier silage while the ADF contents of unwilted

guatemala silage was slightly lower than the ADF content of wilted guatemala silage. Thus, silages which showed high IVDMD were associated with low ADF contents. These results are in agreement with Ademosun (1974) who reported a negative correlation (r = -0.87) between ADF content and digestibility of forages. However, digestibility of forage materials result from interaction of many factors. For example Milford and Minson (1966) reported that, if herbage with CP content below 7 % is fed to ruminants, the microbial activity in the rumen is depressed by lack of nitrogen. The same authors noted that digestibility of herbage was not affected when the CP content exceeded 7 %. Raymond (1969) reported low digestibility of stem fraction as compared to leaf fraction while Minson (1971) observed that in *Chloris gayana*, *Panicum maximum* and *Panicum coloratum* digestibility was not related to leafiness or floral development. Therefore, digestibility of forage material encompassed with many factors.

Addition of FSCC (T3 - T5) resulted in improvement of DM contents of silages as compared to unwilted silages. Regardless of insignificant differences between treatments in wilted napier and unwilted guatemala silages, improvement of DM content with addition of FSCC could be caused by improved fermentation due to additives which lowered DM loss.

Results on CP contents of silages indicated no significant differences between treatments except in wilted guatemala silage. However, untreated forages showed

highest values of CP before ensiling thus indicating that untreated forages succumbed to high CP losses than additive treated forages. Addition of FSCC improved fermentation and therefore reduced the CP losses that could be caused by poor fermentation. Water soluble carbohydrates retained in silages, showed inconsistent variations between treatments . Variations in WSC contents of silages could be caused by the population of microbes in silos during fermentation period. Differences in peak population of microbes can result in differences in WSC contents of silages because the utilization of available WSC could be high in large population as compared to low microbes population.

Regardless of statistical insignificance between treatments in unwilted and wilted napier silage, the ash contents of FSCC treated (T3 - T5) silages were lower than untreated (T1) silages. The low ash content in FSCC treated silage could be caused by low ash content of FSCC materials used as additive. The NDF content of additive treated silages (T2 - T5) were lower than untreated silages (T1). The reason for that could be due to high losses of cell contents in untreated silages leaving large proportion of cell walls in the total DM of silage recovered.

The ADF content of silages did not show significant differences between treatments. Probably, the effect of fermentation on ADF was either the same or the variation of ADF contents between replications was high which could have reduced the power of statistics to detect variations between treatments. The results indicated no significant

differences between treatments in terms of HEM except in molasses treated (T2) silage in wilted guatemala which showed the lowest value while other treatments of wilted guatemala showed no significant difference between them. Hemicellulose contents were calculated as the difference between NDF and ADF so the values of HEM were influenced by the trend of ADF.

Additives improved the digestibility of silages. High digestibility in additive treated silages could be attributed to improved fermentation as well as lower ADF contents in treated silages than in untreated silages.

5.1.3 Fermentation products and sensoric tests of silages

The pH of napier and guatemala silages were not significantly different despite of higher WSC of guatemala grass than napier grass before ensiling. Probably, the buffering capacity of guatemala grass was higher than napier grass. McDonald and Whittenbury (1973) noted that within the pH range 4 - 6 about 68 - 80 % of the buffering capacity of herbage can be attributed by anions such as organic salts, orthophosphates, sulphates, nitrates and chlorides. Woodard *et al.* (1991) working on the effect of frequency of cut and genotype of napier grass on silage characteristics reported that the ease with which napier grass was preserved was attributed to inherently low buffering capacity. Thus differences in buffering capacities between the forages can result into differences in stable pH attained in silages.

Results indicated no significant difference between napier and guatemala silages in terms of lactic acid contents. Type of lactic acid bacteria which dominate during fermentation process could result in differences in lactic acid contents between silages. McDonald and Whittenbury (1973) noted that homolactic fermentation of glucose and fructose results in production of two moles of lactic acid while heterolactic fermentation of glucose results in production of one mole of lactic acid and one mole of acetic acid. The same authors commented that the difference in pathways in which soluble carbohydrates are fermented could explain why silages with apparently sufficient WSC content sometimes fail to preserve satisfactorily. In the present study, guatemala grass had 2.9 gkg^{-1}DM WSC content above that of napier grass but the lactic acid content of napier and guatemala silage were not significantly different. It is suggested that the populations of homofermentative and heterofermentative lactic acid bacteria could be different between the two silages.

Ammonia nitrogen in guatemala silage was higher than in napier silage. This result indicates that proteolysis was higher in guatemala silage than in napier silage. However, ammonia nitrogen content in both silages were within acceptable standards for well preserved silage (below 8 %) as reported by Catchpoole and Henzell (1971) and Breirem and Saue (1973). Chopping of forage materials and compaction assured by the load applied on top of ensiled materials minized the proteolytic activities in both silages.

Acetic acid was higher in guatemala silage than napier silage probably due to higher population of heterofermentatitive bacteria in guatemala silage than in napier silage. Butyric acid content of guatemala silage was higher than napier silage. The values were in agreement with the standard values ranging from 0 to 3 gkg^{-1}DM butyric acid content for well preserved silage (Cathpoole and Henzell, 1971; Breirem and Saue, 1973). The reason for low butyric acid contents in both silages could be due to achievement of optimum anaerobic conditions in well consolidated chopped forage materials.

Wilting napier grass produced silage of high pH value but unwilted and wilted guatemala silages were not significantly different in terms of pH. Lower pH in unwilted napier silage than in wilted napier silage in the present study was in agreement with Spitaleri *et al.* (1995) results. They reported lower pH, greater lactic acid concentration and higher Flieg scores in unwilted Pennisetum hexaploid hybrids than in silage made from wilted forage.

Ammonia nitrogen in nitrogen in wilted grass silages was higher than in unwilted grass silages. This indicates that proteolytic activities were higher in wilted silages than in unwilted silages probably due to difficult in compaction of wilted forage which entrapped large amount of air than in unwilted forage. Entrapped air support aerobic respiration which result into elevation of temperature than in unwilted ensiled forages. High temperature favour proteolytic enzymic activities which result into high ammonia

nitrogen in wilted silages than in unwilted silages. However, ammonia nitrogen of both wilted and unwilted silages were within the acceptable standards for a well preserved silage (below 8 %) as reported by Catchpoole and Henzell (1971).

Lactic acid content of unwilted napier silage was higher than in wilted napier silage while the lactic acid content of wilted guatemala silage was higher than in unwilted guatemala silage. High lactic acid content in unwilted napier silage than in wilted napier silage was also observed by Spitaleri *et al.*(1995). High moisture content in unwilted napier grass could released enough exudate when ensiled, the exudate could provided enough substrates required by lactic acid bacteria for production of lactic acid. On the other hand, higher lactic acid in wilted silage than in unwilted silage was observed by Martinsson (1991) when dealing with silage dominated by *Phleum pratense* and *Festuca pratensis*. The reason for high lactic acid in wilted guatemala silage could be due to higher population of lactic acid bacteria supported by higher WSC content in wilted guatemala grass before ensiling. However, this observation requires further investigation to establish if the difference between lactic acid content of unwilted and wilted guatemala silages are reproducible. If the trend show repetition then microbiological and biochemical examination could be required to find the cause.

Acetic acid content of wilted napier silage was higher than in wilted napier silage while unwilted and wilted guatemala silages were not different in terms of acetic acid content. Similarities or differences in acetic acid contents between silages could be

attributed to similarities or differences in populations of heterofermentative bacteria during fermentation period. Butyric acid content of wilted guatemala silage was higher than in unwilted guatemala silage while wilted and unwilted napier silages were not significantly different in terms of butyric acid. The reason for high butyric acid in wilted guatemala silage could be due to slow rate of drop of pH that allowed clostridia to grow to some extent and therefore produced higher concentration of butyric acid than in unwilted guatemala silage. However, the values of butyric acid in all silages were within the standard set by several authors who reported a range of between 0 to 0.3 % (i.e. 0 - 3 $gkg^{-1}DM$) as optimum for well preserved grass silage (Catchpoole and Henzell, 1971; Breirem and Saue, 1973).

Silages treated with FSCC had lower pH than untreated silages. The lower pH of FSCC silages could be caused by high WSC in FSCC which provided enough substrate required by lactic acid bacteria for the production of lactic acid. Additives resulted into silages of low ammonia nitrogen content than untreated silages regardless of insignificant difference observed in unwilted napier silage. Additives lowered the pH and reduced proteolytic activities of plant and microbial enzymes during fermentation period. However the values of ammonia nitrogen in treated and untreated silages were below 8 % which implies that the silages were well preserved. Addition of FSCC (T3 - T5) improved the lactic acid content of silages due to increased WSC important for lactic acid production by lactic acid bacteria. There were significant differences in acetic acid content between treatments but the trend was not well defined. Probably,

the population of heterofermentative bacteria between silos were different probably due to differences in initial population of bacteria attached on herbage before ensiling. Butyric acid was detected in T1 of unwilted napier silage, T1 and T3 of unwilted guatemala silage and T1, T3 and T4 of wilted guatemala silage. Probably, entrapped air in these treatments allowed growth of Clostridia to some extent which produced butyric acid.

There were no significant difference in sensoric qualities between napier and guatemala silages as well as between treatments. Probably, chopping and consolidation of ensiled materials in laboratory silos enabled achievement of optimum anaerobic condition in silos which induced lactate fermentation.

5.2 Experiment II: Earth pit silos

5.2.1 Dry matter, chemical composition and *in-vitro* DM digestibility of forage materials before ensiling

Results indicated no significant difference between napier and guatemala grasses in terms of DM, CP, WSC, NDF and HEM. The reason for that could be attributed to similar stage of growth at which the grasses were cut. Changes in chemical composition due to stage of growth have been reported by several authors who observed increase in cell wall content and decrease in cell contents with advanced maturity (Miller and Cowlishaw, 1976; Crowder and Chheda, 1982). Both napier and guatemala grasses were cut before flowering at a similar stage of growth and at the

same environmental condition.

Napier grass had high ash content than guatemala grass. Probably, the difference could be caused by difference in botanical composition. Napier grass was stemmy and hairy than guatemala grass which had soft short internodes and leafy. Stemmy and hairy structure of napier grass could contribute to higher ash content in napier grass than in guatemala grass.

The results indicated no significant difference between *in-vitro* dry matter digestibility of napier grass and guatemala grass. The reason for that could be due to similar chemical composition as observed in the former paragraphs.

The DM content of untreated forage (T1) and FSCC treated forages (T3 - T5) in napier grass were not significantly different in terms of DM content but the untreated guatemala forage (T1) had higher DM content than FSCC treated guatemala forages. The reason for insignificant difference between untreated and FSCC treated napier grasses could be due to small difference between untreated and FSCC material in terms of DM (Appendix 1). Thus when small amount of up to 15 % FSCC were added in napier grass could not result in significant dilution effect of DM. On the other hand, the difference between untreated guatemala forage and FSCC material (30.5 vs 23.5 %, respectively) was high. Therefore, when guatemala forage was mixed with FSCC material the dilution effect of DM was significant. Generally, the results did not show

significant increase in DM content due to addition of molasses (T_2). This was caused by dilution of molasses with water at a ratio of 1:1 during ensilage.

Additives (T2 - T5) resulted into forage materials of lower CP content than untreated forage material (T1). Lower CP content in additive treated forage material was attributed to low CP content of additives used. The additives caused dilution effect of CP when they were mixed with grasses.

The results indicated higher WSC content in treated than untreated forage due to high WSC content of the additives. The ash contents of FSCC treated forages (T3 - T5) were lower than the molasses treated forage (T2) in napier grass. The reason for such difference could be due to higher ash content in molasses than in FSCC materials (Appendix 1).

The NDF content of untreated napier and guatemala forages were higher than the NDF contents of additive treated napier forages (T2 - T5). This could be caused by low NDF content of molasses and FSCC which resulted into dilution effect when mixed with grasses. The ADF contents between treatments in both napier and guatemala grasses were not significantly different. This indicates that addition of FSCC did not alter the proportion of ADF of the composite forage significantly. Hemicellulose contents were significantly different between treatments. The HEM was calculated as the difference between NDF and ADF so, any systematic error in determination of

NDF and ADF lead to over-estimation or under-estimation of HEM.

The results indicated no significant difference between untreated napier grass and napier grass treated with FSCC (T3 - T5) in terms of IVDMD. The results comply with non significant variation in ADF contents between treatments. However, additive treated (T2 - T5) guatemala grass had higher IVDMD than untreated guatemala grass (T1). This could be attributed to high WSC contents in additive treated grasses which provided energy for rapid multiplication of rumen microbes that degraded the fibre.

5.2.2 Dry matter, chemical composition and *in-vitro* dry matter digestibility of silages

The DM contents of napier and guatemala silages were not significantly different. This was similar to DM content of the grasses before ensiling. Guatemala silage had higher CP contents than napier silage. This could be caused by the stemmy nature of napier grass which could have resulted into difficult in compaction as compared to guatemala grass. Poor compaction may result into higher temperature in the silos and consequently higher rate of proteolysis and reduction of CP contents.

Water soluble carbohydrate content was higher in napier silage than in guatemala silage. This could be caused by differences in population of microbes responsible for utilization of WSC and napier grass had slightly higher WSC content than guatemala grass before ensiling. Ash content was higher in napier than in guatemala silage

possibly due to higher ash content observed in napier grass than in guatemala grass before ensiling.

The fibre components i.e. NDF, ADF and HEM were higher in guatemala than in napier silage. Probably, guatemala silage lost higher cell contents than napier silage and therefore the proportion of cell wall contents per dry matter weight increased. Visual observation during opening of silos revealed higher effluent in guatemala silage than in napier silage. *In-vitro* DM digestibility of napier and guatemala silages were not significantly different. Probably lower CP content in napier silage could have limited the supply of nitrogen to rumen microbes while higher ADF content in guatemala silage could have limited the digestibility of guatemala silage and therefore balanced the digestibilities.

There were no significant differences in DM contents between treatments in napier silage. This indicates that molasses treated forage (T2) lost DM content to a great extent because it had the highest DM content before ensiling. High DM loss in T2 could be attributed to effluent resulted from diluted molasses used as additive. The DM contents between treatments were significantly different in guatemala silage. The lowest value was observed in untreated silage (T1) probably due to poor fermentation which resulted into high DM loss as compared to treated silages.

The CP contents between treatments in napier silage were more or less the same

except in T3 which showed significant difference from other treatments. On the other hand, the CP contents between treatments in guatemala silage were not significantly different. The results indicated no improvement in CP content due to additives. However, observation with respect to the forage materials before ensiling indicates that untreated forages (T1) lost higher CP content than treated forages (T2 - T5) because untreated forages were highest in CP contents before ensiling. It could therefore be possible that additives reduced the CP loss in forages during fermentation period due to achievement of low pH in additive treated silages which limited growth of proteolytic bacteria as well as limiting the activity of proteases.

Water soluble carbohydrates contents between treatments were significantly different. The difference could be attributed to the difference in efficiency of utilization of available soluble carbohydrates by fermentative microbes. The population size of fermentative microbes could determine how much of the available WSC could be used up. The NDF and ADF contents between treatments were significantly different and this could be due to the differences in extent of hydrolysis of hemicellulose and cellulose during fermentation period.

In-vitro dry matter digestibility was significantly different between treatments. In napier silage the variation of IVDMD comply to some extent with the level of ADF and CP in silages. For example treatments with relatively low ADF and high CP (eg. T4) showed high IVDMD and treatments with high ADF and low CP (eg. T3) showed

low IVDMD. However, there were no relationship between IVDMD, ADF and CP in guatemala silage.

5.2.3 Fermentation products of silages

The pH of guatemala silage was higher than of napier silage. This could be caused by the difference in buffering capacity which limits the easiness with which a pH could be lowered during fermentation. Ammonia nitrogen of napier and guatemala silages were not significantly different and the values were within the acceptable standards of well preserved silage (below 8 %) as described by Catchpoole and Henzell (1971).

Lactic acid and acetic acid were significantly higher in guatemala than in napier silage. This could be due to difference in fermentative microbial populations which utilize the available WSC to form lactic and acetic acids. Butyric acid was not detected in napier silage probably due to achievement of anaerobic condition in silos and the ease with which the pH was lowered in napier silage. This observation agrees well with the findings of Spitaleri *et al.* (1995) who did not detect butyric acid in napier silage. Butyric acid detected in guatemala silage could be caused by slightly higher pH which could allow the existence of Clostridia which produce butyric acid. However, the concentration of butyric acid in guatemala silage was in agreement with the standard of 0 - 0.3 % butyric acid as an optimum on a well preserved grass silage (Catchpoole and Henzell, 1971; Breirem and Saue, 1973).

Use of additives (T2 - T5) resulted into silages of lower pH than untreated silages (T1). This is because additives supplied WSC as substrate required by fermentative microbes which produced acids that reduced the pH. The pH in T1 were greater than 4.2 indicating that the silages were prone to spoilage when conservation period is prolonged. Ammonia nitrogen of untreated silages were higher than in additive treated silages except in T5 of guatemala silage. High content of ammonia nitrogen in T5 of guatemala silage could be caused by puncture of polyethylene sheet which was lining one of the silos and therefore allowed entry of proteolytic microbes from the soil. However, the values of ammonia nitrogen were less than 8 % which indicated good fermentation.

Lactic acid contents were higher in additive treated silages (T2 - T5) than in untreated silages (T1). The results also indicated increase in lactic acid content with increase in levels of FSCC (T3 - T5). Acetic acid contents were signicantly different between treatments in both napier and guatemala silages. The variation in acetic acid contents between treatments could be dependent of the population size of heterofermentative bacteria between silos because they are capable of producing 1 mole of lactic acid and 1 mole of acetic acid from 1 mole of glucose.

5.2.4 Dry matter losses

The DM loss expressed as percentage of DM ensiled was higher in guatemala silage than in napier silage. The reason for high DM loss in guatemala silage could be due

to higher effluent in guatemala than in napier silage. Although measurement of effluent volume was not taken, the visual observation during opening of silos revealed high effluent production in guatemala silage than in napier silage. The leafy nature of guatemala grass could be the cause of guatemala silage to succumb higher squeezing effect due to pressure exerted by the soil piled up on top of ensiled material than the tough stemmy napier silage.

The percentage kgDM loss in napier silage was not significantly different between treatments. Probably, the effluent production between treatments were not significantly different which could have resulted into significant difference between treatments. The results on fermentation products indicated that the silages conserved well which implies that there were minimum losses due to fermentation process. On the other hand, the percentage kgDM loss in guatemala silage was significantly different between treatments. This could be attributed to differences in effluent production between treatments as the factor of DM loss due to fermentation process was minimum because the silages were conserved well.

Higher percentage kgDM loss in guatemala silage was observed in untreated silage (T1) than in additive treated (T2 - T5) silages. Low percentage kgDM loss were observed in molasses treated silage (T2) because of high DM content of molasses (Appendix 1) while the spongy nature of FSCC used could have acted like absorbent which minimized the effluent loss and therefore minimized the percentage kgDM loss

in FSCC treated silages (T3 - T5).

5.2.5 Sensoric test

The appearance score of napier silage was higher than guatemala silage. However, both silages were within the category of good appearance because the scores were between 3 and 4. Good appearance of silages were attributed to the achievement of anaerobic conditions during fermentation period. Napier silage scored higher than guatemala silage in terms of smell. This could be attributed to genotypic difference in terms of smell characteristic of the two grass species because the fermentation characteristics in other sections showed that silages preserved well. The texture of napier and guatemala silages were similar.

The smell scores between treatments were significantly different. However, the smell scores between treatments in napier silage were within the category of good smell due to achievement of anaerobic conditions which resulted into silage of fruit smell aroma. In guatemala silage however, the smell scores between treatments were similar except T4 which had the lowest score. The smell was of moderate pleasant aroma attributed to fruit smell due to fermentation as well as inherent smell of guatemala grass species.

The texture of napier silage between treatments was significantly different. The lowest score was observed in molasses treated silage (T2) probably due to watery characteristics of molasses used as additive. However no significant difference

between treatments was observed in guatemala silage. It should be clear that sensoric test is an arbitrary test due to variation between individuals in terms of preference, sensitivity and skill. This test could however, be useful to small holder farmers as a simple non-sophisticated method of assessment of silage quality because most of them have no access to National laboratories due to economic barrier as well as distance and awareness.

5.2.6 The rate of intake of silages

The rate of intake of fresh napier silage as well as the dry matter intake of napier silage were higher than in guatemala silage. Higher rate of intake of napier silage could be attributed to easiness with which napier silage fermented into fruit smell which might arouse appetite of heifers and consequently increase the intake rate. Rogers *et al.* (1979) noted a negative relationship between organic acids and intake of silage.

Butyric acid was detected in guatemala silage but it was not detected in napier silage. This difference could have contributed to higher intake rate of napier silage than guatemala silage. Teller *et al.* (1991) reported that fermentation products such as amines contribute more than VFA in depression of intake. Therefore, there could be some fermentation products that contribute to low intake rate of guatemala silage.

The results indicated no significant differences between treatments in terms of rate of

intake of napier silage. This could be caused by successful fermentation attributed to achievement of anaerobic conditions in silos. However, despite of statistical insignificance between treatments in napier silages, T4 had slightly higher rate of intake due to high DM content of silage together with good quality of silage as supported by the highest total score observed in sensoric test.

The values of intake rate of guatemala silage were significantly different between treatments. The highest rate of intake in guatemala silage was observed in molasses treated silage (T2) followed by 5 % FSCC treated silage probably due to high DM content of silages as well as good smell supported by insignificant difference in smell between the two treatments as observed in sensoric test. Skerman and riveros (1990) noted a reduction of 19 % of milk yield when animals were fed a mixed silage of *Tripsacum laxum* and *Saccharum officinarum* compared to maize silage. In the present study, higher levels of FSCC (T4 and T5) in guatemala silage had lower intake rate of silage than T3. This suggests that there could be fermentation product which is associated with decrease in intake of guatemala silage mixed with sugar cane. However, further experiments are required to confirm if there are chemical compounds which lower the intake of silage prepared from different levels of fresh sugar cane crush mixed with guatemala grass.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

This study aimed at investigating the possibility of preserving napier and guatemala silages by using fresh sugar cane crush (FSCC) as WSC additive to facilitate fermentation.

Results obtained in this study indicated that napier and guatemala grasses can be conserved well when FSCC is used as additive. The results were comparable to molasses treated silage indicating that FSCC can successfully be used to replace molasses in tropical grass silage making.

The quality of silages treated with FSCC was good. The silages were of good aroma, low pH, low ammonia nitrogen and lactic acid dominated the organic acids produced.

Inclusion of 5, 10 and 15 % FSCC in ensiled materials improved silage quality as compared to untreated silage. Different levels of FSCC resulted into silages of lower pH, ammonia nitrogen and butyric acid than untreated silages. Also, different levels of FSCC resulted into silages of higher lactic acid content than untreated silages.

In napier silage there was no significant difference between treatments in terms of intake rate. In guatemala silage however, the highest value of intake rate was observed in molasses treated silage (T2) followed by 5 % FSCC treated silage (T3). Also, in

case of guatemala silage, the rate of intake of untreated and silage treated with 15 % were similar while the silage treated with 10 % had the lowest in intake rate. This suggests that inclusion of high levels of FSCC (T4 and T5) in guatemala silage did not improve the intake rate.

From this study, the recommended optimum level of inclusion of FSCC in guatemala and napier silages should be 5 % FSCC and 10 % FSCC, respectively because at these levels the silage produced was of good quality and showed high rate of intake by heifers.

Further investigations are recommended to establish the optimum level of inclusion of FSCC in other grass species like guinea grass (*Panicum maximum*) and Nandi setaria (*Setaria splendida*) in small holder dairy farming along the coastal and highland areas, respectively in Tanzania.

REFERENCES

Ademosun, A.A (1974). Utilization of poor quality roughage in the derived Savanna zone. In; AnimalProduction in the Tropics, (*Edited by, J.K. loosli, V.A. Oyenuga and G.M. Babatunde*) Heinmann (Nigeria). Ibadan. pp 152 - 166.

Amos, A. and Woodman, H.E. (1930). Ensilage. *The Journal of the Central Bureau for Animal Husbandry and Dairying in India* 4, 26 - 31.

Arnold, G. W. (1975) Herbage intake and grazing behaviours in ewes of four breeds at different physiological states. *Australia Agricultural Research* 26, 1017 - 1024.

Arnold, G.W.; De Boer, E.S. and Boundy, C.A.R., (1980). The influence of odour and taste on the food preference and food intake of sheep. *Australian Journal of Agricultural Research* 31, 571 - 587.

Association of Official Agricultural Chemists. (1990). *Official methods of analyses*. 13th edition, AOAC Washington D.C.

Baile, C.A. and Forbes, J.M. (1974). Control of feed intake and regulation of energy balance in ruminants. *Physilogy Review* 54, 160 - 214.

Baile, C.A. and McLaughlin, C.L. (1987). Mechanisms of controlling feed intake in ruminants: a review. *Journal of Animal Science* 64, 915 - 922.

Balch,C.C. and Campling, R.C. (1962). Regulation of Voluntary Intake in ruminants. *Nutrition Abstracts and Review* 32, 669 - 686.

Barnajee, G.C. (1991). *Feeds and Principles of Animal Nutrition*. Oxford and IBH Publishing Co. PVT Ltd. New Delhi. pp 636.

Bines, J.A. (1971). Metabolic and Physical control of food intake in Ruminants. *Proceedings of Nutrition Society* 30, 116 - 122.

Bathurst, N.O. and Mitchell, K.J. (1953). The effect of light and temperature on chemical composition of pasture plants. *New Zealand Agricultural Research* 1, 540 - 552.

Baumgardt, B.R. (1970). Control of feed intake in the regulation of energy balance. In: (Editor). *Physiology of Digestion and Metabolism in the Ruminant.(Edited by, A.T Phillips)* Oriel press, Newcastle upon Tyne, UK. pp 235 - 253.

Black, J.L. and Kenney, P.A. (1984). Factors affecting diet selection by sheep. II. Effects of height and density of pasture. *Australian Journal of Agricultural Research* 35, 565 - 578.

Breirem, K. and Saue, O.(1973). Enseilering og forving med silage til melkekyr. *Institutt for Foringsforsokene*. Norges Landbrukshongskole, stensiltrykk nr. 22,1 - 41.

Brown, D.L.; Chavalimu, E.; Fitzhugh, H.A. and Sidahmed, A.E. (1984). Effects of ensiling or drying on fire forage species in western Kenya. *Proceedings of the 3rd Small Ruminants Collaborative Research Program* Workshop, Kabete, Kenya.

Butler, G.W. and Bailey, R.W. (1973). *Chemistry and Biochemistry of Herbage*. Vol. 3. Academic press. London and New York. pp 295.

Campling, R.C. (1970). Physical regulation of voluntary intake. In: *Physiology of Digestion and Metabolism in Ruminant.*(Edited by, A.T. Phillipson) Oriel Press, Newcastle upon Tyne, UK. pp 226 - 34.

Campling, R.C. and Lean, I.L. (1983). Food characteristics that limit voluntary intake. In: *Nutritional Physiology of Farm Animals.(Edited by, J.A.F.Rook and P.C.Thomas)* Longman, London. pp 457 - 475.

Campling, R.C and Balch, C.C (1961). Factors affecting the voluntary intake of food by cows. 1. Preliminary observations of the effects on the voluntary intake of hay, of changes in amount of the reticulo-ruminal contents. *British Journal of Nutrition* 16, 523 - 530.

Catchpoole, V.R. and Henzell, E.F. (1971). Silage and silage making from tropical herbage species. *Herbage abstracts* 41, 213 - 221.

Charmley,E. and Viera, D.M. (1990). Inhibition of proteolysis at harvest using heat in alfalfa silages: effect on silage composition and digestion by sheep. *Journal of Animal Science* 68, 758 - 766.

Conrad, H.R. (1966). Symposium on factors influencing the voluntary intake of herbage by ruminants. Physiological and physical factors limiting feed intake. *Journal of Animal Science* 25, 227 - 235.

Crowder, L.V. and Chedda, R.H. (1982). *Tropical Grassland Husbandry*. Longman. London and New York. pp 562.

Dale, S. (1973).The non structural carbohydrates. In: *Chemistry and Biochemistry of Herbage*. (Edited by, Butler, G.W. and Bailey, R.W) Vol.1, pp 106 - 151. Academic press, London and New York.

Davies, T. (1963). Fodder Conservation in Northern Rhodesia. *Journal of Agricultural Science* 61, 309 - 327.

Doane, P.H.; Pell, A.N. and Schofield, P. (1997). The effect of preservation method on neutral detergent soluble fraction of forages. *Journal of Animal Science* 75, 1140 - 1148.

Doyle, P.T. (1984). Fibre intake, digestion and flow rates in sheep.In: *Ruminant Physiology Concepts and Consequences*. (*Edited by, S.K. Backer, J.M.Gawthorne, J.B.Mackintosh and D.B.Purse*) University of Western Australia. pp 105 - 116.

Flieg, O. (1938). A key for the evaluation of silage samples. *Futterbau und Garfutterbereitieng* 1, 112 -128.

Forbes, J.M. (1971). Physiological changes affecting voluntary food intake in ruminants. *Proceedings of Nutrition Society* 30, 135 - 142.

Forbes, J.M. (1986). *The Voluntary Food Intake of Farm Animal*.Butterworths, London. pp 206.

Forbes, J.M.; Wright, J.A.; Bannister, A.; McLeod, M.N. and Smith, B.R. (1972). A note in rate of eating in sheep. *Animal Production* 15, 211 - 214.

Givens, D.I.; Moss, A.R. and Anderson, A.H. (1993). The digestibility and energy value of badly preserved grass silages. *Journal of Animal Science and Technology* 452, 97 -107.

Göering, H.K.and Van Soest (1970). *Forage fibre analysis*. Agricultural hand book 379, United States Department of Agriculture. Washington D.C. USA. pp 58.

Göhl, B.O. (1975). *Tropical Feeds*. Rome, FAO. pp 95-96, 115.

Grovum, W.L. (1984). Integration of digestion and digesta kinetics with control of feed intake-a physiological framework for a model of rumen function. In: *Herbivore Nutrition in the Subtropics and Tropics* . (*Edited by, F.M.Gilchrist and R.I Mackie*) The Science Press (PTY), South Africa. pp 244 - 268.

Grovum, W.L. (1984). Controls over the intake of straw by sheep:Effects of form of diet and intake stimulants on Sham feeding. *Canadian Journal of Animal Science* 64, 150 - 151.

Henderson, N. (1993). Silage Additives. *Animal Feed Science and Technology*, 45: 35 - 56.

Heron, S.J.E.;Edwards, R.A. and Phillips, P. (1989). The effect of pH on the activity of ryegrass proteases. *Journal of Science of Food and Agriculture* 46, 267 - 277.

Humphreys, L.R. (1978). *Tropical Pasture and FodderCrops*. Essex, UK:Granada Publishing Company. pp 32.

Hutton, J.B. (1963). The effect of lactation on intake in the dairy cow. *Proceedings of New Zealand Society of Animal Production* 23, 39 - 52.

Jacob, J.L. and McAllan,A.B. (1990). The effect of enzyme treatment on silage composition and in sacco degradability of ADF and NDF. *Proceeding of 9th silage conference University of Newcastle upon Tyne*. pp 86-88.

John, A. and Ulyatt, M.J. (1987). Importance of dry matter content to voluntary intake of fresh grass forages. *Proceedings of the New Zealand Society of Animal Production* 47, 13 - 16.

Jones, D.I.H. (1970). The effect of nitrogen fertilizers on the ensiling characteristics of perennial ryegrass and cocksfoot. *Journal of Agricultural Science., Cambridge* 75, 517 - 521.

Kenney, P.A.; Black, J.L. and Colebrook, W.F. (1984a). Factors affecting diet selection by sheep. III. Dry matter content and particle length of forage. *Australian Journal of Agricultural Research* 35, 831 - 838.

Kenney, P.A. and Black,J.L. (1984b). Factors affecting diet selection by sheep. I. Potential intake rate and acceptability of feed. *Australian Journal of Agricultural Research* 35, 551 - 563.

Langston, C.W.; Irvin,H.; Gordon, C.H.; Moore, L.A. and McCalmont, J.R. (1958). Microbiology and chemistry of grass silage. *Technical Bulletin Number 1187* Washington, DC, USA: US Department of Agriculture, pp 54 - 62.

Larsen, R.E. and Jones G.M. (1975). Effects of different dry matter determination methods on chemical composition and in vitro digestibility of silage. *Canadian Journal of Animal Science* 55, 753 - 760.

Lindgren, S.E.; Axelsson, L.T. and McFeeters, R.F. (1990). Anaerobic L-Lactate degradation by Lactobacillus plantarum. *FEMS Microbiology letters* 66, 209 - 214.

Machado Fihlo, L.C.P. and Muhlbach, P.R.F. (1986). Effects of wilting on the quality of chemically evaluated elephant grass cv. Cameron (*Pennisetum purpureum*, schumach) and pearl millet (*Pennisetum americanum*, leek) silages. *Rivista da sociendade Brasileira de zootecnia* 15, 224 - 233.

Maeda, F.E.H. (1996). Conservation of napier grass as silage by small holder dairy farmers in Tanzania. *Dissertation for MSc (Agric.) of Sokoine University of Agriculture*.

Martinsson, K. (1991). Effects of length of Access time to Feed and Conservation Method of Silage on Feed Intake and Production in Lactating Dairy Cows. *Swedish Journal of Agricultural Research* 21, 35-42.

Mbwile, R.P. (1990). Rhodes Grass (*Chloris gayana* Kunth)- Effects of Age and Season on Growth, Chemical composition and Digestibility, and on selective intake by Dairy Cows. *PhD. Thesis*. Swedish University of Agricultural Sciences. Uppsala.

Mbwile, R.P. and Madata, G.S. (1984). Research on dry season feeds at Uyole Agricultural Centre. In:*Proceedings of a seminar held at LPRI on September 20-22nd 1984, Mpwapwa, Tanzania*. Feeding of livestock in the dry season. (*Edited by, A.T.Kitalyi and M.A. Kabatange*).pp 10 - 12.

McCulough, M. E. (1975). New trends in ensiling forages. *World Review of Animal Production* 15: 44 - 49.

McDonald, P.; Edwards,R.A. and Greenhalgh, J.F.D. (1995). *Animal Nutrition*. Longman Singapore Publishers Pte.Ltd. pp 607.

McDonald, P. (1981). *The biochemistry of silage*. John Wiley & Sons. Chichester. New York. Brisbane. Toronto. pp 226.

McDonald, P. and Whittenbury, R. (1973). In: *Chemistry and Biochemistry of herbage*. (*Edited by, Buttler, G.W.and Bailey, R.W*). Academic Press. London and NewYork. pp 33 - 60.

McDonald, P; Watson, S.J. and Whittenbury, R. (1966). *The principles of ensilage.* Z. Tierernahrg.u. Futtermittelkde. 21, 103 - 110.

McDonald, P.; Edwards, R.A. and Greenhalgh, J.F.D. (1988). *Animal Nutrition.* Longman Scientific & Technical,John Wiley & Sons Inc. New York. pp 543.

McDonald, P.; Henderson,A.R. and Heron,S.J.E. (1991). *The biochemistry of silage.* London, UK. Chalcombe Publications. pp 340.

McDonald, P.; Stirling, A.C.; Henderson, A.R.; Deevor, W.A.; Stark, G.H.; Davie, W.G.; MacPherson, H.T.; Reid, A.M. and Slater, J. (1960). Studies on ensilage. Edinburgh School of Agriculture. *Technical Bulletin.* No. 24 pp. 81.

McIlroy, R.J. (1967). Carbohydrates of grassland herbage. *Herbage abstracts* 37, 79 - 87.

McLeod, M.N. and Smith, B.R. (1989). Eating and Ruminating Behaviour in Cattle given forages differing in fibre content. *Animal Production* 48, 503 - 511.

McPherson, H.T. and Violante, P (1966). Ornithine, putresine and cadavarine in farm silage. *Journal of Science of Food and Agriculture* 17, 128 - 130.

Merensalmi M. and Virkki, M. (1991). The role of enzymes in the preservation and utilization of forage. *Proceedings of the 5th International symposium on forage preservation Nitra, Czechoslovakia*

Michelena, J.B. and Molina, A. (1990). The effect of time of sun exposure of king grass on silage quality. *Nutrition Abstracts and reviews* 63, (1)5.

Milford, R. and Minson, D.J. (1966). The feeding value of tropical pastures. In: *Tropical Pastures. (Edited by, W. Davies and C.L. Skidmore)* Faber: London. Ch.7.

Miller, T.B.; Rams, A.B. and Thorpe, R.J. (1964). The nutritive value and agronomic aspects of some fodders in Northern Africa. *Journal of British Grassland Society*, 19: 77 - 81.

Minson, D.J. (1990). *Forage in Ruminant Nutrition.* San Diego: Academic Press, Inc.

Minson, D.J. (1971). The Digestibility and voluntary intake of six varieties of Panicum. *Australian Journal of Experimental Agriculture and Animal Husbandry* 11, 18 - 25.

Mtengeti, E.J. (1993). Plant structure in relation to ease of physical breakdown in the mouth and rumen. *PhD.Thesis*. University of Wales. UK.

Mtengeti, E.J.; Urio, N.A. and Mngulwi, E. (1989). Yield and Nutritive value of Guatemala and Elephant grasses at different stages of growth. In: Development and utilization of forage for Livestock Feeding in Tanzania. *Proceedings of the TALIRO/SAREC Conference held at the LPRI on March 14-15th 1989.*

Nilson, R.; Toth, L. and Rydin, C. (1956). Studies on fermentation process in silage. The role of temperature. *Archives of Microbiology* 23, 366 - 370.

Osborn, D.F.; Terry, R.A.; Outen, G.E. and Cammell, S.B. (1974). The significance of a determination of cell walls as the rational basis for the nutritive evaluation of forages. *Proceedings of the 12th International Grassland Congress* Moscow. pp 514.

Otieno, K.; Onim, J.F.M.; Semenye, P.P.and Mathuwa, M.N. (1986). Evaluation of small scale silage preparation using molasses as an additive. In *Proceedings of the 5th Small Ruminants Collaborative Research Support Programme*, Held on 4-6 Nov.

Otieno, K; Onim, J.F.M. and Mathuva, M.N. (1990). A gunny bag techniques for making silage by small scale farmers. In:*Utilization of research results on forage and Agricultural by product materials as animal feed resources in Africa* (Edited by, Dzowela, B.H.). Addis Ababa, Ethiopia, ILCA. pp 664 - 684.

Panditharatne, S. (1985). Ensiling characteristics, digestibility and palatability of tropical grasses as affected by growth stage, chopping length and additives. *Dissertation Abstract International*, B (Science and Engineering). 46, 363.

Pathak, N.N. and Jakhmola, R.C. (1983). *Forages and livestock production*. Vikas Publishing House PVT Ltd. New Delhi. pp 274.

Ranhawa, S.S. and Gill, R.S. (1992). Effects of stage of maturity on the nutritive value of napier bajra hybrid (NB 21) silage fed to male buffalo calves. *Indian Journal of Animal Production and Management* 8, 196-198.

Raymond, W.F. (1969). The nutritive value of forage. Advances in Agronomy. 21, 1 - 108.

Rechcigl, M. (1975). *Man, Food and Nutrition*. CRC Press, 18901 Cranwood Parkway, Cleveland, Ohio 44128.pp 344.

Robles, A.Y. and Ordoveza, A.L. (1971). The feeding value of napier grass (*Pennisetum purpureum*. Schumach.) for cattle and animal Species. *The Philippine Agriculturist* pp 183 - 189.

Rogers, G.L.; Bryant, A.M.; Jurry, K.E. and Hutton, J.B. (1979). Silage and dairy cow production. *New Zealand Journal of Agricultural Research* 22, 511 - 522.

Sarwatt, S.V.; Urio N.A. and Ekern, A. (1992). Evaluation of some tropical forages as silage. In *Improved Dairy Production From Cattle and Goats in Tanzania*. NORAGRIC reports 11, 14 - 24.

Sarwatt, S.V. (1995). Studies on preservation and evaluation of some tropical forages as silage. *A PhD Thesis submitted at Sokoine University of Agriculture*.

Selma-Olsen, I. (1990). Ensiling experiments on laboratory scale. *PhD Thesis*, Ås, Norway:Agricultural University of Norway. pp 37.

Skerman, P.J. and Riveros, F. (1990). *Tropical Grasses*. FAO,Rome, pp 832.

Spitaleri, R.E.; Sollenberg, L.E.; Staples, C.R. and Schank, S.C. (1995). Harvest management effects on ensiling characteristics and silage nutritive value of seeded Pennisetum hexaploid hybrids. *Post-Harvest Biology and Technology* 5(4) 353 - 362.

Statistical analyses system. (1988). SAS/ STAT users guide, release 6.03 edition. Cary, USA: SAS Institute Inc. pp 549.

Stobbs, T.H. (1973). The effect of plant structure on the intake of tropical pastures. I. Variation in bite size of grazing cattle. *Australian Journal of Agricultural Research* 24, 809 - 818.

Sullivan, J.T. (1973). Drying and Storing herbage as hay. In: (Editors). *Chemistry and Biochemistry of Herbage*. (Edited by, Buttler, G.W. and Bailey, R.W.). Academic Press. London and New York. PP 1 - 31.

Suzuki, S.; Fujita, H. and Shinde, F. (1969). Change in the rate of eating during a meal and the effect of the interval between meals on the rate at which cows eat roughages. *Animal Production* 2, 29 - 41.

Teller, E and Vanbelle, M. (1991). Pre-wilting grass before ensiling. *Nutrition Abstract and Review* 64(1)4.

Thomas, C. and Wilkinson, J.M. (1975). The utilization of maize silage for intensive beef production. 3. Nitrogen and acidity as factors affecting the nutritive value of ensiled maize. *Journal of Agricultural Science*, Cambridge 85, 255 - 522.

Thomas, C.; Wilson, R.F.; Wilkins, R.J. and Wilkinson, J.M. (1975). The utilization of maize silage forintensive beef production. 1. The effect of urea on silage fermentation and on voluntary intake and performance of young cattle fed maize silage based diets. *Journal of Agricultural Science*, Cambridge.

Thomas, T.A. (1977). An automated procedures for the determination of soluble carbohydrates in herbage. *Journal of Food Science and Agriculture* 28, 639 - 642.

Thomas P.C. and Chamberlain, D.G. (1983). Silage as feedstuff. In silage for milk production. *Technical Bulletin* No. 2 pp 63-102.

Tilley, J.M.A. and Terry, R.A. (1963). A two stage technique for the *in-vitro* digestibility of forage crops. *Journal of the British Grassland Society* 18, 104 - 111.

Tisian, G.S. (1994). Comparative rumen degradability of *Pennisetum purpureum* and *Panicum maximum* cultivars in cattle. Special Project. Bsc. Agriculture. Sokoine University of Agriculture. Morogoro, Tanzania.

Van Soest, P.J. (1982). *Nutritional Ecology of ruminants*. Ithaca, New York. pp 139 - 151.

Vilela, D.and Wilkinson, J.M. (1987). The effect of wilting and of addition of urea on the fermentation and in vitro digestibility of ensiled elephant grass (*P. purpureum*, schum.). *Revista da Sociedale Brasileira de Zootecnia*. Vol. 16 pp. 550 - 562.

Vincent, J.F.V. (1990). *Forage in Ruminant Nutrition*. San Diego:Academic Press, Inc.

Virtanen, A.I. (1952). Use of acids in making grass silage. *Proceeding of the 6^{h} International Grassland Congress Pennsylvania*. USA, pp 1147 - 1150.

Waite, R. and Gorrod, A.R.M. (1959). The structural carbohydrates of grasses. *Journal of Science of Food and Agriculture* 10, 308 - 316.

Weston, R.H. (1989). Animal factors affecting feed intake. In:J.B. Hacker (Editor). *Nutritional Limits to Animal Production from Pastures*. CAB, Farnham Royal, UK. pp 183 - 198.

Wilkins, R.J. and Wilson, R.F. (1970). Silage fermentation and feed value. *The British Grassland Society*.26 (2) pp 108.

Wilkins, R.J. (1974). The effects of partial neutralization with sodium bicarbonates or ammonia and the feeding of blood meal on voluntary intake of a whole crop barley by sheep. *Animal Production Journal* 19, 87 - 91.

Wilkins, J.M. (1983). Silage made from tropical forages and temperate crops. 2. Techniques for improving the nutritive value of silage. *World Animal Review*. 46, 35 - 50.

Wilkinson, J.M.; Chapman, P.F.; Wilkins, F.J. and Wilson, R.F. (1982). Interrelationships between pattern of fermentation during ensilige and initial crop composition. *Proceedings of the 14th Iternational Grassland Congress*. Lexington, USA. pp 631 - 633.

Wilson, P.N. and Bringstock, T.D. (1981). *Improved feeding of cattle and sheep*. London, UK: Granada Publishing company. pp 324.

Woodard, K.R.; Prine, G.M. and Bates, D.B. (1991). Silage characteristics of elephant grass as affected by harvest frequency and genotype. *Nutrition Abstracts and Reviews* (series B), 62(6) 359.

Woolford, M.K. (1984). *The silage fermentation*. Florida USA. Marcel Dekker Inc. pp 350.

Zimmer, E. (1967). Uber die prufung vonsillierhilfsmitteln. *Das Witschafts eigene Futter* 12, 299 - 303.

APPENDICES

Appendix 1: Dry matter and chemical composition of additives expressed as percentage of DM

Materials	DM %	CP	WSC	Ash	NDF	ADF	HEM
Molasses	65.3	2.09	44.2	10.6			
FSCC (expt.1)	24.7	1.95	10.51	2.56	46.38	27.17	19.21
FSCC (expt.2)	23.5	1.83	8.97	2.27	38.81	24.68	14.13
Upper internodes	22.5	2.38	5.54	4.54	47.81	27.39	20.42
Middle internodes	23.4	1.81	8.27	2.40	38.76	23.52	15.24
Lower internodes	23.7	1.93	11.75	1.76	39.11	22.55	16.56

Appendix 2: An arbitrary organoleptic test chart used for sensoric evaluation of silage

	condition score			
Treatment number	1	2	3	4
T1				
T2				
T3				
T4				
T5				
Smell				
T1				
T2				
T3				
T4				
T5				
Touch				
T1				
T2				
T3				
T4				
T5				

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)

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

NB: Tick the appropriate score.