EVALUATION OF STRATEGIES FOR IMPROVEMENT OF GRASS SILAGE QUALITY FOR SMALLHOLDER DAIRY FARMERS IN TANZANIA

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EXTENDED ABSTRACT

Silage production strategy has never been widely adopted by majority of dairy farmers in Tanzania. On the other hand, most silage making technologies are expensive and not technically viable under smallholder production. Studies which have been done in developing cheap, practical and technically feasible silage making technologies concentrated on a single dimensional approach of intervention, i.e. pre-ensiling treatments, additives, others on ensiling amount and storage positions. Others dealt with single grass leaving other potential locally available grasses uninvestigated. Studies which specify the most appropriate combination of different techniques to achieve high quality fodder grass silage under smallholder farmers have rarely been conducted. To address these issues, six experiments were conducted in Magadu farm of Sokoine University of Agriculture, Morogoro, Tanzania to evaluate the effectiveness of various technologies used in fodder grass silage production under smallholder dairy farmers.

The first study dealt with determination of the effect of grass species, wilting and ensiled amount in shopping plastic bags on silage quality. Elephant grass (*Pennisetum purpureum*) and guatemala grass (*Tripsacum laxum*) were established and harvested when they were 1.5 and 1 m tall respectively. One portion of grass was wilted for 24 hours and the other portion was unwilted before ensiling. Each portion was chopped into 4 cm particle length before ensiling. The chopped materials were ensiled either in portions of 5 or 10 kg in plastic bag silos. Treatments were assigned to a completely randomized design in factorial arrangement (2 x 2 x 2) as two grasses (elephant and guatemala grasses), two pre-ensiling treatments (unwilted and wilted) and two ensiled amounts (5 and 10 kgs) with two replications. The silage was opened and sampled after 60 days, analyzed for dry matter (DM) losses, chemical composition, fermentation and

sensoric qualities and *in vitro* DM digestibility (IVDMD). The results showed that elephant grass silage had higher ($p < 0.05$) sensoric scores, crude protein (CP), ash, lactic acid (LA), acetic acid (AA) and bulk density (BD) but lower ($p < 0.05$) DM, water soluble carbohydrate (WSC), IVDMD, pH, Ammonia Nitrogen (NH_3N) and DM loss than guatemala grass silage. Wilted fodder grass showed higher ($p < 0.05$) sensoric scores, DM, CP, ash, WSC, pH, LA, AA and bulk density but lower Neutral Detergent Fiber (NDF), NH_3N, butyric acid (BA) and DM loss than unwilted fodder grass. The 5 kg silage showed higher ($p < 0.05$) bulk density than 10 kg silage in plastic bag silo. There was no difference between the two ensiled amounts (5 and 10 kg) in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, LA, AA, BA and DM losses.

The second experiment was conducted to investigate the effect of grass species and different levels of maize bran on silage quality. Elephant grass, guatemala grass and rhodes grass were established and harvested when they were at the age of 120, 63 and 56 days, respectively. Nutritive value declines quickly as plant matures thus were harvested at respective recommended stages of growth for each grass. The harvested grasses were chopped into 4 cm length and subdivided into four portions each of which was treated with different level of maize bran (0, 5, 10 and 15%). The chopped materials were ensiled in portions of 5 kg in plastic bag silo. Treatments were assigned to a completely randomized design in factorial arrangement (3 x 4) as three grasses (elephant, guatemala and rhodes grasses) and four maize bran levels (0, 5, 10 and 15%) with two replications. The silage was opened after 60 days, sampled and analyzed for chemical composition, fermentation, sensoric qualities, IVDMD and keeping quality stability. Elephant grass produced higher ($p < 0.05$) quality silages than those produced by guatemala and rhodes grasses as indicated by higher ($p < 0.05$) sensoric qualities, CP, LA and stability but lower

($p < 0.05$) pH and NH_3N. Maize bran at 10% level produced higher ($p < 0.05$) quality silages than maize bran at 0, 5 and 15% levels as indicated by higher ($p < 0.05$) sensoric scores, CP, WSC, LA, AA and stability but lower ($p < 0.05$) NDF, pH and NH_3N. The interaction between grass species and different maize bran levels showed that, elephant grass silage with maize bran at 10% level produced best silage as indicated by highest sensoric scores, CP, LA and stability but lowest pH.

The third experiment focused on assessing the effect of grass species and different levels of molasses on silage quality. The grasses were harvested when the re-growth was 1.5 and 1 m tall for elephant and guatemala grasses respectively and at flowering stage of growth for rhodes grasses. The harvested grasses were chopped into 4 cm length and subdivided into three portions each of which was treated with different levels of molasses (0, 3 and 5%), packed in 5 kgs plastic bag silo and stored in thatched barn. Treatments were assigned to a completely randomized design in factorial arrangement (3x3) as three grasses (elephant, guatemala and rhodes grasses) and three levels of molasses (0, 3 and 5%) with two replications. The silage was opened and sampled after 60 days, analyzed for sensoric qualities, chemical composition, IVDMD and fermentation. Elephant grass produced higher quality silage and preserved better than guatemala and rhodes grasses as indicated by higher ($p < 0.05$) sensoric qualities, CP, ash, LA, AA and stability but lower DM, pH, NH_3N and BA. Silages produced from molasses at 5% level had higher ($p < 0.05$) quality and preserved better than silages mixed with molasses at 0 and 3% levels as indicated by higher ($p < 0.05$) DM, CP, WSC, ash, IVDMD, LA, AA and stability but lower ($p < 0.05$) NDF, pH and NH_3N. Elephant grass at 5% level of molasses showed highest CP and WSC but lowest pH and NH_3N. The fourth experiment aimed at determination of the effect of wilting, chopping length and maize bran additive levels on fodder grass silage quality. Elephant grass was harvested when the re-growth was 1.5 m tall. The harvested grass was divided into two portions. One portion of grass was wilted for 24 hours prior to ensiling while the other portion was ensiled unwilted. Before ensiling each portion was chopped into either 2 or 4 cm length pieces using a machete. Within each chop length (2 or 4 cm) the material was subdivided into four portions each of which was treated with one of the four levels (0, 5, 10 and 15%) of maize bran. Treatments were assigned to a randomized factorial design (4 x 2 x 2) as four maize bran level (0, 5, 10 and 15%), two pre-ensiling treatments (wilted and unwilted) and two chopped treatments (2 or 4 cm) with two replications. The silage was opened and sampled after 60 days analyzed for; sensoric qualities, chemical composition, *in vitro* DM digestibility, fermentation characteristics and stability. Wilted grass produced silages with higher ($p< 0.05$) appearance, smell and texture scores, DM, CP, WSC, LA AA, pH and stability but lower ($p< 0.05$) IVDMD, NDF, NH_3N and butyric acid than unwilted grass silages. Silages produced from 2 cm chop showed higher ($p< 0.05$) sensoric scores, DM, CP, WSC and IVDMD, LA, AA and stability but lower ($p< 0.05$) NDF, pH, NH_3N and butyric acid than those from 4 cm chop. Silages treated with maize bran at 10 and 15% levels had higher ($p< 0.05$) DM, WSC and ash but lower ($p< 0.05$) NDF than the other levels (0 and 5%). Silages treated with maize bran at 10% level had higher ($p< 0.05$) sensoric scores, CP, IVDMD, lactic acid, acetic acid and stability but lower ($p< 0.05$) NDF, pH, NH_3N and butyric acids than the other levels (0, 5 and 15%). Wilting with 2 cm chop and maize bran at 10% produced silage with highest IVDMD, CP and acetic acid.

Experiment 5 dealt with the investigation of the effect of wilting, chopping lengths and different levels of molasses on grass silage. Elephant grass (*Pennisetum purpureum*) was harvested when the re-growth was 1.5 m tall. The harvested grass was divided into two portions. One portion of grass was wilted for 24 hours prior to ensiling while the other portion was ensiled unwilted. Before ensiling each portion was chopped into either 2 or 4 cm length pieces using a machete. Within each chop size (i.e. 2 or 4 cm) the material was subdivided into three portions each of which was treated with one of the three levels (0, 3 and 5%) of molasses as additive. Treatments were assigned to a randomized factorial design (3 x 2 x 2) as molasses additive levels (0, 3 and 5%), two pre-ensiling treatments (wilted and unwilted) and two chopping treatments (2 or 4 cm) with two replications. The silage was opened and sampled after 60 days, analyzed for sensoric qualities; chemical composition IVDMD, fermentation characteristics and stability. Wilted grass produced silages with higher ($p < 0.05$) appearance, smell and texture scores, higher DM, CP, WSC, ash, LA, AA, pH and stability but lower NDF, IVDMD, NH_3N and BA than unwilted grass silages. Silages produced from 2 cm chop showed higher ($p < 0.05$) sensoric scores, DM, CP, WSC, IVDMD, LA, AA and stability but lower NDF, pH, NH_3N and BA than those from 4 cm chop. Silages treated with molasses at 5% level had higher ($p < 0.05$) sensoric scores, DM, CP, WSC, ash, IVDMD, LA, AA and stability but lower ($p < 0.05$) NDF, pH, NH_3N and BA than silages treated with molasses at 0 and 3% levels. Wilting with 2 cm chop and molasses at 5% produced silage with highest sensoric scores, DM, WSC, LA but lowest NDF, pH and NH_3N.

Experiment 6 dealt with determination of the effect of grass species, ensiled amount in shopping plastic bags and storage positions on grass silage quality. The grasses were harvested when the re-growth was 1.5 m and 1 m tall for elephant and guatemala grasses and at flowering stage of growth for rhodes grasses. The harvested grasses were chopped in 2 cm particle length before ensiling. The chopped materials were ensiled in portions of 5, 10 or 12 kg in plastic bag silos. Then the plastic bags were stored either in thatched barn or in trench. Treatments were assigned to a completely randomized design in factorial arrangement (3 x 3 x 2) as three grasses (elephant, guatemala and rhodes

grasses), three ensiled amount of grasses in shopping plastic bag silos (5, 10 and 12 kgs) and two storage positions (thatched barn and trench) with two replications. The silage was opened and sampled after 60 days, analyzed for chemical composition, fermentation, sensoric qualities, IVDMD and stability. Elephant grass produced higher ($p < 0.05$) quality silage and preserved better than those of guatemala and rhodes grasses as indicated by higher ($p < 0.05$) sensoric scores, CP, ash, LA, AA and stability but lower ($p < 0.05$) pH, NH_3N and butyric acid. The 5 and 10 kg ensiled amounts showed higher ($p < 0.05$) appearance, smell and texture scores, DM, CP, WSC, ash, IVDMD, LA, AA and stability but lower ($p < 0.05$) NDF, pH, NH_3N and BA than 12 kg ensiled amounts. There was no difference ($p < 0.05$) between the two ensiled amounts (5 and 10 kg) in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, LA, AA and BA. There were no differences ($p < 0.05$) between silages stored in thatched barn and trench in terms of sensoric scores, DM, CP, WSC, ash, NDF and IVDMD, pH, NH_3N, LA, AA, BA and stability.

It was therefore concluded that, wilted elephant grass chopped 2 cm, treated with either maize bran at 10% or molasses at 5% levels, ensiled either at 5 or 10 kg in shopping plastic bag silo, stored in either thatched barn or in trench was the most optimal combination of technologies to achieve high quality grass silage.

DECLARATION

I, BERTHA JACOB LYIMO, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work done within the period of registration and has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This work is dedicated to our ALMIGHTY GOD who is the source of all knowledge. To my beloved parents, Jacob I. Lyimo and Luise N. who laid the foundation of my education and sacrificed a lot for my education and well being. May the Almighty GOD bless their work from generation to generation. AMEN.

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LIST OF PAPERS AND MANUSCRIPTS

This thesis is based on the following studies (papers and manuscripts), which will be referred to in the text by their roman numerals:

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Lyimo B J, Mtengeti E J, Urio N A and Ndemanisho E E 2016a. Effect of fodder grass species, wilting and ensiled amount in shopping plastic bags on silage quality. *Livestock Research for Rural Development. Volume 28, Article #142.* Retrieved July 31, 2016, from http://www.lrrd.org/lrrd28/8/lyim28142.html (Published).

Paper II:

Lyimo B, Mtengeti E J, Urio N A and Ndemanisho E E 2016b. Effect of grass species and different levels of maize bran on silage quality. *Livestock Research for Rural Development. Volume 28, Article #155.* Retrieved August 31, 2016, from http://www.lrrd.org/lrrd28/9/lyim28155.html (Published).

Paper III:

Lyimo, B. Mtengeti, E.J. Urio, N.A. and Ndemanisho, E.E. 2016c. Effect of Grass Species and Different Levels of Molasses on Silage Quality. *International Journal Recent Science Research* 7(8): 12795-12803 (Published). Retrieved August 28, 2016 fromhttp://www.recentscientific.com.

Paper IV:

Lyimo, B., Mtengeti, E.J., Urio, N.A and Ndemanisho, E.E. (2017). Effects of wilting, chopping length and maize bran levels on grass silage quality (Manuscript to be submitted in any reputable journal).

Paper V:

Lyimo, B., Mtengeti, E.J., Urio. N.A and Ndemanisho, E.E (2017). Effects of wilting, chopping length and molasses levels on grass silage quality (Manuscript to be submitted in any reputable journal).

Paper VI

Lyimo, B., Mtengeti, E.J., Urio, N.A and Ndemanisho, E.E. (2017). Effect of grass specie, ensiled amount in shopping plastic bags and storage positions ongrass silage quality (Manuscript to be submitted in any reputable journal).

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ABBREVIATIONS AND SYMBOLS

%	Percent
°C	Degree Celsius
a.s.l	Above sea level
Afs	Atomic Fluorescence Spectrometry
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
C min^{-1}	Centigrade per minute
Cm	Centimeters
CP	Crude protein
CP-Sil 19 CB	type of capillary column in gas chromatography
D	Day
DM	Dry matter
e.g.	For example
EG	Elephant grass
et al.	And others
FAO	Food and Agriculture Organization of the United Nations
FID	Flame Ionization Detector
Fig.	Figure
G	Gram
GDP	Gross Domestic product
GG	Guatemala grass
GLM	General Linear Model
GPS	Global Positioning Systems

H_2	Hydrogen
Ha	Hectare
i.e	id est (that is to say)
IVDMD	*In vitro* Dry Matter Digestibility
Kg	Kilogram
kg/ha/yr	Kilogram per hectare per year
Km	Kilometres
kPa	kiloPascal
LAB	Lactic Acid Bacteria
Lts	Litres
M	Metre
m^3	Cubic metre
MAFF	Ministry of Agriculture, Forestry and Fisheries
MB	Maize Bran
ME	Metabolize Energy
MLFD	Ministry of Livestock and Fisheries Development
Mm	Millimetre
MOL	Molasses
NBS	National Bureau of Statistics
NDF	Neutral Detergent Fiber
NH_3N	Ammonia Nitrogen (as %TN)
Nm	Nanometer
No.	Number
NRC	National Research Council
$P<0.05$	Significant at the 5% level of probability

P>0.05	Not Significant at the 5% level of probability
pH	Hydrogen ion concentration
RG	Rhodes Grass
S	Seconds
SAS	Statistics Analysis System
SEM	Standard Error of Means
SUA	Sokoine University of Agriculture
t	Ton
tDM/ha	Tonnes Dry Matter per Hectare
TDN	Total Digestible Nutrient
TN	Total Nitrogen
TPC	Tanganyika Planting Company
Tshs	Tanzanian Shillings
URT	United Republic of Tanzania
Vs	Versus
WCOT	Wall-Coated Open Tubular
WSC	Water Soluble Carbohydrates
µL	Microliter
µM	Micrometer

CHAPTER ONE

1.0 INTRODUCTION

Demand for milk worldwide is steadily increasing due to population growth and rise in per capita milk consumption, particularly in developing countries (FAO, 2006). According to United Nations (2015) the current world population of 7.3 billion is expected to reach 8.5 billion by 2030 and projected to be 9.7 billion by 2050 and 11.2 billion by 2100. It is growing by 1.18% per year or approximately an additional 83 million people annually (United Nations, 2015). In Tanzania, dairy industry has been playing an important role in improving living standards of people through milk consumption and cash income from sales of milk and milk products (Njombe *et al.*, 2011). Total annual milk production is currently estimated at 1.85 billion litres in Tanzania, out of which 0.597 billion litres are from high breed cows and 1.26 billion litres from indigenous cows (NBS, 2008). To date, per capita milk consumption in the country is estimated at 43 litres per annum compared to the per capita milk consumption of 200 litres per annum recommended by FAO (Njombe *et al.*, 2011; Swai and Karimuribo, 2011). Smallholder farmers produce most of the food in developing world but are poorer than the rest of the population (Dixon *et al.*, 2001). There is no sustainable way of reducing poverty and hunger without improving livelihoods (a means to a living) in rural areas (FAO, 2003) where most of smallholder farmers are found. Smallholder farmers usually keep a small number of cattle indoors (Zero grazing practice). According to Mlay (2001) few animals (1-10 cows per household) are kept due to smallholding and high labour demand. Dairy industry has also been contributing significantly to poverty alleviation particularly among rural dwellers (Kurwijila *et al.*, 2002). However, dairy industry in Tanzania is faced with various constraints. Milk production in the country is rather low and has not kept pace with the demand of human population growth in the country (Kurwijila, 2001). This scenario is associated with the annual inconsistent supply of high quantity and quality forages especially during the dry seasons. In the wet season there is excess forage than demand and thus left to be over mature and sometimes just rot and get lost (Hall *et al*., 2008). This seasonal fluctuation of forages signifies that, the surplus forage in the wet season should be conserved so as to carry them over to the dry season. Therefore, testing of the appropriate combination of technologies of grass conservation for scaling up to the smallholder dairy farmers is very important so as to reduce the shortage of feeds during the dry season.

1.1 Problem Statement and Justification

Shortage of forages during the dry season is a limiting factor to improved dairy production in smallholder dairy farms in Tanzania. Smallholder dairy farmers have to spend up to three hours collecting forages far away from the homestead. Due to poor feeding in this period both milk production and reproduction are negatively affected. The dairy cattle in Tanzania produce on average about 6-7 litres of milk per day in the wet season and decline to nearly 3 litres per day in the dry season (Msangi and Kavana, 2002). According to MLFD (2011) the low milk productivity is mainly associated with inadequate nutrition. Moreover, areas of natural grazing available to smallholder farmers are decreasing rapidly as more land is put under crop production and other uses e.g. for houses and road construction. Low lands such as valleys with high soil moisture even in the dry seasons, which had provided some dry season grazing, are now used for vegetables and other off season cropping. This implies more stall-feeding of stock, increased cut-and-carry systems on small farms and forage conservation must be done to cover the dry period scarcity of forage (Mtengeti and Urio, 2006; Lyimo, 2010). However, apart from shortage of feeds during the dry season, there is also surplus forage material exists during the wet / rainy season (Figure 1). The surplus yields of fodder grass during the wet season are wasted as they are not carried over into the dry season through conservation (Hall *et al.,* 2008). If Smallholder dairy farmers conserve available forages during wet seasons they could not only save grass that would otherwise be spoilt, but also encourage regrowth that would improve the quality of standing forage crop during the dry season.

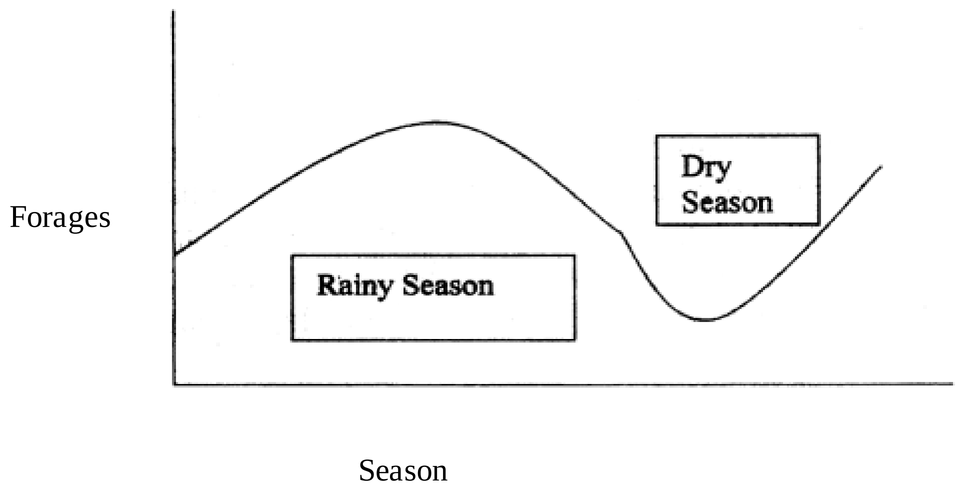

Figure 1: Forages Seasonal fluctuation

In order to alleviate the dry season feeding problems for dairy animals, it has been considered plausible to conserve the surplus forage material that exists during the wet season (Abdelhadi, 2007). The most conventional feed conservation methods are hay and silage (Njarui, 2011) however, hay making in eastern coast of Tanzania is rather difficult because in most cases the optimal hay making period coincides with the wet season which limits sun drying of forage material. In addition, according to Mtengeti and Urio (2006) it is not easy to make hay from thick stemmed fodder grasses. In this respect, surplus yields of fodder grass during the wet season can safely be carried over into the dry season through silage making. Silage is moist forage, stored in the absence of oxygen and preserved by acids produced during ensiling. Silage making is one of the feed conservation strategies which can improve availability of high quality feeds all the year round for smallholder dairy farmers in the country (Mtengeti and Urio, 2006; Lyimo, 2010). However, silage making technologies have not been practiced by majority of smallholder dairy farmers in Tanzania. Lack of know - how accounts for this failure (Mtengeti and Urio, 2006; Lyimo, 2010). On the other hand, silage making technologies are expensive and not technically viable under smallholder production (Ashbell *et al*., 2001). Also, studies in developing cheap, practical and technically feasible silage making technologies have concentrated on a single dimensional approach of intervention, i.e. concentration on pre-ensiling treatments (Ojeda, 2000; Balsalobre *et al*., 2001; Manyawu *et al*., 2003; Keles *et al*., 2009; Kung, 2009) and others on ensiled amounts and storage positions (Ashbell *et al*., 2001; Pariyar, 2005). Others dealt with single fodder grass (Lyimo, 2010) leaving other potential locally available grasses uninvestigated. Studies which specify the most optimal combination of different techniques to achieve high quality silage under smallholder dairy farmers have rarely been conducted. A smallholder dairy farmer in Tanzania needs a technology that is versatile enough to accommodate his/her resource constraints and still able to produce silage that meets the quality desired, hence the need for this study.

The main objective of the study was therefore to evaluate the effect of various silage making techniques on silage quality of elephant grass, guatemala grass and rhodes grass under small scale dairy farming in Tanzania. This main objective was addressed through the following specific objectives:

(i) To determine the effect of grass species, wilting and ensiled amount in shopping plastic bags on grass silage quality

(ii) To evaluate the effect of grass species and maize bran / molasses additive levels on grass silage quality

(iii) To determine the effect of wilting, chopping length and maize bran / molasses additives levels on grass silage quality

(iv) To determine the effect of grass specie ensiled amount in plastic bags and storage positions on grass silage quality

(v) To evaluate the effect of different ensiling technologies on grass silage stability during feeding out.

Study general hypothesis

Various silage making techniques have no significant effect on grass silage quality ensiled in plastic bags.

Study questions

(i) Which fodder grass is most suitable for smallscale silage making?

(ii) What silage making techniques should be followed so as to improve grass silage quality?

1.2 Literature Review

1.2.1 Forage conservation by smallholder farmers in Tanzania

In most parts of the world, forage conservation is a key element for productive and efficient ruminant livestock farms (Macedo *et al.*, 2010). Forage conservation also provides farmers with means of preserving forage when there is surplus production. In Tanzania, dry season forage production is minimal and dairy farmers have to collect forages from communal ground or crop residues from household farms far away from the homestead (Lyimo, 2010). Smallholder farmers deliberately underfed dairy cattle during dry season. Efforts have been done to introduce forage conservation technologies, such as hay and silage in dairy potential areas under smallholder farmers such as in Njombe and Morogoro regions (Mtengeti and Urio, 2006; Lyimo, 2010; Mtengeti *et al.*, 2013) with less success. According to authors, some of challenges facing silage production in the country include: - lack of know how, lack of finance and negative attitude of farmers on silage making (silage making is considered cumber some and labour intensive). According to Wilkinson *et al*. (2003) innovative participatory approaches to forage conservation with appropriate technologies are required.

1.2.2 Silage and ensiling processs

Silage is moist forage, stored in the absence of oxygen and preserved by acids (lactic and volatile fatty acids) produced during ensiling (Mciteka, 2008). The ensiling process (Figure 2) is an anaerobic microbial fermentation of water soluble sugars to lactic acid, lowering the pH to a point that inhibits further microbial fermentation. The goal is a rapid pH drop to minimize fermentation losses of feedstuff nutrients, especially protein (Baytok *et al*., 2005) to preserve nutrients to optimize livestock intake and performance (Bagg, 2010). The conversion of fresh forage to silage (ensiling) progresses through four phases of fermentation that are normally completed within 21 days of ensiling (Jones *et al*., 2004). According to Pahlow *et al*. (2003) and Jones *et al*. (2004) ensiling process has four phases namely; aerobic, fermentation, stable and feed-out phases Jones *et al*. (2004) explained the fore-mentioned four phases accordingly (Figure 2).

According to Jones *et al*. (2004) phase 1 (aerobic phase) begins as soon as forage is mown. This phase can only occur in the presence of oxygen. When cut, green plants continue to live and respire for several hours (or longer if packed poorly in storage). The plant cells within the chopped forage mass continue to take in oxygen because many cell walls are still intact and plant enzymes that breakdown proteins (proteases) continue to function. At the same time, aerobic bacteria naturally present on the stems and leaves of plants begin to grow. These processes consume readily available carbohydrates stored in the plant and produce carbon dioxide, water and heat i.e.

$$\textbf{Sugar} + O_2 \rightarrow CO_2 + \textbf{water} + \textbf{heat.}$$

The phase usually lasts 3-5 hours, depending on the oxygen supply present. Further more, according to Jones *et al.* (2004) from a management stand point, the primary goal is to eliminate oxygen as soon as possible and keep it out for the duration of the storage period. Practices that help rapidly exclude air from the silage mass include chopping forage at proper particle length, harvesting at proper moisture for the crop and the storage structure, packing adequately by distributing silage evenly and compacting silage well and sealing the storage structure immediately.

Phase two (fermentation phase) begins as the supply of oxygen is depleted and anaerobic bacteria that grow without oxygen begin to multiply. The acetic acid bacteria begin the silage “pickling” process by converting plant carbohydrates to acetic acid. This acidifies the forage mass, lowering the pH from about 6.0 in green forage to a pH of about 5.0. The lower pH causes the acetic acid bacteria to decline in numbers, as they cannot tolerate an acidic environment. The early drop in pH also limits the activity of plant enzymes that break down proteins. This phase of the fermentation process continues for 1 - 2 days and merges into phase 3.

The third phase (stable phase) of the fermentation process begins as the acetic acid-producing bacteria begin to decline in numbers. The increased acidity of the forage mass enhances the growth and development of lactic acid-producing bacteria that convert plant carbohydrates to lactic acid, acetic acid, ethanol, mannitol and carbon dioxide. Homolactic bacteria are preferred because they can convert plant sugars to lactic acid exclusively. Bacterial strains within this group grow in anaerobic conditions and they require low pH.

Lastly, Jones *et al*. (2004) explained that, the fourth phase (feed-out phase) is a continuation of phase 3; lactic acid production continues and peaks during this time. Phase 4 will continue for about 2 weeks or until the acidity of the forage mass is low enough to re-strict all bacterial growth, including the acid-tolerant lactic acid bacteria. The silage mass is stable in about 21 days and fermentation ceases if outside air is ex-cluded from the silage.

	Phase 1	Phase 2	Phase 3	Phase 4	Storage
	Day 1	Day 2	Day 3 to 6	Day 7 to 21	After Day 21
Chemical changes	Oxygen + Sugar ↓ CO_2, Heat Water Proteins Degraded	Sugar ↓ Acetic acid ($C_2H_4O_2$)	Sugar ↓ Lactic acid ($C_3H_6O_3$) Acetic acid Ethanol Mannitol CO_2	Sugar ↓ Lactic acid Acetic acid Ethanol Mannitol CO_2	Stable state until silage is exposed to oxygen
Oxygen					
Micr obial growth	Aerobic Bacteria	Acetic Acid Bacteria	Lactic Acid Bacteria		
Temperature	26.7 to 37.8°C 21.1°C				21.1°C
pH	6.0	5.0	4.2	~4.0	

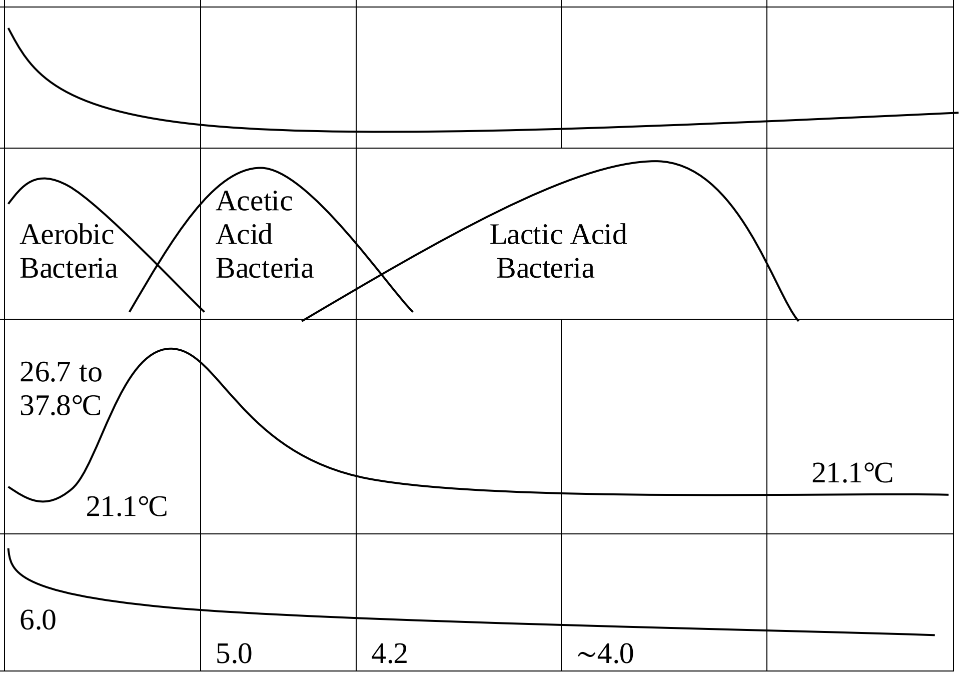

Figure 2: Phases of normal silage fermentations (Jones *et al.*, 2004)

1.2.3 Factors affecting the ensiling process

The ensiling of forage is a process where many variables influence the course and outcome of silage fermentation. Two over riding features of any silage which will affect fementation can be distinguished (Woolford, 1984). The first is the nature of the raw material which is determined by the chemical and microbial composition of the crop (Table 1). The second feature is related to ensiling conditions imposed by the silage-maker and includes processes such as wilting, mechanical treatment of forage and use of additives.

Table 1: Factors affecting the silage process

Factor	Component		Explanation
Crop	WSC in crop	-	WSC influence the ensilability of crops. The concentration of WSC in forages often depends on the forage species and the stage of maturity.
	Crop DM	-	Clostridia are generally more sensitive to reduced water availability than lactic acid bacteria e.g wilting reduced clostridial activity (DM of 250 to 400 g/kg)
	Buffering capacity of crop	-	The buffering capacity of plants determines the ability to resist a pH drop down to 4.0. Buffering capacity can be increased during the ensiling process due to the production of various organic acids.
Mechanical forage treatment		-	The level of laceration affects the silage fermentation in terms of bacterial activity in a crop e.g. chopping
Silage additives		-	Silage stimulants are employed to encourage the lactic acid fermentation by promoting the growth of lactic acid bacteria through the provision of fermentable substrate whereas silage inhibitors partially or completely restrict microbial growth.

Source: Knický (2005)

1.2.4 Micro-organisms involved in the ensiling process

According to Knický (2005) several genera described as lactic acid bacteria (LAB) play a fundamental role in the ensiling process. Members of this group compete for available nutrients with undesirable “microorganisms’’ in the ensiling process. The representatives of these detrimental microorganisms are in particular clostridia, enterobacteria, bacilli and fungi. The main difference between the LAB flora and detrimental flora is in the quality of their end-products and way of degradation of valuable nutrients (Table 2). If the LAB prevails, the silo pH will be ideally reduced to 4.0 over a period of several days and plant material will be well preserved (McDonald *et al*., 2002). According Lücke (2000) gram-negative bacteria are less susceptible to the action of bacteriocins from LAB due to the presence of outer membrane, which limits the access of peptides to the target site. In addition, the gram-negative bacteria are more sensitive to organic acid produced by LAB compared with the gram-positive bacteria (Ennahar *et al*., 2000).

Table 2: Micro-organisms involved in the ensiling process

Name	Explaination
Lactic acid bacteria	They are Gram-positive and belong to the epiphytic microorganisms which occur on the lower parts of forage plants. The transition of hexoses by LAB to fermentation acids proceeds under anaerobic condition and is of particular importance for ensiling. LAB possesses the capability to ferment a wide range of substrates using different pathways. In the ensiling process, homo fermentative LAB are preferred due to fast and abundant formation of lactic acid, which has a high acidifying potential.
Enterobacteria	They are Gram-negative and their presence in silage is undesirable as they possess saccharolitic and proteolytic abilities and thereby compete for substrate with LAB. This occurs mainly at the beginning of fermentation before LAB dominates the fermentation process.
Clostridia	They are Gram-positive and are one of the most detrimental microorganisms involved in the fermentation process. Fast and abundant production of lactic acid resulting in a fast pH drop are one of the most important factors inhibiting clostridial activity
Fungi	Fungi play a major role in the aerobic instability of silages. They represent two major subgroups; moulds which grow mainly as multicellular, filamentous colonies and yeasts which grow mainly as single cells. Their role in aerobic deterioration of silages is usually associated with yeast growth. Moulds degrade a variety of substrates that can lead to complete decomposition of plant tissues which is highly undesirable in silage making
Bacilli	They are Gram-positive, spore-forming microorganisms but their ability to grow under aerobic conditions differs from that of clostridia. Bacilli seems to be unable to initiate aerobic deterioration of silages, but they can play a secondary role in aerobic deterioration after initiation by yeasts

Source: Knický (2005).

1.2.5 Principles of making high quality silage

Some key principles for achieving high quality grass silages are presented by Coblent (2009) the following are principles:-

i. Harvest forage silage at the right maturity stage and moisture (65%). High forage moisture levels at ensiling may cause silage effluent to be produced and favour undesirable fermentations. In contrast, ensiling forages when the moisture is low (< 50%) can result in restricted fermentations, thereby producing less stable silages that have low lactic acid and high pH.

ii. Chop at the precision length to eliminate oxygen from the ensiling mass during packing.

iii. Achieve an anaerobic environment as quickly as possible to limit respiration, spontaneous heating, DM loss and mould development.

iv. Maintain low temperature (15 to 25 °C) to allow growth of the more important lactic acid producing species of bacteria while inhibiting the undesirable clostridial species which result in increased butyric acid and NH_3N which is detrimental to silage quality.

v. Avoid soil contamination to keep away from millions of bacteria which could be introduced to the forage. Soil contaminated silages resulting to poor fermented forage containing lower levels of protein, high levels of ammonia, acetic and butyric acids, which will reduce feed intakes and can also seriously affect animal health with listeria eye, abortion and brain diseases (such as meningitis).

vi. Avoid water contamination to reduce risks of soil contamination and achieve a sufficient dry matter content in the cut crop because it won’t be as easy to wilt. This dry matter content is crucial and has a large effect on the intake of the resultant silage and therefore on the level of nutrients which are available to your animals. So even on a dull day, if the ground is free draining and dry, it is worth spreading the crop to speed-up the wilting process or consider using appropriate silage additives.

vii. Avoid direct sunlight as deterioration of silage often results from the direct sunlight.

1.2.6 Techniques for evaluating silage quality

According to Chin (2002), the quality of silage is one of the parameters that determine successful silage use. Techniques for evaluating the quality of silage involve sensory evaluation or organoleptic test, chemical composition and physical characteristics (Saun and Heinrichs, 2008). According to Otieno *et al.* (1990) three distinct types of silage involved in sensoric evaluation namely:- well fermented silage, badly fermented and overheated silage have been identified on the basis of smell, taste, colour and texture (Table 3). According to Bagg (2010) desirable lactic acid has little smell. Lactic acid is the most desirable product of fermentation because it is produced most efficiently, with the least dry matter losses. Too much acetic acid relative to lactic acid means the fermentation was less than optimally efficient. Ammonia odor indicates excessive protein breakdown to ammonia and amines, which could be due to a clostridia fermentation or high pH. Heat-damaged silage is the result of forage that is too dry (Bagg, 2010).

Table 3: Sensory evaluation of silage quality

Status of silage	Smell	Taste	Colour	Texture	Cause	Ranking
Well fermented silage	Pleasant (nearly ordoless)	Sharply Acid	Light green	Very firm (soft tissue not easily rubbed away from the leaf).	Lactic acid production	4
	Vinegar	moderate sharply acid	Light Yellow	Moderate firm	Acetic acid production (Bacillus)	3
	Fruity	not very much sharply acid	green brown	firm	alcohol react with acids in the silage, producing esters	
Badly fermented silage	Offensive (ammonia)	Strong, offensive and clinging	Olive green/ blue green	Slimy	Butyric acid production (Clostridium)	2
Over heated silage	Caramel/ Tobacco	-	Dark brown to black	Friable and dry	heating from ferm-entation and moisture damage	1

Source: Otieno *et al.* (1990); (except cause cited by Saun and Heinrichs (2008), ranking cited by Lyimo *et al.* (2016a)

Indices in conjunction with chemical composition to evaluate and express the quality of silage (Table 4) include DM, CP, WSC, ash, NDF and IVDMD. DM of silage obtained by measuring the moisture content in the silage. Diets that are excessively wet or dry may limit intake (Saun and Heinrichs, 2008). Excessively wet or dry silages usually result in inadequate fermentation and unstable products (Saun and Heinrichs, 2008).

Crude Protein in a feed is often a measure of quality, mainly due to the high cost of providing additional protein supplements in the diet. Forages containing higher protein values are of higher quality (Saun and Heinrichs, 2008). Sufficient dietary protein is necessary to facilitate rumen microbial fermentation and if deficient, reduced dry matter intake will result. Unbalanced rumen protein results in lower nitrogen utilization efficiency, increased nitrogen excretion and potentially reproductive inefficiency (Saun and Heinrichs, 2008). As a result, partitioning silage crude protein into rumen soluble, degradable and unavailable fractions can be more enlightening in evaluating silage quality.

Ammonia nitrogen measures the non-protein nitrogen (NPN) component of the soluble protein fraction (Saun and Heinrichs, 2008). One goal of silage is to minimize proteolytic activity from plant respiratory enzymes or microbes, primarily *Clostridium*. Amounts of NPN compounds increase greatly with proteolytic activity. This will buffer and increase silage pH making it less stable. Also, some toxic NPN compounds such as amines can reduce feed intake. The goal is to have ammonia nitrogen less than 8% of crude protein for grass silage.

According to the Saun and Heinrichs (2008) Neutral Detergent Fiber (NDF) of a feed characterizes the amount of cell wall material and is inversely proportional to dry matter intake. Plant maturity is directly proportional to NDF content. High NDF feeds have lower potential intake, although feed processing (grinding) can improve intake potential.

Digestibility is the most important factor influencing silage feed value. According to Keady (1998) wilting reduces silage digestibility due to a loss of available nutrients and an increase in ash concentration. When wilting, a rapid wilt is desirable to minimize the decline in digestibility. Prolonged wilting reduces digestibility. The author reported that, poorly-preserved untreated silage with a low lactic acid concentration and a high concentration of ammonia nitrogen normally has lower digestibility. The author reported also, silage digestibility declines by 3.3% units for each one week delay in harvest date. Application of excess fertilizer N has a negative effect on silage digestibility (Keady, 1998).

Indices in conjunction with physical characteristics of silage to evaluate and express the quality of silage (Table 4) include pH, NH_3N, LA, AA and BA. Lactic acid should make up over 65-70% of the total silage acids, with a lactic/acetic acid ratio of at least 3:1. Lactic acid is the most effective in lowering pH and is what one is trying to improve by using additives (Bagg, 2010). Excessive amounts of acetic, propionic, or butyric acids as well as ethanol indicate a poorer quality fermentation process resulting from other microbes that are not exclusive lactic acid producing bacteria (Saun and Heinrichs, 2008).

pH is a measure of acidity and highly influenced by fermentation process. High moisture silages are unstable with respect to pH and good quality silages being associated with low pH. According to Yang *et al.* (2004) attainment of low pH is one of the important determinants for final silage fermentation quality. Well fermented silage should have a pH of <4.2 (Mciteka, 2008). High pH at high water content is associated with proteolysis (aberrant clostridial fermentation) and low pH is associated with lactic acid production. In high dry matter silages, pH is a less useful criterion of quality since deficiency of water restricts fermentation (Lyimo *et al*., 2016a) and acid production.

Table 4: Chemical and physical characteristics evaluation of silage quality

Parameter	Recommended values of well fermented silage
DM	≥30 – 45 (65-70% moisture content)
CP	>17
WSC	6-12
pH value	<4.2
NH_3N	<10%, 8 (good), 8.1-12.1 (acceptable), 12.2-18 (poor), above 18 (not accepted)
Lactic acid	<0.1%, 6-8% wet silage, 3-4% dry silage
Acetic acid	< 2 %, Max 0.1% (good)
Butyric acids	0 (optimal value), 0.1-0.3% (acceptable), 0.4-0.6% (poor), above 0.6% (not accepted)

Source: Mciteka (2008)

1.2.7 Technologies for grass silage quality improvement

High quality silage is likely to be achieved when lactic acid is the predominant acid produced, as it is the most efficient fermentation acid and reduces silage pH more efficiently than other fermentation products (McDonald *et al*., 2002). Technologies for grass silage quality improvement include: wilting, chopping, additives (maizebran and molasses), ensiled amount and storage positions (thatched barn and trench).

1.2.7.1 Effect of wilting and chopping on grass silage quality

Successful wilting prevents effluent production (Keles *et al.,* 2009). According to Borreani *et al*. (2009) wilting is applied to reduce DM losses in the effluent and to lower the amount of water to be transported from the field to the silo. Kung (2009) observed reduced pH after wilting. The optimum moisture for precision-chopped silage is about 65 % (Bolsen *et al*., 2002). When moisture level is between 65 and 70 % effluents will not be produced and better fermentation will be promoted (Ojeda, 2000). The wetter silages are reported to ferment longer than wilted silages and require high WSC levels and lower pH for stability (Kung and shaver, 2004). Excessively wet silage (>70 % moisture) usually results in fermentation dominated by undesirable butyric acid-forming bacteria, the loss of large volumes of highly digestible nutrients through seepage and poor animal performance due to low consumption (Mueller and Green, 2009). On the other hand, ensiling forage when the moisture content is low (<50 %) can result in restricted fermentations, thereby producing less stable silages that have low lactic acid and high pH.

Chopping helps to breakdown cell wall structure which aid in fermentative efficiency (Balsalobre *et al*., 2001). Forage chopping may be alternative way in which *Clostridium* fermentation is minimized. *Clostridium* fermentationis also minimized by promoting greater packing density and thus exclusion of air, closer substrate contact with the fermenting bacteria, leads to higher lactate yield and faster pH reduction (Balsalobre *et al*., 2001). According to O'Kiely (2001) the recommended chopping length of forage is 1-2 cm.

Chopping between 2 and 4 cm in length has an additional benefit of ease of ingestion, regurgitation and posterior rumination (Ojeda, 2000). The grass should be chopped in order to increase bulk density and easy compaction of ensiling material so as to remove air and encourage anaerobic bacterial activities thus leading to lower losses of DM. Silage fermentation can be influenced by the particle size of the forage being ensiled (McEniry *et al*., 2008; Rinne and Seppälä, 2011). Furthermore, silage particle size affects chewing activity, intake and performance of cattle (Rustas and Nadeau, 2011).

1.2.7.2 Effect of additives on grass silage quality

Silage additives are used to improve the concentrations of WSC and are according to Kaiser (2004) and Tauqir (2004) classified into five categories, based on their modes of action. These include: i) stimulants which encourage lactic acid fermentation (e.g. whey, sugarcane molasses, enzymes etc) ii) fermentation inhibitors, which partially or completely restrict microbial growth iii) aerobic deterioration inhibitors, which prevent the deterioration of silage during feed out phase iv) nutrients to enhance the nutritive value of the crop after ensiling and v) absorbents for preventing effluent loss by raising the DM content of silage.

Maize bran and molasses are feed supplement materials that are locally available in Tanzania and could also be used as additives to improve the grass silage quality. Maize bran is a by-product of various maize processing industries including starch and ethanol production and the production of maize-based foods. Maize bran can be used as additive partly to provide fermentable substrate but also facilitate fermentation by absorbing excessive moisture. To optimize their effectiveness by avoiding effluent losses they have to be used in relatively high rates (about 10-15%) of the ensiled material (Manyawu *et al*., 2003) and adequately mixed with the chopped forage. Maize bran may be used as an absorbent additive and therefore, reduce the effect of high moisture fodder grass crop and thus produce acceptable silage with good quality (Manyawu *et al*., 2003; Lyimo, 2010). Maize bran can be purchased from local maize milling machines.

The most prevalent form of added sugar to the dairy diet has been sugar cane molasses. Sugarcane molasses, a waste product of sugar production has been widely used as a silage additive (Kwak *et al*., 2009; Nkosi *et al*., 2009). Molasses is made of 45 to 50 % of sucrose containing 79 % soluble carbohydrates (Oladuso *et al*., 2016). It provides a relatively cheap source of fermentable carbohydrate for lactic acid. It is one of the most important WSC's used most frequently and is of particularly benefit when applied to crops low in soluble carbohydrates. WSCs are the carbohydrates that can be solubilized and extracted in water (CAST, 2003). Adding molasses (stimulant) or other sources of WSC is widely used to promote low pH and high proportions of lactate in such silages (Andrade and Melotti, 2004; Mtengeti *et al.*, 2006). With added sucrose silages acidify rapidly to pH 3.8 (Catchpoole, 2003). Addition of 4% molasses reduce silage pH and improved it`s quality (Aminah *et al*., 2000). Molasses, a source of WSC, is often used to help prevent silage instability (Jaurena and Pichard, 2001). Different studies reported decreasing pH with the addition of molasses (Aminah *et al*., 2000; Baytok *et al.*, 2005). In Tanzania, Molasses can be purchased from local sugar processing industries basically in Mtibwa, Kilombero, TPC Moshi, Kagera sugar companies and in authorized livestock feed and pharmaceutical shops.

1.2.7.3 Effect of ensiled amount in plastic silos on grass silage quality

Silos for silage are the facilities in which the crops ferment and where silages are stored until feeding. Trench (1 m^3) silos are commonly used by smallholder farmers as they are cheap and affordable (Delacollette *et al*., 2005). Small plastic bags allow milking cow to be fed one or two bags per day and therefore, reduce silage feed out losses due to the exposure to the air. Bags should be completely air impermeable and that the volatile fatty acids which are produced during the fermentation are retained within the bags and inhibit spoilage yeasts and moulds (Ashbell *et al.*, 2001). Use of plastic bags in silage making for smallholder farmers is therefore worthwhile to be conducted as it will reduce the ensiling costs. Shopping plastic bags silos are rather adaptive to low household labour compared to pit or bunker, which require expenses for diging the trench and compaction as it has been reported in Pakistani, Benin, Zimbabwe, Kenya and Tanzania (Lane, 2000; Ashbell *et al*., 2001; Delacollette *et al.*, 2005; Pariyar, 2005; Mtengeti and Urio, 2006).

According to Mtengeti and Urio (2006) with small plastic bags the problem of silage contamination with soil, which frequently happens in earth pit silos is eliminated. Moreover, small plastic bags are conducive cheap and can provide piecemeal with prolonged dry season and availability of forage to ensile (Lyimo, 2010). However, amount of silage required depends on number of livestock to feed, length of feeding period, percentage of silage in full ration and material resources available e.g. equipment, labour, financial means and technical assistance. In modern farming, dairy cows are fed between 10 and 20 kg of wet silage per day. Where silage is the only forage, cows will eat about 3 kg of silage per 50 kg of body weight (Ashbell and Weinberg, 1999). Silage is better suited for optimal amounts of grasses ensiled in small plastic bags to meet the feeding requirement of the animal. However, studies on the optimal ensiled amount in small plastic bags are scantly.

1.2.7.4 Effect of storage positions on grass silage quality

Storage positions are places where silage is kept to allow fermentation process to take place. Silos provide conducive environment for fermentation bacteria (Lyimo, 2010). A thatched barn is chosen as an above ground storage place because it will always remain cool as compared to corrugated iron roofed barn (Mtengeti and Urio, 2006). Mtengeti and Urio (2006) also reported high quality silage from both thatched barn and trench. Weinberg *et al*. (2001) reported silage stored at elevated ambient temperatures (37-41^{o}C) result in unfavorable ensiling characteristics (higher pH and DM losses, and less lactic acid) and less aerobic stability when compared to silage stored at room temperature ($\leq$ 33^{o}C). High environmental temperature (40^{o}C) decreased the activities of acetic acid bacteria (Kızılsimsek *et al.,* 2005). Silo must favor the fermentative bacteria for stable and high quality silage. High temperatures lead to unsuitable fermentation of the silage (Gonzalez *et al*., 2003). According to Coblent (2009) low temperature (15 to 25°C) allows growth of lactic acid bacteria which are very impotant for fermentation process. Smallholder dairy farmers require the above mentioned technologies to improve silage quality.

1.2.7.5 Effect of different technologies for improvement of silage quality on the stability of silages

Aerobic stability is a measure of the shelf life of silage and an indirect measure of the likelihood of undesirable microbial activity which predispose to heating, nutrient depletion and growth of pathogenic organisms. According to Santos *et al*. (2006) aerobic stability is the inhibition of the fungi multiplication through the contact with oxygen. Silage stability was defined by Moran *et al.* (1996) as the number of hours the silage remained stable before rising more than 3^{0}C above the ambient temperature and it is determined by observing the change of temperature of exposed silage for several days.

According to Lyimo *et al.* (2016b) silage stability is determined by observing the change of pH of exposed silage for several days.

If silage is more stable than the other it means that it is more stable in terms of maintaining low pH value (<5) for longer period than the other. According to Jonsson (1991) the growth of most acid tolerant clostridia will be inhibited by a pH just below 5.0. According to Holland and Kezar (1995) stability dependent upon: air penetration; remaining soluble sugars; fermentation acids present; presence of yeasts and molds. Properly fermented silage will remain relatively stable for indefinite lengths of time provided that air cannot gain access to the silage. If air (oxygen) is allowed access to stable silage, populations of yeasts and molds will increase and cause heating in the silage mass via respiration. This can cause substantial dry matter losses and also reduce silage nutritive value (Figure 3). Some species of molds found under these conditions can produce mycotoxins and other substances that negatively affect animal health. The organic acids produced by fermentation, mainly acetic acid, have fungicidal effect and can mitigate the deterioration, increasing silage aerobic stability (Ranjit and Kung, 2000; Kung and Ranjit, 2001).

Silage that is unstable when exposed to air heats rapidly and spoils leading to a loss of DM and nutrients the potential for production of undesirable compounds. Even short term exposure to air results in losses. For example, DM losses from corn silage exposed to air for just 1 to 2 d was measured to be as high as 6% (Ranjit and Kung, 2000). Besides an economic loss of nutrients, feeding spoiled silage to ruminants depresses nutrient intake and decreases production (Whitlock *et al*., 2000). Preventing silage from spoiling when it is exposed to air can improve the efficiency of a farm by preserving forage as high quality silage that is palatable to cows.

Silage is exposed to air

↓

Dormant yeast that degrade lactic acid are revived

↓

Yeast degrade lactic acid to co_2 and water, producing heat

↓

Numbers of yeasts increase in the silage mass

↓

pH of silages increases

↓

Molds and aerobic bacteria revived and further degrade the silage

↓

Massive spoilage

Source: Kung (2010)

Figure 3: The main effect of air causing aerobic spoilage in silages

Rapid removal of air from the forage mass and the ability to prevent air from infiltrating the silage mass during storage and feedout can have profound effects on feed quality. Prolonged infiltration of air during storage or feedout into the silage mass can lead to aerobic spoilage. According to Kung (2010) air can be eliminated by fast filling (but not too fast), even distribution of forage in the storage structure, chopping to a correct length and ensiling at recommended dry matters (DM) for specific storage structures. Excessive air due to slow silo filling or poor packing (overly dry forage orforage chopped too coarsely) allows the plant to respire for prolonged periods of time. This results in utilization of sugars and excessive degradation of plant protein. Air also encourages the growth of undesirable microbes such as yeasts and molds. Proper management for removal of silage from silos can help producers to maximize profits and production. According to Lyimo *et al*. (2016b) who dealt with effect of maize bran and molasses additives on stability of silage, additives have ability to enhance the aerobic stability of silages. The grass should be chopped in order to increase bulk density and easy compaction of ensiling material so as to remove air and encourage anaerobic bacterial activities thus leading to lower losses of DM.

1.2.8 Grass production

The chemical composition of the forage at ensiling has a major influence on the silage fermentation. Low nutritive value grasses found in most of tropical areas (Lyimo, 2010) can be improved by using pre-ensiling treatment like addition of additives. However, major problem encountered in the use of these natural grasses is that, most of the valuable grass species have disappeared under uncontrolled grazing and have been replaced by low producing, less palatable grasses, weeds and bushes. To overcome this problem, grasses are grown in the home gardens around the smallholder homestead (Lyimo, 2010; Mtengeti *et al*., 2003). Elephant (*Pennisetum purpureum*), guatemala **(***Tripsacum laxum***)** and rhodes (*Chloris gayana*) grasses are high yielding grass species that have been grown by smallholder dairy farmers in Tanzania. These grass species can be used for silage.

Elephant grass also known as Napier grass is a perennial tropical grass native to the African grasslands. It originated from sub-Saharan tropical Africa (Clayton *et al*., 2013). It was named after colonel Napier of Bulawayo in Zimbabwe who early in the last century insists on Rhodesia's (now Zimbabwe), Department of Agriculture to explore the possibility of using elephant grass for commercial livestock production (Boonman, 1993). Napier grass has been promoted in Uganda for soil conservation and for mulching coffee. According to Acland (1971) it turned out that very few smallholders mulched their coffee and found it more profitable to sell Napier grass to coffee estates or feed the grass to their livestock. The grass was then promoted as a livestock feed. It has been introduced as forage into most tropical and subtropical regions worldwide. It was introduced into the USA in 1913, in the 1950's into Central and South America and the West Indies and in the 1960s into Australia. It is commonly naturalized and sometimes becomes invasive (CABI, 2014). According to Farrell *et al*. (2002) elephant grass is the most important fodder crop for the dairy farmers in East Africa. It is a valuable forage and very popular throughout the tropics (FAO, 2015).

Elephant grass is a robust, rhizomatous, tufted perennial grass. It has a vigourous root system, developing from the nodes of its creeping stolons. It is often regarded as a weed in crops, along roadsides, waterways, wetlands, floodplain, swamps, forest edges, disturbed areas and wastelands (CABI, 2014). It can withstand drought conditions and is a pioneer species in arid lands such as the Galapagos Islands (CABI, 2014). Napier can be propagated through seeds; however, as seed production is inconsistent, collection is difficult (Farrell *et al*., 2002). Altenatively, it can be planted through stem cuttings. It does better on rich, deep soils, such as friable loams but can grow on poorly drained clays, with a fairly heavy texture, or excessively drained sandy soils with pH ranging from 4.5 to 8.2 (FAO, 2015). The spacing is 0.5 m x 0.5 m in areas with over 1400 mm of rainfall. In areas with 900-1400 mm rainfall the spacing is 1 by 0.5 m (Ouda, 2001).

Phosphorus is required at the time of planting (20 kg/ha/year) to enable Napier grass to develop a strong root system later it requires nitrogen (75 kg/ha/year) for photosynthesis. Application of nitrogen, phosphorus and farmyard manure increase elephant grass DM production. According to Ouda (2001) at planting farmyard manure should be applied at a rate of 10 tons/ha (1 ha = 10 000 m^2 and 1ton =1000 kg). According to Moran (2005) at sowing, a rate of 500 kg/ha of NPK (nitrogen, phosphorus, potassium) fertiliser should be incorporated, with an annual maintenance dressing of 300 kg/ha of NPK fertilizer. After each harvest, 100 kg/ha of urea should be applied to the forage production area.

To obtain optimal quality and quantity, the first harvest of Napier grass should be when it attains a height of 1-1.5 m which is usually 3-4 month after planting. Thereafter, in the wet season the grass should be re-harvested at intervals of 6-8 weeks when it attains the same height. According to Ouda (2001) a stubble height of 5-10 cm from the ground level at each harvest should be maintained to avoid weakening of root system which leads to low production in subsequent harvests. According to Moran (2005) elephant grass should be harvested down to 20 cm, when it reaches about 1.5 m in height. This species has high biomass production, at 40 tons/ha/year (Strezov *et al*., 2008) and can be harvested 4-6 times per year (Farrell *et al*., 2002). It requires low water and nutrient inputs (Strezov *et al*., 2008) compared to rhodes and guatemala grasses. It has low water and nutrient requirements (Strezov *et al*., 2008). It has low DM, WSC and CP (Andrade and Melotti, 2004; Mtengeti *et al*., 2006; Zanine *et al*., 2006 and Lyimo, 2010). The composition of the herbage makes it difficult to produce high quality silage without the use of additives.

Guatemala grass is a robust, strongly rhizomatous, tufted and leafy perennial grass that can form large bunches. It originated from Mexico and South America and has been introduced for fodder in Sri Lanka and some other tropical countries, including Fiji. The stems can be up to 3.5-4.5 m high and up 1-5 cm in diameter (Heuzé *et al.*, 2013). They develop at a very late stage and guatemala grass remains leafy during a long time. The roots are shallow and the plant does not grow well during a long dry season. As the grass matures, the roots become stronger and store nutrients that will be necessary for re-growth after cuttings (Heuzé *et al*., 2013). The leaves are tall (0.4-1.2 m long x 9 cm broad), glabrous or sparsely hairy (Quattrocchi, 2006; Clayton *et al*., 2006; Cook *et al*., 2005). Flowers are mostly sterile and guatemala grass is usually propagated by sprigs or suckers at the beginning of the rainy season (Heuzé *et al*., 2013). It does better under good soil moisture but can withstand short droughts while it does not bear water logging nor flooding (FAO, 2012; Cook *et al*., 2005). Heavy fertiliser applications needed for optimum growth as herbage removal quickly extracts soil nutrients. According to Risopoulos (1966) *Tripsacum laxum* removes 400 kg nitrogen, 80 kg phosphorus, 50 kg potassium, 50 kg calcium and 50 kg magnesium annually per hectare of soil and so must be adequately fertilized. Any deficiency can severely lower the production of pastures and cropland.

The first cut can be done 4-6 months after planting (Cook *et al.*, 2005). Guatemala grass has high persistence than elephant grass but with low average DM yield about 18-22 t/ha/year and nutritive value (Cook *et al.*, 2005). In the eastern highlands of Africa, yields ranging from 9 to 50 tDM were recorded (Nivyobizi *et al.*, 2010; Mtengeti *et al.*, 2001). It can also be stored as silage for dry season supply.

Smallholder dairy producers of the highland areas of East Africa (Kenya and Tanzania) have been encouraged since the 1970s to grow guatemala grass as a high-yielding fodder. However, such initiatives have been met with mixed reception. In Kenya, when compared to other forage species evaluated for herbage dry matter yields and farmer acceptance, guatemala grass was ranked lowest mainly because of foliar diseases and poor regeneration ability after defoliation (Muyekho *et al.*, 2003). It is sometimes recommended to let guatemala grass establish and harvest it at least one year after planting. This management will make guatemala grass more perennial and results in healthier re-growth (Vargas-Rodriguez, 2009).

When guatemala grass is intended for silage, it is recommended that the re-growth (after first cut for direct feeding) reaches 0.8-1 m high and still in the vegetative state (about 8 week-old). Ensiling guatemala grass results in 12% DM loss during the process (FAO, 2012). Guatemala grass has relatively high moisture content (69%) and a relatively low content of water soluble carbohydrates (3 to 9% DM) which can result as in most tropical grasses in ineffective pH reduction during ensiling and a low storage stability. It is thus recommended to wilt the guatemala grass before ensiling in order to increase dry matter (%) and the content of water soluble carbohydrates and to reduce nutrient losses through effluent production (Nussio, 2005).

Rhodes grass is a perennial tropical grass. It is native to Africa but it can be found throughout the tropical and subtropical world as a naturalized species. It is a short rotational grass pasture species drought resistant and highly productive species. It is a leafy grass, 1-2 m in height. It is drought resistant due to its deep roots. Few grasses have roots going down to 1 m. Rhodes grass can withstand long dry period, over 6 months (FAO, 2014; Cook *et al.*, 2005). The culms are tufted or creeping, erect or decumbent, sometimes rooting from the nodes. Rhodes grass can survive in areas where annual rain fall range is between 310 and 4030 mm and where temperature extremes are 5 and 50^0C (Cook *et al.*, 2005). Seasonal water logging over 30 cm kills the plant (FAO, 2014). Rhodes grass has short season of nutritive peak in many cultivars and requires high fertility to persist (Strezov *et al.*, 2008). It does better on fertile, well structured soils and it prefers soil pH between 5.5 and 7.5. Establishment on acidic soil is difficult. It is full sunlight species which does not grow well under shade (Ecocrop, 2014; FAO, 2014; Cook *et al.*, 2005).

Rhodes grass spreads naturally by seed and runners. Planting rates are 1-2 kg/acre dry land and 3-5 kg/acre in irrigated situations. Rhodes grass responds well to nitrogen application if soil phosphorus is adequate, with yield and palatability improved. For good productivity nitrogen fertilizers were applied at the rates of 40 kg /acre (Kitalyi *et al.*, 2005). Stands develop quickly and can be grazed 4-6 months after planting, although highest production is reached in the second year. Rhodes grass can be propagated vegetatively or from seed. A more rapid cover can generally be obtained by planting from seed. The highest recorded yield is about 30-40 tDM/ha while the average yield is in the 10-16 tDM/ha ranges (Ecocrop, 2014). Rhodes grass can form pure stand or is sown with other grasses or legumes. Prostrate cultivars are suitable to grazing and erect cultivars are adapted to hay (FAO, 2014; Quattrocchi, 2006; Cook *et al*., 2005).

1.3 Materials and Methods

1.3.1 Study area

This study was conducted between November 2012 and April 2016 at Magadu dairy farm in Department of Animal, Aquaculture and Range Sciences, College of Agriculture, Sokoine University of Agriculture (SUA), in Morogoro Urban District (Figure 4). Morogoro Urban District is in the eastern part of Tanzania, 196 km west of Dar es Salaam, the country's largest city and commercial centre and 260 km east of Dodoma. The study site was located at the altitude of 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates). It is characterized by ambient temperature between 20-27 ^{o}C in the coolest months of April to August and 30 - 35 ^{o}C during the hottest month of October to January with relative humidity ranging from 64 to 85%. The annual rainfall ranges from 600-1000 mm of rains per annum, falling in two seasons - the long rains (March to June) and the short rains (September to November). Magadu farm was specifically selected because of its accessibily and its use for training University students and Smallholder dairy farmers in the Easten zone of Tanzania.

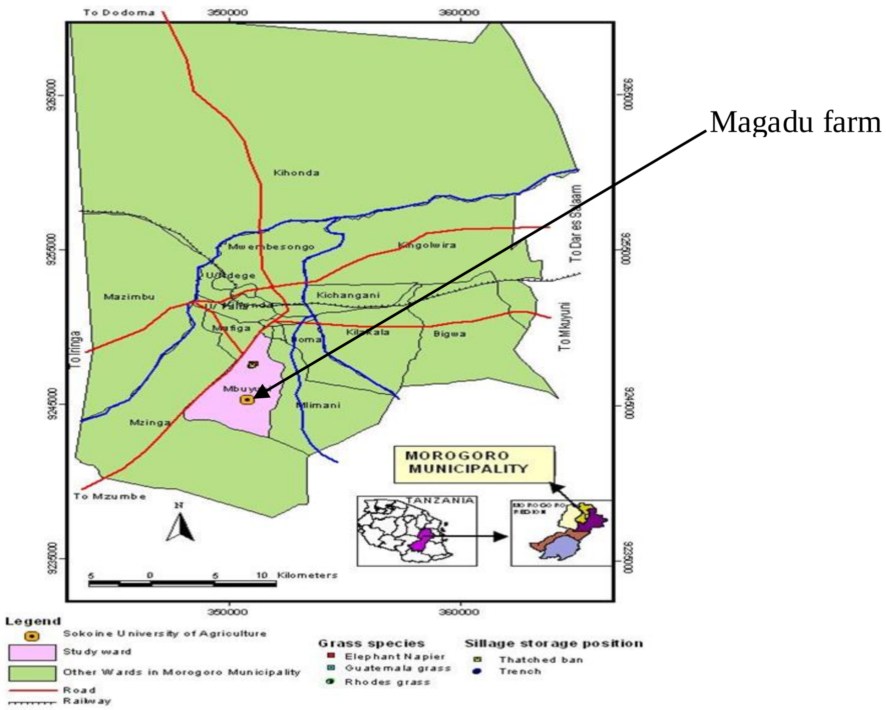

Figure 4: Morogoro Urban District's Map

1.3.2 Selection of forage Species

The grass species used in this study were elephant grass (*Pennisetum purpureum*), guatemala grass (*Tripsacum laxum*) and rhodes grass (Chloris *gayana*). These grasses were selected because they are abundant along the valleys and home fodder gardens in the wet season (Mtengeti and Urio, 2006; Lyimo, 2010) and they have high biomass production.

1.3.3 Plot management of fodder grasses used in this study

All grass species selected were well established in pasture plots. Each pasture plot for the grass specie covered an area of about 400 m^2. Elephant grass is best adapted for planting in deep, well drained fertile soils in high rainfall areas. It was grown from cuttings 1 to 2 cm in diameter with 4 nodes cut from the middle of 12 month old stem a spacing of 1 by 0.5 m. Guatemala grasses was planted from splits/suckers at spacing of 0.5 by 1 m.

Rhodes grasses was planted at a seeding rate of 5 kg/ha. The forages were plantedat the onset of rain so as to get optimum establishment. At sowing, 20 kg of NPK (nitrogen, phosphorus, potassium) fertilizer was applied in each grass plot with an annual maintenance dressing rate of 2 kg NPK plot of each grass. Urea was top dressed at rate of 4 kg per plot after every harvest. The grasses were weeded by hand weeding frequently till full establishment. Elephant grass was harvested after 120 d, guatemala 63 d and Rhodes 56 d so as to obtain optimal quality and quantity. A stubble height of 5–20 cm was maintained from the ground level at each harvest to avoid soil contamination of grasses and weakening of the root system.

1.3.4 Sampling of fresh and ensiled forages for laboratory analysis

Grass species used in these experiments were elephant, guatemala and rhodes grasses. Experiment 1 was carried out before experiment 2 and 3 to point out the optimal ensiled amount of grasses in plastic bag silos so as to be used in other subsequent experiments. Then, experiment 4 and 5 were conducted before experiment 6 to show clearly the precision chopping length to be used in experiment 6.

Fresh forages

Before cutting the plants for ensiling purpose, tufts were clipped at a height of 10 cm above the ground. The material from these tufts was pooled, weighed (> 500 g each) and a sample was oven dried at 100 °C for 24 h to determine the initial DM concentration of the herbage. This was essential to be able to estimate the amount of sugar that had to be added to each treatment during ensiling. After chopping, 500 g of fresh forage was dried at 55°C for 48 h in duplicate for each treatment and then the dried material was ground to pass a 1 mm screen and stored in dark vacuum plastic bags at room temperature (20±2°C) for chemical analysis and *in vitro* incubation.

Ensiled forages

The silages were evaluated after 60 d ofensiling. Before evaluation, the plastic bag silos were opened and spoiled silage was separated from well preserved silage and kept for DM loss calculation. Then a 500 g fresh sample from each bag was transferred into vacuum plastic bags and frozen at - 10°C for subsequent analysis. A 30 g sample of fresh silage was mixed with 270 ml distilled water (1:9 ratios) and blended using a kitchen blender for 50 to 60 seconds at high speed. The extract was then filtered through four layers of cheese cloth and the pH was determined using a pH meter (model 219-MK 2; Pye Unicam). Some of the extract was stored at -20°C until analyzed for acetic acid, lactic acid, butyric acid and NH_3-N. The frozen silage samples were oven-dried at 55°C for 48 h and ground through a 1 mm sieve for determination of chemical composition.

1.4 Main findings from this study

The overall objective of this thesis was to evaluate the effects of various techniques on silage quality of elephant, guatemala and rhodes grasses in smallholder dairy farms in Tanzania. The main findings from this study are organized from six papers i.e. effect of fodder grass species, wilting and ensiled amount in shopping plastic bagsonsilage quality (paper 1), effect of grass specie and maize bran/molasses additive levels on silage quality (paper 2 and 3). The fourth and fifth experiments (papers 4 and 5) aimed at investigation of effect of wilting, chopping length and maize bran/molasses additives levels on grass silage quality. The sixth experiment (paper 6) determined the effect of grass specie, ensiled amount in shopping plastic bags and storage positions on silage quality. The main findings of the study may therefore be summarized as follows:-

(i) Elephant grass silage had higher sensoric scores, CP, ash, lactic and acetic acids, stability but lower DM, pH, NH_3N and butyric acid than guatemala and rhodes grasses silage

(ii) Wilted grass showed higher sensoric scores, DM, CP, ash, WSC, pH, LA, AA, bulk density and stability but lower IVDMD, NDF, NH_3N, BA and DM loss than unwilted fodder grass.

(iii) There was no difference between the two ensiled amounts (5 and 10 kg) in terms of silage quality but the two amounts showed higher sensoric scores, DM, CP, WSC, ash, IVDMD, LA, AA and stability but lower NDF, pH, NH_3N and BA than 12 kg ensiled amounts.

(iv) Grass silages treated with 5% molasses had higher sensoric scores, DM, CP, WSC, ash, IVDMD, LA, AA and stability but lower NDF, pH, NH_3N and BA than silages treated with molasses at 0% and 3% levels.

(v) Grass silages treated with maize bran at $\geq$10% level had higher sensoric scores, CP, WSC, IVDMD, LA, AA and stability but lower NDF, pH, NH_3N and BA than the other lower levels (0 and 5%).

(vi) Grass silages produced from 2 cm chopping showed higher sensoric scores, DM, CP, WSC, IVDMD, LA, AA and stability but lower NDF, pH, NH_3N and BA than those from 4 cm chopping.

(vii) There were no differences between silages stored in thatched barn and trench in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, LA, AA, BA and stability.

(viii) Combination of elephant grass, chopped at 2 cm ensiled with 10% maize bran or 5% molasses and stored in either thatched barn or in trench produced highest CP, WSC but lower pH and NH_3N than other interactions.

1.5 Conclusions and Recommendations

It was therefore concluded that, wilted elephant grass and chopped into 2 cm, treated with 10% maize bran or 5% at molasses ensiled at either 5 kg or 10 kg shopping plastic and stored in either thatched barn or trench was the most optimal combination of technologies to achieve high quality silage under smallholder farmers. Based on the findings obtained from this study, it is recommended that:-

(i) Wilted elephant grass, chopped at 2 cm, treated with maize bran at 10% level or with molasses at 5% level, ensiled in either 5 or 10 kg shopping plastic bag, stored in either thatched barn or in trench is the appropriate technology recommended under smallholder dairy farmers to achieve high quality grass silage production.

(ii) Further research on the use of the technologies under this study for grass silage production from other locally available grasses, such as *Panicum maximum* and *Pennisetum polystachion* for smallholder dairy farmers is highly recommended.

(iii) Sustainable solution to forage shortage is possible when technical efforts are invested to improve production and utilization of forages. Participatory effort and approaches in collaboration with government, researchers, farmers and livestock stakeholders is really required.

(iv) Government, Researchers and Livestock Development Agencies are advised to incorporate silage as one of prior criteria in solving the problem of livestock feed deficit during dry season in the country.

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CHAPTER TWO

2.1 PAPER I

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Effect of fodder grass species, wilting and ensiled amount in shopping plastic bags on silage quality

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Abstract

Lack of know how on which fodder grass specie to ensile, handling and processing before ensiling and amount to ensile in plastic bag silos have reduced the adoption of grass silage making technologies among the smallholder farmers. An experiment was therefore conducted to assess effects of fodder grass specie, wilting and amount ensiled in plastic bag silos on silage quality. Elephant ***(Pennisetum purpureum)*** and guatemala grasses ***(Tripsacum laxum)*** were established and harvested when they were 1.5 and 1m tall respectively. One portion of grass was wilted for 24 hours and the other portion was un-wilted before ensiling. Each portion was chopped into 4cm particle length before ensiling. The chopped materials were ensiled either in portions of 5 or 10 kg in plastic bag silos. Treatments were assigned to a completely randomized design in factorial arrangement (2 x 2 x 2) as two grasses (elephant and guatemala grasses), two pre-ensiling treatments (un-wilted and wilted) and two ensiled amounts (5 and10 kgs) with two replications. The silage was opened and sampled after 60 days, analyzed for dry matter (DM) losses, chemical composition, fermentation and sensoric qualities and **in vitro** DM digestibility.

Elephant grass silage had higher sensoric scores, crude protein (CP), ash, lactic acid, acetic acid and bulk density but lower DM, water soluble carbohydrate (WSC), IVDMD, pH, NH_3N and DM loss than guatemala grass silage. The guatemala silage was more digestible than elephant grass silage. Wilted fodder grass showed higher sensoric scores, DM, CP, ash, WSC, pH, lactic acid, acetic acid and bulk density but lower NDF, NH_3N, butyric acid and DM loss than un-wilted fodder grass. Un-wilted guatemala grass silage had higher DM than wilted elephant grass silage. The 5kg silage in plastic bag silo showed higher bulk density than 10kg silage in plastic bag silo. There was no difference between the two ensiled amounts (5kg and 10kg) in terms of appearance, smell and texture scores, DM, CP and WSC, ash, NDF, IVDMD, pH, NH_3N, lactic acid, acetic acid, butyric acid and DM losses. It was therefore concluded that, either 5 or 10 kg of wilted elephant grass ensiled in shopping plastic bag silo was the most optimal combination technology to achieve high silage quality under smallholder farmer conditions.

Key words: **ensiled amount, grass specie, silage quality, smallholder dairy farmers, wilted and un-wilted grasses**

Introduction

Smallholder dairy farming in Tanzania has been recognized as an important means of attaining human food security, household income and as a source of employment (Lwelamira et al 2010, Swai et al 2005). The productivity of dairy cattle under smallholder farmers has however, been low, producing up to from 6 – 10 liters of milk in the rain season and 3 – 5 liters in the dry season due to unavailability of adequate quality feeds throughout the year (Kavana and Msangi 2005; Hall et al 2007; Njarui et al 2009). In order to stabilize dairy animal productivity throughout the year, there is a need therefore, to look for technologies which could maintain the continuity of quantity and quality of feed supply. Forage conservation in form of silage is one of the promising options reported to increase feed availability particularly in the dry season (Lyimo 2010). The adoption of silage making among the smallholders dairy farmers has however been minimal (’t Mannetje 2000) because of lack of appropriate knowledge and skills on how to handle and process the ensiling materials and an appropriate amount to ensiling in shopping plastic bag silos. In Tanzania, the most predominant fodder grass species found in smallholder dairy farms are elephant (Farrell et al 2002) and guatemala grasses and can be used to produce high quality silage. In order to improve their preservation and feeding value silage conservation technologies such as wilting could have been applied. According to Nussion (2005) wilting the forage before ensiling is recommended as a means of increasing dry matter content, WSC and reducing losses from effluent and undesired fermentation. Simple small shopping plastic bags have been noted that they are appropriate to ensile instantaneous fodder grasses found around the smallholder dairy farmers homestead (Mtengeti and Urio 2006). The advantage of shopping plastic bags silos in terms of reducing the ensiling costs has rendered them rather adaptive to low household labour as it has been reported in Benin, Zimbabwe, Kenya and Tanzania (Ashbell et al 2001; Delacollette et al 2005; Pariyar 2005). Despite the benefits obtained from these available grasses, wilting and shopping plastic bags, animal feed shortage during the dry season is still constrainting the smallholder dairy farming. There is however, limited information on silage conservation technologies such as, appropriate grass specie, wilting method and ensiled amount of grasses using plastic bags for high silage quality. This study was therefore conducted so as to evaluate the effect of grass specie, wilting and ensiled amount in shopping plastic bags on silage quality characteristics.

Materials and methods

Study area

This study was conducted at Magadu dairy farm in Department of Animal, Aquaculture and Range Sciences, College of Agriculture, Sokoine University of Agriculture (SUA). The study site was located at about 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates. It is characterized by ambient temperature between 20-27 ^{o}C in the coolest months of April to August and 30 - 35 ^{o}C during the hottest month of October to January. The annual rainfall ranges from 600-1000mm.

Experimental design and treatments

The study adopted a completely randomized design with a 2x2x2 factorial arrangement for two grass species (elephant and guatemala grasses), two pre-ensiling treatment (un-wilted vs. wilted grass species) and two ensiled amounts (5 and10kgs) of chopped fodder grass in plastic bag silos. The experiment had 8 treatments combinations designated as 5kgs of un-wilted elephant grass; 5kgs of wilted elephant grass; 10kgs of un-wilted elephant grass; 10 kgs of wilted elephant grass; 5kgs of un-wilted guatemala grass; 5kgs of wilted guatemala grass; 10kgs of un-wilted guatemala grass and 10kgs of wilted guatemala grass. Each treatment had two replications.

Source, harvesting and preparation of ensiling fodder grasses

The fodder grasses, elephant grass and guatemala grass were established in 400 m^2 each and were ready to harvest when they were 1.5m and 1 m tall respectively. The grasses were harvested using the machete and thereafter each divided into two portions. The first portion was chopped into 4 cm length particles and ensiled in the same day while the second portion was wilted for 24 hours before ensiling. Two amounts of the chopped fodder grass whether wilted or un-wilted was ensiled in shopping plastic bag silos. These amounts were 5 and 10 kgs of ensiling material.

Ensiling procedure

The ensiling was done by filling the chopped grass materials in the ensiling plastic bag silo with 30 nm thickness. Air was removed and the neck of the bag was twisted, turned over and tied with a rubber band. Thereafter, the ensiling plastic bag was labeled for treatment identity**.** Each bag was then inserted into a second empty shopping plastic bag which was also tied, labeled and put in a hessian bag to protect it from rupturing. Hessian bags were then stored in thatched barn. Thatched barn is cheaper and affordable when compared with earth-pit (Lyimo 2010). In the thatched barn, the hessian bags were carefully stacked on a wooden rack to allow ventilation and lower the temperature. Chicken wire mesh surrounded the wooden rack protecting the bags against rats, mice and birds, especially the crow who would view the bags as bin bags full of kitchen waste to consume.

Data collection procedures

After 60 days of fermentation, the plastic bag silos were opened and spoiled silage was separated from well preserved silage and kept for DM loss calculation. Samples (weighing 500 g) from each bag were collected placed in polythene bags and immediately placed in a cool ice box and taken to the analytical laboratory. The sample was sub-divided into two samples. One sample was used for organoleptic test and pH determination. The other sub-samples were put in plastic bags and stored in a deep freezer at -10 °C until when they were used for chemical composition analysis and determination of *in vitro*dry matter digestibility.

The DM of the fresh ensiling material and silages were determined by drying in an oven at 65°C for 48 h (AOAC 1984). The silages were freeze-dried in a Lyphilizer maintained at -40 °C for 24 hrs according to Snowman (1988) so as to get a dry sample for ash, crude protein (CP), neutral detergent fiber (NDF), water soluble carbohydrates (WSC) analysis and *in vitro* dry matter digestibility (IVDMD) determination. Ammonia-nitrogen (NH_3N) was analyzed from fresh silage samples. The ash, CP and NH_3N were analyzed according to AOAC (2005) procedures while WSC was analyzed according to Thomas (1977). The NDF was analyzed according to Van Soest et al (1991). A pH meter (model

219-MK 2; Pye Unicam) was used to measure the pH of the fresh silages samples. Samples of 40g from each silo were soaked in 200 ml of cool distilled water for 12 hours then filtered and the supernatant used for the determination of the pH. The *invitro* dry matter (IVDMD) of the silages were determined according to the two stage technique developed by Tilley and Terry (1963) and modified by Salabi et al (2010)**.** The silages were analyzed for volatile fatty acid according to Shirlaw‘s (1967) procedure. Gas Chromatograph analyses were performed on a wide bore fused silica Cp-sil 19CB column, gas chromatograph equipped with a flame ionization detector (FID) $512x10^{-12}$ Afs. The technique used was gas chromatograph capillary column (10 m, 0.53 mm fused silica WCOT Cp-Sil 19CB (2.0 µm Cat.no.7647). The injector and detector temperatures were 275°C and 300°C respectively. The carrier gas was H_2 40kPa (0.4bar) 170 cm/s. The analyses were performed using a temperature programme: a linear gradient from 80°C to 280°C at 25°C min^{-1}. In each case a 0.1µL of sample was injected (a flow splitting 1:10).

Organoleptic test

The organoleptic test was carried out at the Department of Animal Sciences laboratory of SUA by thirty assessors of Animal Science Undergraduate and Postgraduate Students. Each assessor assessed the silage from each treatment and scored its physical characteristics in terms of appearance, texture and smell (Lyimo 2010). Appearance score No. 1 (poor) indicated spoiled silage which was dark brown in color with mould growth, score No. 2 (moderate) greenish in colour with some mould growth, score No. 3 (good) yellowish green to brown colour and score No.4 (very good) indicated well pickled yellowish green to light brown colour silage. Smell score No. 1 (poor) indicated foul smell associated with putrefaction, score No. 2 (moderate) pungent smell of ammonia, score No. 3 (good) pleasant aroma and score No.4 (very good) pleasant estery aroma typically silage smell. Texture score, No. 1 (poor) slimy and watery, score No. 2 (moderate) less slimy and wet No. 3 (good) non-slippery and wet No. 4 (very good) non-slippery and slightly wet. The test was carried once after 60 days of fermentation, when ensiling bags (silos) were opened and spoiled silage separated from well preserved silage.

Bulk density

Silage samples were collected using plastic bag for the assessment of bulk density. Two samples were collected per silo and then taken to the analytical laboratory at SUA. The samples put in a measuring cylinder of known volume, recoded its volume and thereafter were dried at 105^0C for 48 hours in a forced-air oven. Bulk density was calculated as mass of dry silage per volume of field-moist silage i.e. weight of sample (kg) /volume of sample (m^3).

Dry matter loss

The amount of dry matter loss 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: - kg DM loss = kg DM of ensiled forage - kg DM of recovered silage where, kgDM of recovered silage = kg DM of good silage + kg DM of spoilage silage. DM loss was finally expressed as percentage of DM present in the original forage material.

Data analysis

Collected data were entered in coded excel sheets then transferred to SAS for General Linear Model procedure of Statistical Analysis System (SAS, 2008) for analysis of variance of means. Means of factors were then separated using Multiple Duncan Range test. The model used to study effects of fodder grass specie, wilting and ensiled amount in shopping plastic bags was: $Y_{ijkl} = \mu + Gi + W_j + A_k + (GW)_{ij} + (GA_{ik} + (WA)_{jk} + (GWA)ijk + E_{ijkl;}$ whereby Y_{ijkl} = observation taken on the l^{th} replicate sample taken from the k^{th} ensiled amount and j^{th} wilting method of the i^{th} grass species; μ= general mean common to all observation; Gi= effect of the $_i{}^{th}$ grass species;W_j= effect of the $_j{}^{th}$ wilting method;A_k = effect of the $_k{}^{th}$ ensiled amount; $(GW)_{ij}$, $(GA)_{ik}$, $(WA)_{jk}$ are two-factor interactions involving grass species, wilting method and ensiled amount as indicated by corresponding symbols; E $_{ijkl=}$ random effect peculiar to each observation.

Results and discussion

Elephant grass had relative higher CP and ash but lower DM, IVDMD and WSC than guatemala grass (Table 1).

Table 1: Chemical composition and digestibility of the fodder grasses material at the time of ensiling

Parameter (%)	Elephant grass	Guatemala grass
DM	19.9	29.3
CP	10.1	8.5
WSC	3.2	3.4
Ash	13.5	9.5
NDF	73.9	73.2
IVDMD	59.3	66.3

DM –Dry matter, CP-Crude protein, WSC-Water soluble carbohydrates, NDF-Neutral detergent fibre, IVDMD-in vitro dry matter digestibility

Effect of fodder grass specie, wilting and amount ensiled on silage organoleptic tests

Elephant grass silages had higher appearance, smell and texture scores than guatemala grass silages (Table 2). These differences might have been caused by improved fermentation condition in elephant grass silages which gave microbes' conducive environment during fermentative process than in guatemala grass silage. This is in agreement with Lyimo (2010) who found good physical scoring after having well preserved elephant grass. Loures et al (2003) reported that, the final quality of silage is directly related to the original ensiling material.

Wilted grass silage had higher appearance, smell and texture scores than un-wilted grass silage. This might have been due to reduced moisture and increased concentration of WSC for the fermenting microbes that lead to good fermentation process. The results are in agreement with Wright et al (2000) who observed moisture reduction in wilted silages, and claimed that wilting may solve the problem of many negative effects of high moisture in silage making. There was no difference between the two ensiled amounts (5 and 10kg) on appearance, smell and texture scores. This implies that either of the two ensiled amount can be used in silage making. However, for a smallholder farmer with only one cow, a 5kg could be appropriate since the animal may require only 5kg of silage per day since it should be combined with other feeds such as hay and concentrates for a healthy rumen.

Table 2: Mean effect of specie, wilting and amount ensiled on organoleptic of fodder grass silage quality

Parameter	Factors		SEM	P-value
	Effect of specie			
	Elephant grass	**Guatemala grass**		
Appearance	2.58	2.25	0.0899	0.0127
Smell	2.45	2.15	0.0866	0.0167
Texture	2.45	2.10	0.0935	0.0100
	Effect of wilting			
	Un-wilted grass silage	**Wilted grass silage**		
Appearance	2.15	2.68	0.0899	0.0001
Smell	2.00	2.60	0.0866	0.0001
Texture	2.00	2.55	0.0935	0.0001
	Effect of amount ensiled			
	5 kgs	**10 kgs**		
Appearance	2.48	2.40	0.0888	0.329
Smell	2.33	2.28	0.0935	0.684
Texture	2.33	2.23	0.0983	0.452

Score 1 = Poor Score 2=Moderate Score 3= good, 4= very good, SEM- Standard error of means. Means within row are significantly different at $P < 0.05$.

Effect of species, wilting and amount ensiled on chemical composition of fodder grass silages

Elephant grass silage had higher CP and ash but lower DM, IVDMD and WSC than guatemala grass silage (Table 3). This is related to the original chemical compositionof individual grass specie before ensiling. The higher CP and ash in elephant grass implied that, elephant grass silage produced higher quality silage in terms of nutritive value than guatemala grass silage. The same trend of results for the two grasses was observed by Mtengeti et al (2006). There was no difference between guatemala and elephant grass silages in terms of NDF. The guatemala grass silage was more digestible than elephant grass silage. Higher digestibility in guatemala grass silage was probably due to provision of useful energy substrate for ruminal microbes and thus improves their effectiveness in digesting feed particles.

Wilted grass silage showed higher DM, CP, ash and WSC but lower NDF than un-wilted grass silage. This implies that wilting of grasses improved the quality of the silage. The results are in agreement with Mtengeti et al (2006) who found improvement after wilting fodder grasses. This was also in agreement with Nussio (2005) who reported wilting as a means of increasing silage DM, WSC and reducing undesired fermentation. According to Borreani et al (2009) wilting is applied to reduce the moisture of ensiling material so as to reduce effluent production that may impair fermentation. Reduced NDF due to increased acidity which stimulated further hydrolysis of linked sugar molecules in the cell wall causing further breakdown of hemicelluloses. The results also showed that un-wilted guatemala grass silage has higher DM than wilted elephant grass silage. This could be related to the original DM of individual grass specie before ensiling. Wilting for

24 hours increased slightly the DM of both grasses. The DM increase was lower in elephant grass than in guatemala grass. According to Henderson (1993) wilting period if is however, extended over several days, the WSC may be lost and protein may be reduced through deamination of amino acids that may lead to increase in the production of NH_3N during silage fermentation. Therefore, it is better to wilt grasses in optimal period of time in order to retain their nutrients during fermentation than to extend their wilting time and lose their fermentative quality.There was no difference between the two ensiled amounts (5 and 10kgs) in terms of, DM, CP, WSC, ash, NDF and IVDMD. This implies that either of the two ensiled amount can produce good quality silage and the amounts provided reasonable compaction to the ensiled grasses culminating to good fermentation condition. Good compaction favors anaerobic conditions, this not only reducing losses caused by deterioration but also reducing storage costs, increasing DM recovery and ***in vitro*** DM digestibility (Muck et al 2003).

Table 3: Mean effect of fodder grass species, wilting and amount ensiled on chemical composition of silages

Parameter (%)	**Factors**		**SEM**	**p-value**
	Effect of species			
	Elephant grass	**Guatemala grass**		
DM	17.4	27.05	0.0468	0.0001
CP	9.5	7.05	0.0390	0.0001
WSC	1.29	1.38	0.0058	0.0001
Ash	12.7	9.22	0.0654	0.0001
NDF	69.08	69.03	0.0559	0.5447
IVDMD	49.9	62.05	0.0771	0.0001
	Effect of wilting on elephant grass silage			
	Un-wilted grass silage	**Wilted grass silage**		
DM	16.90	18.00	0.0662	0.0001
CP	9.13	9.88	0.0559	0.0001
WSC	1.35	1.24	0.0082	0.0001
Ash	12.60	12.90	0.0925	0.0001
NDF	74.60	69.80	0.0791	0.0001
IVDMD	51.40	48.50	0.1090	0.0001
	Effect of wilting on guatemala grass silage			
	Un-wilted grass silage	**Wilted grass silage**		
DM	25.80	28.40	0.0662	0.0001
CP	6.78	7.33	0.0559	0.0001
WSC	1.03	1.74	0.0082	0.0001
Ash	9.13	9.32	0.0925	0.0001
NDF	74.50	73.10	0.0791	0.0001
IVDMD	63.70	60.40	0.1090	0.0001
	Effect of amount ensiled			
	5 kg	**10 kg**		
DM	22.20	22.30	0.0468	0.587
CP	8.26	8.28	0.0395	0.667
WSC	1.33	1.33	0.0358	0.120
Ash	11.03	10.90	0.0398	0.156
NDF	69.00	69.10	0.0559	0.242
IVDMD	56.10	55.90	0.8140	0.104

SEM- Standard error of means. Means within row are significantly different at $P < 0.05$.

Effect of species, wilting and ensiled amount in shopping plastic bag silos on fermentative quality of fodder grass silages

Elephant grass silage had lower pH and NH_3N but higher lactic acid and acetic acid than guatemala grass (Table 4). Low pH and NH_3N could be due to higher lactic acid in elephant grass silage. Bilal (2009) found highest lactic acid in silage with the lowest pH. The optimum pH for high quality silage is between 3.8 and 4.5 where the activity of proteolytic enzymes stops. There was no difference between the elephant and guatemala grass silages on butyric acid concentrations.

Wilted silage had higher pH, lactic and acetic acid but lower NH_3N and butyric acid than un-wilted grass silage. The higher proportion of lactic and acetic acids observed in silages made from wilted herbage indicates the dominance of lactic acid bacteria, especially homofermentative lactic acid bacteria, during ensiling. This was in agreement with Whiter and Kung (2001) and Rizk et al (2005) who observed wilting increased lactate to acetate ratio. The ratio of lactic acid to acetic acid is a good indicator of the efficiency of the silage fermentation. Ideally, the ratio of lactic acid to acetic acid should not be less than 3:1 and higher is better. Higher pH in wilted grasses could be attributed by high WSC concentration of the wilted herbage which increased the subsequent silage fermentation quality. These effects are explained by the lower water activity of the wilted herbage (Greenhill 1964) which would have created more inhibitory conditions for microbial fermentation (Woolford 1984). These finding concurs with McEniry et al (2008) and Keles et al (2009) who found higher pH in wilted grasses.

The lower NH_3N in wilted grasses indicated that, proteolysis has not taken place during fermentation. This might have been due to reduced moisture by wilting which provided good condition for fermentation. The low butyrate value showed relative difficulty in clostridial growth in the wilted fodder grass material. Meeske (2000) stated that clostridia are very sensitive to water availability and require wet conditions for active development. There was no difference between ensiled amounts in plastic bag silos with respect to pH, NH_3N, lactic acid, acetic acid and butyric acid. Thus, either of the two ensiled amount in shopping plastic bag silos can be used to produce high quality silage.

Table 4: Mean effect of fodder grass species, wilting and amount ensiled on fermentation of silages

Parameter			SEM	p-value
	Effect of specie			
	Elephant grass	**Guatemala grass**		
pH	4.31	4.36	0.0073	0.0013
NH_3N(% TN)	3.42	4.28	0.0078	0.0001
Lactic acid (%)	0.66	0.43	0.0074	0.0001
Acetic acid (%)	0.24	0.18	0.0064	0.0004
Butyric acid (%)	0.09	0.09	0.0388	0.327
	Effect of wilting			
	Un-wilted grass silage	**Wilted grass silage**		
pH	4.29	4.38	0.0073	0.0001
NH_3N(% TN)	4.075	3.62	0.0078	0.0001
Lactic acid (%)	0.52	0.57	0.0074	0.0036
Acetic acid (%)	0.194	0.233	0.0064	0.0134
Butyric acid (%)	0.103	0.0143	0.0389	0.0001
	Effect of amount ensiled			
	5kg	**10kg**		
pH	4.33	4.33	0.0073	0.184
NH_3N (% TN)	3.84	3.84	0.0078	0.448
Lactic acid (%)	0.55	0.55	0.0074	0.105
Acetic acid (%)	0.22	0.22	0.0064	0.112
Butyric acid (%)	0.03	0.05	0.0388	0.332

SEM- Standard error of means. Means within row are significantly different at $P < 0.05$.

Bulk density (kg DMm^{-3}) of fodder grass as affected by specie and ensiled amount in shopping plastic bags

It was observed that bulk density was higher in elephant grass than in guatemala grass and probably this was due to stem density of elephant grass which led to higher biomass than in guatemala grass (Table 5). Wilting produced higher biomass per unit volume than un-wilted grass because it concentrated the DM of the ensiling mass. The 5kg silage ensiled in plastic bag silos had higher biomass per unit volume than 10kg plastic bag silos. This could be due to higher compaction provided to 5kg silage ensiled in plastic bag silos than to 10kg silage.

Table 5: Mean effects of species, wilting and ensiled amount of silages on bulk density (kg DMm^{-3}) of fodder grass silages

Parameter	Factors		SEM	P - value
	Effect of specie			
	Elephant grass	**Guatemala grass**		
Wet silage	773	714	1.36	0.0001
DMsilage	170	155	0.69	0.0001
	Effect of wilting			
	Unwilted grass silage	**Wilted grass silage**		
Wet silage	724	763	1.36	0.0001
DMsilage	159	166	0.69	0.0001
	Effect of amount ensiled			
	5kg	**10kg**		
Wet silage	745	733	1.36	0.0001
DMsilage	164	151	0.69	0.0001

SEM- Standard error of means. Means within row are significantly different at P < 0.05.

Effect of specie, wilting and ensiled amount in shopping plastic bags on percentage Dry mater (DM) losses of fodder grass silage

The percentage DM loss was higher in guatemala grass silages than in elephant grass silages and was higher in un-wilted grass silage than in wilted grass silage (Table 6). The results are in agreement with the observations made by Mtengeti and Urio (2006) who noted that the DM loss was higher in un-wilted grass silage than in wilted grass silage. This could be attributed to less moisture in wilted grass which enhances available DM of grasses to be retained during fermentation. The DM losses did not differ between the ensiled amounts in shopping plastic bag silos. It implies that either of the two amounts ensiled in plastic bag can be used in grass silage making without DM losses.

Table 6: Mean effects of species, wilting and ensiled amount of silages on percentage dry matter losses

Parameter	Factors		SEM	p-value
	Effect of species			
	Elephant grass	**Guatemala grass**		
kgDM ensiled	30.00	30.00	0.000	-
kgDM of silage recovered	27.8	27.1	0.088	0.0005
% DM loss	7.22	9.58	0.307	0.0006
	Effect of wilting			
	Unwilted grass silage	**wilted grass silage**		
kgDM ensiled	30.00	30.00	0.000	-
kgDM of silage recovered	27.03	27.9	0.088	0.0001
% DM loss	9.92	6.89	0.307	0.0001
	Effect of amount ensiled			
	5kg	**10kg**		
kgDM ensiled	30.00	30.000	0.000	-
kgDM of silage recovered	27.5	27.4	0.088	0.426
% DM loss	8.22	8.59	0.307	0.411

SEM- Standard error of means. Means within row are significantly different at $P < 0.05$

Conclusions

- Elephant grass silage had higher sensoric scores, crude protein, ash, lactic acid, acetic acid and bulk density but lower DM, WSC, IVDMD, pH, NH_3N and DM loss than guatemala grass silage.

- The guatemala grass silage was more digestible than elephant grass silage.

- Wilted fodder grass showed higher sensoric scores, DM, CP, ash, WSC, pH, lactic acid, acetic acid and bulk density but lower NDF, NH_3N, butyric acid and DM loss than un-wilted fodder grass.

- Un-wilted guatemala grass silage has higher DM than wilted elephant grass silage.

- The 5kg silage in plastic bag silo showed higher bulk density than 10kg silage in plastic bag silo.

- There was no difference between the two ensiled amounts (5kg and 10kg) in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, lactic acid, acetic acid, butyric acid and DM losses.

- It was therefore concluded that, either 5 or 10 kg of wilted elephant grass ensiled in shopping plastic bag silo was the most optimal combination technology to achieve high silage quality under smallholder farmers.

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CHAPTER THREE

3.1 PAPER II

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Effect of grass species and different levels of maize bran on silage quality

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Abstract

The composition of tropical grasses as fodder for dairy cattle produces low quality silages without the use of additives. Maize bran additive has been used by smallholder dairy farmers to improve the quality of silages. However, the effect of different levels of maize bran on various grass silages quality is rarely documented. This study therefore was conducted to investigate the effect of grass species and different levels of maize bran on silage quality in smallholder dairy farms. Elephant *(Pennisetum purpureum),* guatemala ***(****Tripsacum laxum****)*** and rhodes grasses ***(****Chloris gayana****)*** were established and harvested when they were at the age of 120, 63 and 56 days respectively. Nutritive value declines quickly as plant matures thus were harvested at respective recommended stages of growth for each grass. The harvested grasses were chopped into 4cm and subdivided into four portions each of which was treated with a different level of maize bran (0, 5, 10, and 15%). The chopped materials were ensiled in portion of 5kg in plastic bag silo. Treatments were assigned to a completely randomized design in factorial arrangement (3 x 4) as three grasses (elephant, guatemala and rhodes grasses) and four maize bran additive levels (0, 5, 10 and 15%) with two replications. The silage was opened after 60 days, sampled and analyzed for chemical composition, fermentation, sensoric qualities and in vitro DM digestibility (IVDMD). Elephant grass produced higher quality silages than those produced by guatemala and rhodes grasses as indicated by higher sensoric qualities, crude protein (CP), lactic acid and stability but lower pH and NH_3N. Maize bran at 10% level produced higher quality and preserved better than maize bran at 0, 5 and 15% levels as indicated by higher sensoric scores, CP, WSC, lactic acid, acetic acid and stability but lower NDF, pH and NH_3N. The interaction between grass species and different maize bran levels showed that, elephant grass silage with maize bran at 10% level produced best silage as indicated by highest sensoric scores, CP, lactic acid and stability but lowest pH. Therefore, elephant grass mixed with maize bran at 10% level was the most optimal combination techniques to achieve high quality silage under smallholder farmers.

Key words: **Chloris gayana, Pennisetum purpureum, smallholder dairy farmers, Tripsacum laxum**

Introduction

In Tanzania, dairying is one of the fast growing enterprises in the livestock sector contributing 30% of the livestock Gross Domestic Product (URT 2012). Despite the high benefits obtained from dairying, the problem of feed shortage during dry season constraint the sector. To mitigate this, silage is one of the alternative feed from otherwise wasted surplus herbage from the rainy season (Lyimo 2010). However, making silage in small African farms is not easy, one of the problem of ensiling fodder grasses within smallholder’s fodder garden, is the available biomass at a particular time that may be enough to use trench or earth pit silos which may require at least half a tone of ensiling forage materials (Mtengeti et al 2013). In solving this problem plastic bags have been used elsewhere (Mtengeti and Urio 2006, Delacollette et al 2005 and Ashbell et al 2001). In Tanzania, the high-yielding fodder grass species that have been grown by smallholder dairy farmers are elephant, guatemala and rhodes grasses (Lyimo 2004, Mtengeti et al 2006). Ensiling those fodder grass could prolong their shelf life and increase their nutrient composition and digestibility. Ensiling is a preservation method for moist forage crops. However, the composition of the herbages makes them difficult to produce high quality silage without the use of additives. Additives applied to herbage during silage-making are used primarily to reduce conservation losses and therefore retain as much as feasible the nutritive values of the ensiled herbage. Thus, their mode of action can include limiting respiration or proteolysis by plant enzymes, manipulating fermentation, inhibiting the activity of aerobic micro-organisms such as yeast and mould, and reducing effluent output (Kung et al 2003). According to Kung et al (2003) various nutritive additives have been added to forage to maintain or improve the nutritive value of a crop as silage.

Use of appropriate additives can increase nutritional value and have positive effect on silage quality (Weinberg et al 2002). Several studies on grass silage reported to improved silage especially increase in WSC after mixing fodder grass with additives (Aminah et al 2000; Andrade and Melotti 2004; Iqbal et al 2005; Mtengeti et al 2006; Lyimo 2010 and Mtengeti et al 2013). Maize bran has been reported as silage additive, it is also used as absorbent water soluble carbohydrate and authors applied it at different levels (’t Mannetje 2000; Manyawu et al 2003; Mtengeti et al 2006; Lyimo 2010 and Mtengeti et al 2013). Maize bran is a product of milling of dried maize grain and is composed of the bran coating (with high fibre) and few maize germ and starch particles. It is a good source of energy in ruminant and non ruminant rations (Dotto et al 2004). It has 88%DM, 12% CP, 26 %NDF, 4.6% Ash, 11 %ME (Weisbjerg et al 2007); 89.5% DM, 10.7% CP, 75.7% CF, 6.18% Ash (Laswai et al 2002); has 11.8% CP, 79.5% CF, 25.9 % NDF, 6.5% Ash (Doto et al 2004). Silage production studies have verified its potential for promoting fermentation efficiency when mixed with grasses (Manyawu 2003; Lyimo 2010). In Tanzania maize bran is feed supplement materials that is locally available within most smallholder dairy farmers reach and could be used as low cost additive to improve the grass silage quality (Mtengeti et al 2013). According to Makkar and Ankers (2014) the efficient use of available feed resources is the key to efficient animal production and food security. However, the effect of maize bran on various grass silages quality and the optimal inclusive levels are rarely documented. Therefore, the study was conducted to investigate the effect of fodder grass species and different levels of maize bran on silage quality in smallholder dairy farms.

Materials and methods

Study area

This study was conducted at Magadu dairy farm in Department of Animal Science and Production (DASP) at Sokoine University of Agriculture (SUA). The study site was located at about 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates). It is characterized by ambient temperature between 20-27 ^{o}C in the coolest months of April to August and 30 - 35 ^{o}C during the hottest month of October to February. The annual rainfall ranges from 600-1000mm.

Experimental design and treatments

The study adopted a completely randomized design (CRD) with 12 treatment combinations of two factors (i.e. three grass species (Elephant grass, guatemala grass, rhodes grass) and four different levels of maize bran (0, 5, 10 &15%)) in two replications. The experiment had 12 treatments designated as elephant grass mixed with 0% maize bran, elephant grass mixed with 5% maize bran, elephant grass mixed with 10% maize bran, elephant grass mixed with 15% maize bran, guatemala grass mixed with 0% maize bran, guatemala grass mixed with 5% maize bran, guatemala grass mixed with 10% maize bran, guatemala grass mixed with 15% maize bran, rhodes grass mixed with 0% maize bran, rhodes grass mixed with 5% maize bran, rhodes grass mixed with 10% maize bran and rhodes grass mixed with 15% maize bran.

Source, harvesting and preparation of ensiled grasses

The ensiled grass species used in the study were elephant grass ***(****Pennisetum purpureum****)***, guatemala grass ***(****Trypsacum laxum****)*** and rhodes grass ***(****Chloris gayana****).*** All ensiled grass species were harvested from well established pasture plots. Each pasture plot for the grass specie covered an area of about 400m^{2}. The elephant grass was harvested at 1.5m of height (120 days after planting), guatemala grass was at 1.0 m of height (63 days) after planting whereas rhodes grass 0.5m of height (56 days) when it was at flowering stage of growth. Nutritive value declines quickly as plant matures thus were harvested at respective recommended stages of growth for each grass. The grasses were cut using the machete and thereafter each bundle of harvested grass specie was chopped by a machete into 4cm length. The harvested grass was chopped into 4cm and divided into two portions. One portion of the ensiling material was subdivided into four lots out of which each was treated with a different level of maize bran (0, 5, 10, and 15%) as additive (Table 1). The additives were mixed thoroughly with forage material and ensiled in small plastic bag silos of 5kg plastic bags.

Maize bran availability and affordability

In Tanzania, maize bran is cheap, affordable and locally available. For a smallholder farmer with only one cow, a 5kg of grass silage could be appropriate since the animal may require only 5kg of silage per day since it should be combined with other feeds such as hay and concentrates for a healthy rumen. The 5kg of elephant grass silage required 4.5kg of elephant grass mixed with 0.5kg of maize bran at 10% level with the price of 0.05 US$ /day or 125Tshs (Table 1). The price is affordable considering that, feed is the major cost item among variable costs and accounts for over 70% of the production costs

(Norris et al 2002). The productivity of dairy cattle under smallholder farmers has however, been low, producing up to from 6 – 10 liters of milk in the rain season and 3–5 liters in the dry season due to unavailability of adequate quality feeds throughout the year (Kavana and Msangi 2005; Hall et al 2007; Njarui et al 2009). This implies that, in average, the lowest income from milk production in dry season could be 3liters/day x 0.4US$/liter = 1.2US /day (1liter of milk = 0.4US$= 1000Tshs) and the highest income during rainy season could be 10liters/day x 0.4US$/liter = 4US$/day. Therefore, smallholder farmer with the income of 1.2US$ can afford to make silage using maize bran at 10% with the price of 0.05 US$ /day even during dry season.

Table 1: Amount of grasses ensiled with different levels of maize bran and their prices/day/cow

Grass species and amount ensiled (kg)	Levels of maize bran (%) and amount added (kg)				Levels of maize bran (%), and price (US$)			
	0%	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
EG = 5, 4.75, 4.5, 4.25	0	0.25	0.5	0.75	0	0.025	0.05	0.075
GG = 5, 4.75, 4.5, 4.25	0	0.25	0.5	0.75	0	0.025	0.05	0.075
RG = 5, 4.75, 4.5, 4.25	0	0.25	0.5	0.75	0	0.025	0.05	0.075

EG =elephant grass GG=guatemala grassRG –rhodes grass, price (1kg maize bran=250 Tsh=0.1dollar; 1dollar=2500Tshs year 2016)

Ensiling procedure and storage

The ensiling was done by filling the chopped grass materials in the ensiling plastic bag silo with 30 nm thickness. Air was removed and the neck of the bag was twisted, turned over and tied with a rubber band. Thereafter, the ensiling plastic bag was labeled for treatment identity. Each bag was then inserted into a second empty shopping plastic bag which was also tied and labeled and put in a hessian bag to protect it from rupturing. Hessian bags were then stored in thatched barn. Thatched barn is cheaper and can be affordable compared with earth-pit (Lyimo 2010). In the thatched barn, the hessian bags were carefully stacked on a wooden rack to allow ventilation and lower the temperature. Chicken wire mesh surrounded the wooden rack protecting the bags against rats, mice and birds, especially the crow who would view the bags as bin bags full of kitchen waste to consume.

Data collection procedures

After 60 days of fermentation, the plastic bag silos were opened and spoiled silage was separated from well preserved silage. Samples (weighing 500 g) from each bag were collected placed in polythene bags and immediately placed in a cool ice box and taken to the analytical laboratory. The sample was sub-divided into two samples. One sample was used for organoleptic test and pH determination. The other sub-samples were put in plastic bags and stored in a deep freezer at -10°C until when they were used for chemical composition analysis and determination of ***in-vitro*** dry matter digestibility (IVDMD).

The DM of the fresh ensiling material and silages were determined by drying in an oven at 65°C for 48 h (AOAC 1984). The silages were freeze-dried in a Lyphilizer maintained at -40 ºC for 24 hrs according to Snowman (1988) so as to get a dry sample for ash, crude protein (CP), neutral detergent fiber (NDF), water soluble carbohydrates (WSC) analysis and IVDMD determination. Ammonia-nitrogen (NH_3N) was analyzed from fresh silage samples. The ash, CP and NH_3N were analyzed according to AOAC (2005) procedures while WSC was analyzed according to Thomas (1977). The NDF was analyzed according to Van Soest et al (1991). A pH meter (model 219-MK 2; Pye Unicam) was used to measure the pH of the fresh silages samples. Samples of 40g from each silo were soaked in 200 ml of cool distilled water for 12 hours then filtered and the supernatant used for the determination of the pH. The IVDMD of the silages were determined according to the two stage technique developed by Tilley and Terry (1963) and modified by Salabi et al (2010). The silages were analyzed for volatile fatty acid according to Shirlaw's (1967) procedure. Gas Chromatograph analyses were performed on a wide bore fused silica Cp-sil 19CB column, gas chromatograph equipped with a flame ionization detector (FID) $512x10^{-12}$ Afs. The technique used was gas chromatograph capillary column (10 m, 0.53 mm fused silica WCOT Cp-Sil 19CB (2.0 μm Cat.no.7647). The injector and detector temperatures were 275°C and 300°C respectively. The carrier gas was H_2 40kPa (0.4bar) 170 cm/s. The analyses were performed using a temperature programme: a linear gradient from 80°C to 280°C at 25°C min^{-1}. In each case a 0.1μL of sample was injected (a flow splitting 1:10). Silage stability was determined by observing the change of pH of exposed silage after sixty days of fermentation. Each day the pH of each treatment was recorded for 7 days consecutively.

Organoleptic Test

The organoleptic test was carried out at the Department of Animal Sciences laboratory of SUA by thirty assessors of Animal Science Undergraduate and Postgraduate Students. Each assessor assessed the silage from each treatment and scored its physical/sensoric characteristics in terms of appearance, texture and smell (Lyimo 2010). Appearance score No.1 (poor) indicated spoiled silage which was dark brown in color with mould growth, score No. 2 (moderate) greenish in colour with some mould growth, score No. 3 (good) yellowish green to brown colour and score No.4 (very good) indicated well pickled yellowish green to light brown colour silage. Smell score No.1 (poor) indicated foul smell associated with putrefaction, score No. 2 (moderate) pungent smell of ammonia, score No. 3 (good) pleasant aroma and score No.4 (very good) pleasant estery aroma typically silage smell. Texture score, No.1 (poor) slimy and watery, score No.2 (moderate) less slimy and wet No.3 (good) non-slippery and wet No.4 (very good) non-slippery and slightly wet. The test was carried once after 60 days of fermentation, when ensiling bags (silos) were opened and spoiled silage separated from well preserved silage.

Data analysis

Collected data were entered in coded excel sheets then transferred to SAS for General Linear Model procedure of Statistical Analysis System (SAS, 2008) for analysis of variance of means. Means of factors were then separated using Multiple Duncan Range test. The model used to study effect of maize bran at different levels of elephant, guatemala and rhodes grasses was: The statistical model:- $Y_{ijkl} = \mu + Gi + L(A)_{jk} + (GA)_{ij} + E_{ijkl}$; whereby Y_{ijkl} = observation taken on the l^{th} replicate sample taken from the k^{th} level of the j^{th} additive applied on the i^{th} grass species; μ= general mean common to all observation; Gi= effect of the $_i{}^{th}$ grass species; A_j = effect of the j^{th} additive; $L(A)_{jk}$ =

effect of the k^{th} level of application of the j^{th} additive; $(GA)_{ij}$ = interaction between the i^{th} grass specie and j^{th} additive; $L(A)_{jk}$ and $(GA)_{ij}$ are two-factor interactions involving grass species and additive level as indicated by corresponding symbols; $E_{ijkl=}$ random effect peculiar to each observation.

Results and discussion

Chemical composition and digestibility of fodder grasses at the time of ensiling

The results revealed that, elephant grass had higher CP and ash but lower DM and digestibility than guatemala and rhodes grasses (Table 2). Maize bran had relative higher DM and CP than grasses.

Table 2: Mean chemical composition and digestibility of the grasses and maize bran at the time of ensiling

Parameter (%)	Elephant grass	Guatemala grass	Rhodes grass	Maize bran
DM	19.9	29.3	21.8	90.04
CP	10.1	8.45	7.8	11.9
WSC	3.19	3.40	3.01	4.51
Ash	13.5	9.5	9.2	6.2
NDF	73.9	73.2	66.4	42.8
IVDMD	59.3	66.3	58.1	64

DM–Dry matter, CP-Crude protein, WSC-Water soluble carbohydrates, NDF-Neutral detergent fibre, IVDMD-in-vitro dry matter digestibility

Effect of grass specie and different levels of maize bran on organoleptic of silage quality

Elephant grass silageproduced silage with higher sensoric scores than guatemala and rhodes grasses (Table 3). Higher scores possibly were due to improved fermentation condition in elephant grass silages which leads to efficient fermentation than in the other two grass silages. This was in consistence with Mtengeti et al (2013) who observed good physical scoring of elephant grass silage.

Maize bran at 10% level had higher sensoric scores than the other treatments probably due to optimal substrate provided to fermenting microbes' leads to efficient fermentation condition resulted to good color. Similar result has also been reported by Lyimo (2010) who observed improvement after adding 10% maize bran to fodder grass silages and claimed that, maize bran is used as absorbent WSC as it has ability to absorb moisture which could adversely affect the fermentation process.

Table 3: Mean effect of grass specie and different levels of maize bran on organoleptic of silage quality

Parameter (%)	Factors				SEM	p-value
	Effect of grass specie					
	Elephant grass silage	**Guatemala grass silage**	**Rhodes grass silage**			
Appearance	3.25[a]	2.63[b]	1.70[c]		0.195	0.0001
Smell	3.13[a]	2.75[a]	1.79[b]		0.167	0.0001
Texture	3.25[a]	2.63[a]	1.79[b]		0.243	0.0001
	Effect of different levels of MB					
	MB0%	**MB5%**	**MB10%**	**MB15%**		
Appearance	1.83 [c]	2.33[cb]	3.28[a]	2.67[ba]	0.226	0.0001
Smell	1.67[c]	2.33[b]	3.39[a]	2.83[a]	0.193	0.0001
Texture	1.50 [b]	2.50[a]	3.39[a]	2.83[a]	0.281	0.0001

MB - Maize bran, Score 1 = Poor Score 2=Moderate Score 3= good, 4= very good, SEM- Standard error of means. Means within row with different superscript letters are significantly different ($P < 0.05$).

Effect of interaction of grass specie and different levels of maize bran on organoleptic test of silage quality

The interaction of elephant grass and 10% level of maize bran produced silage with higher sensoric scores than other interaction (Table 4). Higher scores possibly was due to improved fermentation condition in elephant grass mixed with maize bran at 10%level which leads to efficient fermentation than in the other mixed interactions. This was in agreement with Manyawu et al (2003) who found good sensoric scoring after mixing elephant grass with 10% level of maize bran.

Table 4: Mean effect of interaction of grass specie and different levels of maize bran on organoleptic test of silage quality

Parameter	MB (%)	Elephant grass	Guatemala grass	Rhodes grass	SEM	p-value
Appearance	0	2.5[c]	2.0[b]	1.00[a]	0.391	0.0001
	5	3.0[d]	2.0[b]	1.50[a]	0.391	0.0001
	10	4.0 [e]	3.5[d]	2.33[b]	0.391	0.0001
	15	3.5[d]	2.5[c]	2.00[a]	0.391	0.0001
Smell	0	2.0[a]	2.0[a]	1.00[a]	0.330	0.0001
	5	3.0[d]	2.5[c]	1.50[a]	0.330	0.0001
	10	4.0[e]	3.5[d]	2.60[c]	0.330	0.0001
	15	3.5[d]	3.0[d]	2.00[a]	0.33 0	0.0001
Texture	0	2.0[b]	1.5[a]	1.00 [a]	0.486	0.0001
	5	3.5[d]	2.5[c]	1.50[a]	0.486	0.0001
	10	4.0[e]	3.5[d]	2.60[c]	0.486	0.0001
	15	3.5[d]	3.0[d]	2.00[b]	0.486	0.0131

Effect of grass species and different levels of maize bran on chemical composition and in vitrodry matter digestibility

The CP and ash concentrations of elephant grass silages were higher but DM and WSC were lower than those of guatemala and rhodes grass silages (Table 5). This is related to the original chemical composition of individual grass specie before preparation of the silage. There was no difference among elephant, guatemala and rhodes grasses in terms of NDF. Maize bran at 10 and 15% level had higher DM and digestibility but lower NDF than the other treatments. Higher DM probably was due to ability of maize bran to absorb moisture from silage than other levels. Maize bran at 10% level had higher CP than other treatments. Increased CP could be due to efficient fermentation and early stability of silage which inhibit proteolytic activity during fermentation process (Kung et al 2000). The results were inconsistent with those found by Lyimo (2010) and Mtengeti et al (2013) who found higher CP in silages treated with maize bran at 10% level than those without maize bran. The observed higher WSC in silages with maize bran additive level 10% than other levels might have be due to increased substrate for fermentation leads to rapid pH reduction and when the process stops WSC remains as recovery substrate. This was in agreement with McDonald et al (2002) who observed good fermentation after adding more WSC to the herbage with high water and low WSC. There was no difference between additive levels in terms of ash. Reduced NDF may be explained by the hydrolysis of NDF-N bound during fermentation (Jaakkola et al 2006, Huisden et al 2009). Higher digestibility could be attributed to the provision of useful energy substrate for ruminal microbes and thus improve their effectiveness in digesting feed particles. These results were in agreements with those reported by Manyawu et al (2003), Mtengeti et al (2006), Lyimo (2010), Mtengeti et al (2013), who found an improvement of the IVDMD of the elephant grass silage with addition of maize bran at 10% level.

Table 5: Mean effect of grass specie and different levels of maize bran on chemical *and **in vitro*** dry matter digestibility of silage quality

Parameter (%)	**Factors**				**SEM**	**p-value**
	Effect of grass specie					
	Elephant grass silage	**Guatemala grass silage**		**Rhodes grass silage**		
DM	18.30^{c}	27.07^{a}		22.50^{b}	0.138	0.0001
CP	9.69^{a}	7.44^{b}		6.86^{c}	0.033	0.0001
WSC	2.34^{b}	2.45^{a}		2.10^{c}	0.006	0.0001
Ash	13.90^{a}	9.43^{c}		12.10^{b}	0.007	0.0001
NDF	65.50^{a}	65.80^{a}		65.60^{a}	0.158	0.0001
IVDMD	55.70^{b}	66.10^{a}		54.00^{c}	0.221	0.0001
	Effect of different levels of MB					
	MB0%	**MB5%**	**MB10%**	**MB15%**		
DM	21.10^{c}	22.50^{b}	23.50^{a}	23.50^{a}	0.159	0.0001
CP	7.48^{d}	7.91^{c}	8.46^{a}	8.14^{b}	0.038	0.0001
WSC	1.52^{d}	2.15^{c}	2.82^{a}	2.70^{b}	0.007	0.0001
Ash	11.80^{0a}	11.80^{a}	11.80^{a}	11.80^{a}	0.008	0.0001
NDF	68.60^{a}	67.70^{b}	61.60^{d}	64.60^{c}	0.182	0.0001
IVDMD	55.80^{c}	58.20^{b}	60.20^{a}	60.20^{a}	0.255	0.0001

MB - Maize bran, SEM- Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different ($P < 0.05$).

Effect of interaction of grass specie and different levels of maize bran On crude protein of grass silage quality

The interaction of elephant grass and maize bran at 10% level produced silage with higher CP than other interactions (Table 6). Higher CP possibly was due to improved fermentation condition in elephant grass mixed with maize bran at 10% level which leads to efficient fermentation than other interactions. The results implicated that nutrient of the grass silage vary depending on the specie and silage additives levels. The results are related to those of Rinne et al (2002) who found that, nutrient contents of the grass silage vary depending on the specie, vegetation period and silage additives.

Table 6: Mean effect of interaction of grass specie and different levels of maize bran on CP of silage

Parameter	MB (%)	Elephant grass silage	Guatemala grass silage	Rhodesgrass silage	SEM	p-value
CP	0	9.06^{c}	6.78^{a}	6.59^{a}	0.066	0.0001
	5	9.60^{c}	7.41^{b}	6.73^{a}	0.066	0.0001
	10	10.20^{d}	8.0^{b}	7.21^{b}	0.066	0.0001
	15	9.93^{c}	7.58^{b}	6.92^{a}	0.066	0.0001

MB – maize bran, SEM- Standard error of means.Means within column with different superscript letters are significantly different ($P < 0.05$).

Effects of species and different levels of maize bran on fermentative quality of fodder grass silages

Elephant grass silage had lower pH and NH_3N but higher lactic acid than guatemala and rhodes grass silage (Table 7). The results indicated that, elephant grass preserved better than these two fodder grasses. Low pH and NH_3N could be due to higher lactic acid in elephant grass which allows fermentation and increases acids that could preserve fodder grass well. According to Ranjit and Kung (2000) in silage, lack of oxygen and the accumulation of lactic acid inhibit its microbial metabolism and preserves nutrients. Low NH_3N means less proteolysis in elephant grassthan in the other grasses. Many researchers have found that silage made from tropical crops generally have high pH values (Imura et al 2001). Thus, it is difficult to ensure good quality silage using tropical pasture crops because they usually have low lactic acid.

Maize bran additive level 10% had higher lactic acid and acetic acid but lower pH and NH_3N than other levels (0%, 5% and 15%). This might be due to achievement of optimal maize bran level for satisfactory fermentation. The results were nearly similar to those found by't Mannetje (2000) who reported that energy supplied by the additives create more conducive environment for the anaerobic fermentation bacteria. Similar observations have been reported in the country and elsewhere (Manyawu et al 2003; Mtengeti and Urio 2006; Mtengeti et al 2013). Reduced silage NH_3N and increased WSC suggested a decreased fodder grass proteolysis by elevated external WSC supply and a hastened lactic acid bacteria settlement. Ammonia nitrogen (NH_3-N) works as an important indicator of proteolytic activity during the fermentation process. According to Whiter and Kung (2001) silage NH_3N is reduced when plant enzyme activity, nitrate reduction and proteolysis decrease. The butyric acid concentration is an important indicator of proteolytic activity in the materials. Butyrates were not detected in the additive level 10% silages and were significantly lower in treated silages compared to untreated silages. This indicated that, additives restrict the development of yeast which could increase butyric acid but optimal additive level hinders the development of yeast completely and promote adequate fermentation patterns. Rapid drop in pH during ensiling and increasing organic acid concentration can inhibit the growth of undesirable microorganisms (Pahlow et al 2003).

Table 7: Effect of specie and different levels of maize bran on fermentative quality of fodder grass silages

Parameter	Factors				SEM	p-value
	Effect of grass specie					
	Elephant grass silage	Guatemala grass silage	Rhodes grass silage			
pH	4.22^{c}	4.36^{b}	4.47^{a}		0.0114	0.0001
NH_3N(% TN)	2.27^{c}	3.50^{b}	4.22^{a}		0.0120	0.0001
Lactic acid (%)	1.44^{a}	1.26^{b}	0.75^{c}		0.0254	0.0001
Acetic acid (%)	0.74^{a}	0.66^{b}	0.36^{c}		0.0072	0.0001
Butyric acid (%)	0.005^{b}	0.007^{b}	0.036^{a}		0.0036	0.0001
	Effect of different levels of MB					
	MB0%	MB5%	MB10%	MB15%		
pH	4.97^{a}	4.44^{b}	3.98^{c}	4.01^{c}	0.0132	0.0001
NH_3N(% TN)	4.55^{a}	3.07^{b}	2.84^{c}	2.86^{c}	0.0139	0.0001
Lactic acid (%)	0.44^{d}	1.09^{c}	1.62^{a}	1.45^{b}	0.0293	0.0001
Acetic acid (%)	0.23^{d}	0.52^{c}	0.83^{a}	0.76^{b}	0.0083	0.0001
Butyric acid (%)	0.041^{a}	0.021^{b}	0.000^{c}	0.002^{c}	0.0041	0.0001

MB-Maize bran, SEM- Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different ($P < 0.05$).

Effect of interaction grass specie and different levels of maize bran on fermentative quality of silage

The interaction of elephant grass and 10% level of maize bran produced silage with significantly lower pH but higher Lactic acid than other combinations (Table 8). Higher Lactic acid possibly was due to provision of good improved fermentation condition in elephant grass mixed with maize bran at 10% level which leads to efficient fermentation than other combinations. The results implicated that nutrients and pH of the grass silage vary depending on the specie and silage additives levels. The results are related to those of Baytok and Muruz (2003) who found that, both nutrients and pH of the grass silage vary depending on the specie, vegetation period and silage additives.

Table 8: Mean effect of interaction of grass specie and different levels of maize bran on fermentative quality of silage

Parameter	MB (%)	Elephant grass silage	Guatemala grass silage	Rhodes grass silage	SEM	p-value
pH	0	4.85^{d}	4.93^{d}	5.12^{d}	0.023	0.0001
	5	4.11^{c}	4.52^{c}	4.69^{c}	0.023	0.0001
	10	3.83^{a}	3.97^{a}	4.03^{a}	0.023	0.0001
	15	3.99^{b}	4.10^{b}	4.14^{b}	0.023	0.0001
Lactic acid (%)	0	0.68^{a}	0.36^{a}	0.28^{a}	0.051	0.0001
	5	1.08^{b}	1.17^{b}	0.86^{b}	0.051	0.0001
	10	2.30^{d}	1.80^{d}	1.01^{d}	0.051	0.0001
	15	1.70^{c}	1.69^{c}	0.75^{c}	0.051	0.0001

MB – Maize bran, SEM- Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).

Effect of species and different levels of maize bran on fodder grass silages stability during feed out

Aerobic stability is a term used to define the length of time that silage remains cool and does not spoil after it is exposed to air. Stability helps farmer to prepare how to handle silage. It prevents silage from spoiling when exposed to air and by doing so, it can improve the efficiency of a farm by preserving forage as high quality silage that is palatable to cows. The measurement of forage pH along with moisture can be used to evaluate whether silage is stable or prone to spoilage (David and Casper 2002). Normally, assays of aerobic stability for silage produced in tropical climates are carried out for five or more days (Pedroso et al 2008, Basso et al 2012, Rabelo et al 2015). Therefore, the aerobic stability assay was performed for seven days because it is representative of the majority of dairy farmers in tropical areas (Table 9). A pH below 5 indicates stable silage (Lyimo 2010). The results showed that, elephant grass silage had higher stability than guatemala and rhodes grass silage. Elephant grass silage was stable up to fourth day. Guatemala grass silage up to third day and rhodes grass silage up to second day. Good condition in elephant grass allows fermentation and increases acids that could preserve fodder grass and prevent growth of yeasts which could cause early deterioration of silage (Weissbach 2003). The results implied that, fodder grasses silage should be fed within four days for elephant grass, three days for guatemala and one day for rhodes grass silage, thereafter deterioration becomes unbearable and the silage becomes unsuitable for feeding the animals. The results were similar to those observed by Lyimo (2010) who dealt with elephant grass silage stability and observed stable silages from elephant grass.

The results indicated that, maize bran at 10% level silage was stable up to fourth day, at 15% up to third day and at 5% level was stable up to second day. Silage at 0% level seemed to be unstable from day 0 as it had pH higher than 5 from day 0. This implied that additives levels have an influence on the stability of grass silage that was more stable with maize bran at 10% level than with other treatments. This was in consistent with other workers elsewhere (Lyimo 2010, Mtengeti et al 2013) who found good fermentation after 10% maize bran additive level was applied to the fodder grass. These observations were also in agreement with those observed by Jaurena and Pichard (2001) and ‘t Mannetje (2000) who reported an influence of additives on the stability of the silage quality during the feeding out. The concomitant production of lactic acid and acetic acid is considered positive because acetic acid increases the aerobic stability due to the inhibition of spoilage organisms (Danner et al 2003).

Table 9: Effect of grass specie and different levels of maize bran on stability of fodder grass silages

Parameter	Factors				SEM	p-value
	Effect of grass specie					
	Elephant grass silage	**Guatemala grass silage**	**Rhodes grass silage**			
Phdy0	4.30^{b}	4.65^{ba}	4.76^{a}		0.141	0.0001
Phdy1	4.54^{c}	4.73^{b}	4.82^{a}		0.031	0.0001
Phdy2	4.58^{a}	4.77^{a}	5.00^{a}		0.145	0.0001
Phdy3	4.66^{c}	4.93^{b}	5.27^{a}		0.068	0.0001
Phdy4	4.99^{c}	5.43^{b}	5.60^{a}		0.031	0.0001
Phdy5	5.78^{b}	5.97^{a}	6.01^{a}		0.024	0.0001
Phdy6	5.81^{c}	6.04^{b}	6.17^{a}		0.042	0.0001
Phdy7	5.47^{c}	5.60^{b}	5.73^{a}		0.009	0.0001
	Effect of different levels of MB					
	MB0%	**MB5%**	**MB10%**	**MB15%**		
Phdy0	5.23^{a}	4.63^{b}	4.17^{b}	4.25^{b}	0.163	0.0001
Phdy1	5.28^{a}	4.77^{b}	4.33^{c}	4.41^{c}	0.036	0.0001
Phdy2	5.48^{a}	4.88^{b}	4.40^{b}	4.50^{b}	0.168	0.0001
Phdy3	5.72^{a}	4.91^{b}	4.50^{c}	4.62^{c}	0.079	0.0001
Phdy4	6.07^{a}	5.40^{b}	4.89^{c}	4.99^{c}	0.036	0.0001
Phdy5	6.79^{a}	5.70^{b}	5.57^{c}	5.63^{cb}	0.028	0.0001
Phdy6	6.75^{a}	5.85^{b}	5.66^{c}	5.76^{cb}	0.0491	0.0001
Phdy7	5.91^{a}	5.57^{b}	5.43^{d}	5.49^{c}	0.0104	0.0001

MB-Maize bran, SEM- Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different ($P < 0.05$).

Effect of grass specie and different levels of maize bran on stability of silage

The interaction of elephant grass and 10% level of maize bran produced silage with lowest pH (Table 10). Lowest pH possibly was due to improved fermentation condition in elephant grass mixed with maize bran at 10% level which leads to efficient fermentation. The results showed that, the interaction of elephant grass and maize bran at 10% level were stable from day 0 up to day 5 as it was indicated by pH below 5. This implied that, the silage from elephant grass mixed with maize bran at 10% level can remain stable for five days without deterioration after opening the silo and it is safelyfor feeding the dairy cattle. On the other hand the silages from elephant grass mixed with maize bran at level 0%, 5%, 15% and silages from guatemala and rhodes grasses had pH below 5 before day five.

Table 10: Mean effect of interaction of grass specie and different levels of maize bran on stability of silage quality

Parameter	MB (%)	Elephant grass silage	Guatemala grass silage	Rhodes grass silage	SEM	p-value
pHdy0	0	5.10^{d}	5.30^{d}	4.99^{d}	0.092	0.0001
	5	4.60^{c}	4.80^{c}	4.20^{c}	0.092	0.0001
	10	3.90^{a}	4.40^{a}	4.03^{a}	0.092	0.0001
	15	4.2^{b}	4.50^{b}	4.13^{b}	0.092	0.0001
pHdy3	0	5.01^{d}	5.44 ^{d}	5.70^{d}	0.089	0.0001
	5	4.80^{c}	4.93^{c}	5.15^{c}	0.089	0.0001
	10	3.99^{a}	4.62^{a}	4.7 ^{a}	0.089	0.0001
	15	4.30^{b}	4.84^{b}	4.85^{b}	0.089	0.0001
pHdy5	0	5.30^{d}	6.40^{d}	6.7^{d}	0.486	0.0001
	5	5.10^{c}	5.90^{c}	6.13^{c}	0.486	0.0001
	10	4.50^{a}	5.00^{a}	5.07^{a}	0.486	0.0001
	15	4.80^{b}	5.30^{b}	5.40^{b}	0.486	0.0001

MB – Maize bran, SEM- Standard error of means. Means within column with different superscript letters are significantly different ($P < 0.05$).

Conclusion

- Elephant grass silage had higher appearance, smell, texture scores, CP, lactic acid and stability but lower pH and NH_3N than guatemala and rhodes grass silage.
- Maize bran at 10% levels had higher appearance, smell and texture scores, CP, WSC, lactic acid, acetic acid and stability but lower NDF, pH and NH_3N than grass silages treated with maize bran at 0%, 5% and 15% levels
- The interaction between grass species and different maize bran levels showed that, elephant grass silage with maize bran at 10% level produced best silage as indicated by highest sensoric scores, CP, lactic acid and stability but lowest pH.
- It was concluded that, elephant grass mixed with maize bran at 10% level was the most optimal combination techniques to achieve high quality silage under smallholder farmers compared to maize bran at 0%, 5% and 15% levels mixed with guatemala and rhodes grasses.

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3.2 PAPER III

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Research Article

EFFECT OF GRASS SPECIES AND DIFFERENT LEVELS OF MOLASSES ON SILAGE QUALITY

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ABSTRACT

The experiment was conducted to investigate the effect of grass species and different levels of molasses on silage quality in smallholder dairy farms. Elephant, guatemala and rhodes grasses were established and harvested when they were at the age of 120, 63 and 56 days respectively. The harvested grasses was chopped into 4cm and subdivided into three portions each of which was treated with different levels of molasses (0, 3 and 5), packed in 5kgs plastic bag silo and stored in thatched barn. Treatments were assigned to a completely randomized design in factorial arrangement (3x3) with two replications. The silage was opened after 60 days, analyzed for sensoric qualities; chemical composition, *in vitro* DM digestibility and fermentation. Elephant grass silage produced higher quality and preserved better than guatemala and rhodes grasses as indicated by higher sensoric qualities, crude protein, ash, lactic acid, acetic acid and stability but lower, pH, NH_3N and butyric acid. Silages produced from molasses at 5% level had higher quality than silages mixed with molasses at 0 and 3% levels as indicated by higher DM, CP, WSC, ash, IVDMD, lactic acid, acetic acid and stability but lower NDF, pH and NH_3N. The interaction of elephant grass and 5% level of molasses showed highest CP and WSC but lowest pH and NH_3N. Elephant grass with molasses at 5% level was the most optimal techniques to achieve high quality silage fermentation under smallholder farmers.

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INTRODUCTION

Dairy production has contributed significantly to poverty alleviation and reduction of malnutrition among the smallholder dairy farmers particularly in rural areas (Kayunze *et al.*, 2001 and Kurwijila *et al.*, 2002). Despite this, it has not expanded substantially in the tropical countries due to lack of quality pastures particularly during the dry season. In Tanzania, lack of quality pastures constraint the overall productivity of the smallholder dairy cattle (Lyimo, 2010). Conservation of forage in form of silage for later use in periods of feed shortage could be way out of this problem. Elephant, guatemala and rhodes grasses are high-yielding grass species that have been grown by smallholder dairy farmers in Tanzania and can be used to produce silage.

According to Evangelista *et al.* (2004), the tropical grasses present low dry matter, high buffering capacity and low soluble carbohydrates endangering the conservation through ensilage, once secondary fermentations are possible to occur. In order to improve herbage preservation and its feeding value various additives such as molasses have been applied (Keady *et al.*, 2000). The additives enhance efficient fermentation of sugar to lactic acid. Efficient fermentation of sugar and minimal proteolysis are crucial for silage preservation (Nadeaue *et al.*, 2000). It was well documented that the fermentation quality of silage can be improved through lactic acid bacteria based additives (Kung *et al.*, 2003; Filya *et al.*, 2007).

The mode of action of the additive applied to the herbage during silage making can include limiting respiration or proteolysis by plant enzymes, manipulating fermentations, inhibiting the activity of clostridia and aerobic micro-organism such as yeast and moulds (Laitila *et al.*, 2002; Rooke and Hatfield, 2003 and Kung *et al.*, 2003).

Good silages have been observed when molasses were applied at different additive levels i.e. 3-5% (Manyawu *et al.*, 2003), 4% (Aminah *et al.*, 2000), 5% (Lyimo, 2010; Mtengeti *et al.*, 2013). However, the effect of different levels of molasses and grass species on silage quality is rarely documented. Therefore, the study was conducted to investigate the effect of fodder grass species and different levels of molasses on silage quality in smallholder dairy farms.

Materials and methods

Study area

This study was conducted at Magadu dairy farm in Department of Animal, Aquaculture and Range Sciences, College of Agriculture, Sokoine University of Agriculture (SUA). The study site was located at about 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates). It is characterized by ambient temperature between 20-27 °C in the coolest months of April to August and 30 - 35 °C during the hottest month of October to January. The annual rainfall ranges from 600-1000mm

Experimental design and treatments

The experimental design was completely randomized design under 3 x 3 factorial arrangement of three grass species (elephant, guatemala and rhodes grasses), three molasses levels (0 (control), 3 and 5%). The experiment had 9 treatments combinations and each in four replications.

Source, harvesting, preparation of ensiled grasses and ensiling procedure

The ensiled grass species used in study were elephant grass (*Pennisetum purpureum*), guatemala grass (*Tripsacum laxum*) and rhodes grass (*Chloris gayana*). All ensiled grass species were harvested from well established pasture plots (Plate 1 - 3). Each pasture plot for the grass specie covered an area of about $400m^2$.

The elephant grass was harvested at 1.5m. of height (120 days after planting), guatemala grass was at 1.0m of height (63 days) after planting time whereas rhodes grass 0.5m of height (56 days) when it was at flowering stage of growth. Nutritive value declines quickly as plant matures thus were harvested at respective recommended stages of growth for each grass. The grasses were cut using the machete and thereafter each bundle of harvested grass specie was chopped by a machete into 4cm length (Plate 4). The harvested grass was chopped into 4cm and divided into two portions. One portion of the ensiling material was subdivided into three lots each of which was treated with a different level of molasses (0, 3, and 5%) as additive (Plate5). Molasses was used as water soluble carbohydrate additive. The molasses was mixed thoroughly with forage material and ensiled in small plastic bag silos of capacities of 5kg (Plate 6). Then, the ensiled material was stored in thatched barn (Plate 7). The ensiling was done by filling grass materials in the plastic silo bag. The neck of the bags was twisted, turned over and tied with a rubber band. Thereafter, the treatment of plastic bag was labeled for identity. Each bag was then inserted into a second empty shopping plastic bag which was also tied and labeled and put in a hessian bag to protect it from rupturing. For each in-bag silo treatment there were four hessian bags each containing two shopping bags. Hessian bags were then stored in thatched barn. Thatched barn is cheaper and can be affordable compared with earth-pit (Lyimo, 2010). In the thatched barn, the hessian bags were carefully stacked on a wooden rack and allow ventilation so as to low temperature.


Plate 1 Grasses were planted


Plate 2 Grasses were weeded


Plate 3 Grasses were harvested


Plate 4 Chopped grasses


Plate 5 Grasses with molasses


Plate 6 Ensiling


Plate 7 Ensiled material were stored

A chicken wire mesh all over so as to protect the bags against rats surrounded the wooden rack, mice and birds especially crow that would view the bags as bin bags full of kitchen waste to consume.

Molasses availability and affordability

In Tanzania, molasses is cheap, affordable and locally available. For a smallholder farmer with only one cow, a 5kg of grass silage could be appropriate since the animal may require only 5kg of silage per day since it should be combined with other feeds such as hay and concentrates for a healthy rumen. The 5kg of elephant grass silage required 4.75kg of elephant grass mixed with 0.25kg of molasses at 5% level with the price of 0.02US$ /day or 50Tshs (Table 1). The price is affordable considering that, feed is the major cost item. among variable costs and accounts for over 70% of the production costs (Norris *et al.*, 2002). The productivity of dairy cattle under smallholder farmers has however, been low, producing up to from 6 – 10 liters of milk in the rain season and 3–5 liters in the dry season due to unavailability of adequate quality feeds throughout the year (Kavana and Msangi, 2005., Hall *et al.*, 2007 and Njarui *et al.*, 2009). This implies that, in average, the lowest incomefrom milk production in dry season could be 3liters/day x 0.4US$/liter = 1.2US/day (1 liter of milk = 0.4US$= 1000Tshs) and the highest income during rainy season could be 10 liters/day x 0.4US$/liter = 4US$/day. Therefore, smallholder farmer with the income of 1.2US$ can afford to make silage using molasses at 5% with the price of 0.02 US$ /day even during dry season.

Table 1 Amount of grasses ensiled with different levels of molasses and their prices/day/cow

Grass species and amount ensiled (kg)			Levels of molasses (%) and amount ensiled (kg) (kg)			Levels of molasses (%) and price (US$)		
			0%	3%	5%	0%	3%	5%
EG = 5,	4.85,	4.75	0	0.15	0.25	0	0.012	0.02
GG = 5,	4.85,	4.75	0	0.15	0.25	0	0.012	0.02
RG = 5,	4.85,	4.75	0	0.15	0.25	0	0.012	0.02

EG = elephant grass GG=guatemala grass RG – rhodes grass, price (1kg molasses *=200 Tsh=0.08 dollar; 1dollar=2500Tshs year (2016)*

Data collection procedures

After 60 days of fermentation, silos were opened and spoiled silage was separated from well preserved silage. Samples (weighing 500g) from each bag were collected placed in polythene bags and immediately placed in a cool ice box and taken to the analytical laboratory. The sample was sub-divided into two samples, for organoleptic test, pH determination and chemical composition analysis. The sub-samples were put in polyethylene bags and stored in a deep freezer at -10 °C until when they were used for laboratory work. The DM of the fresh ensiling material and silages were determined by drying in an oven at 65°C for 48 h (AOAC, 1984). The silages were freeze-dried in a Lyphilizer maintained distilled water for 12 hours then at -40 °C for 24 hrs according to Snowman (1988) so as to get a dry sample for ash, crude protein, neutral detergent fiber (NDF), WSC analysis and *in vitro* dry matter digestibility (IVDMD) determination. Ammonia-nitrogen (NH_3N) was analyzed from fresh silage samples. The ash, CP and NH_3N were analyzed according to AOAC (2005) procedures while WSC was analyzed according to Thomas (1977). The NDF was analyzed according to Van Soest *et al.* (1991). A pH meter (model 219-MK 2; Pye Unicam) was used to measure the pH of the fresh silages samples. Samples of 40g from each silo were soaked in 200 ml of cool the supernatant used for the determination of the pH. The *in vitro* dry matter (IVDMD) of the silages were determined according to the two stage technique developed by Tilley and Terry, (1963) and modified by Salabi *et al.* (2010). The silages were analyzed for volatile fatty acid according to Shirlaw's (1967) procedure. Gas Chromatograph analyses were performed on a wide bore fused silica Cp-sil 19CB column, gas chromatograph equipped with a flame ionization detector (FID) $512x10^{-12}$ Afs. The technique used was gas chromatograph capillary column (10 m, 0.53 mm fused silica. WCOT Cp-Sil 19CB (2.0 µm catalog number 7647). The injector and detector temperatures were 275°C and 300°C respectively. The carrier gas was H_2 40kPa (0.4bar) 170 cm/s. The analyses were performed using a temperature programme: a linear gradient from 80°C to 280°C at 25°C min^{-1}. In each case a 0.1µLof sample was injected (a flow splitting 1:10). Silage stability was determined by observing the change of pH value of exposed silage after sixty days of fermentation. Each day the pH of each treatment was recorded for 7 days consecutively.

Organoleptic Test

The organoleptic test was carried out at the Department of Animal, Aquaculture and Range Sciences, Undergraduate and Postgraduate Students. Each assessor assessed the silage from each treatment and scored its physical characteristics in terms of appearance, texture and smell (Lyimo, 2010). In this study, each factor including smell, color and texture has given a number based on Otieno *et al.* (1990). Appearance score No.1 (poor) indicated spoiled silage which was dark brown in color with mould growth, score No.2 (moderate) greenish in colour with some mould growth, score No.3 (good) yellowish green to brown colour and score No.4 (very good) indicated well pickled yellowish green to light brown colour silage. Smell score No.1 (poor) indicated foul smell associated with putrefaction, score No.2 (moderate) pungent smell of ammonia, score No. 3 (good) pleasant aroma and score No.4 (very good) vinegar fruity, estery aroma typically silage smell. Texture score, No.1 (poor) slimy and watery, score No.2 (moderate) less slimy and wet No.3 (good) non-slippery and wet No.4 (very good) non-slippery and slightly wet. The test was carried once after 60 days of fermentation, when ensiling bags (silos) were opened and spoiled silage separated from well preserved silage

Data analysis

Collected data were entered in coded excel sheets then transferred to SAS for General Linear Model procedure of Statistical Analysis System (SAS, 2008) for analysis of variance of means. Means of factors were then separated using Multiple Duncan Range test. The model used to study effects of molasses additive levels of elephant, guatemala and Rhodes grasses was: The statistical model:- $Y_{ijkl} = \mu + Gi + L(A)_{jk} + (GA)_{ij} + E_{ijkl}$; whereby Y_{ijkl} = observation taken on the l^{th} replicate sample taken from the k^{th} level of the j^{th} additive applied on the i^{th} grass species;μ= general mean common to all observation;Gi= effect of the i^{th} grass species; A_j = effect of the j^{th} additive; $L(A)_{jk}$ = effect of the k^{th} level of application of the j^{th} additive; $(GA)_{ij}$ = interaction between the i^{th} grass specie and j^{th} additive; $L(A)_{jk}$ and $(GA)_{ij}$ are two-factor interactions involving grass species and additive level as indicated by corresponding symbols; E_{ijkl}= random effect peculiar to each observation.

Results and Discussion

Chemical composition and digestibility of fodder grasses at the time of ensiling

The results revealed that, elephant grass had higher CP and ash but lower DM and digestibility than guatemala and rhodes grasses (Table 2). Molasses had relative higher WSC but lower CP than grasses.

Table 2 Mean chemical composition and digestibility of the grasses material at the time of ensiling

Parameter (%)	EG	GG	RG	Molasses
DM	19.9	29.3	21.8	65.30
CP	10.1	8.45	7.8	2.17
WSC	3.19	3.40	3.01	52.9
Ash	13.5	9.5	9.2	10.60
NDF	73.9	73.2	66.4	Nd
IVDMD	59.3	66.3	58.1	Nd

EG - elephant grass GG - guatemala grass RG rhodes grass, DM - Dry matter, CP - Crude protein, WSC - Water soluble carbohydrates, NDF - Neutral detergent fibre, IVDMD-in-vitro dry matter digestibility, Nd - not determined

Effect of grass specie and different levels of molasses on organoleptic of silage quality

Elephant grass silage had higher ($p \leq 0.05$) sensoric scores than guatemala and rhodes grass silage (Table 3). These differences might have been caused by improved fermentation condition in elephant grass silages than in guatemala and rhodes grass silages. Good silage usually preserves the original colour of the pasture or any forage. The olive green color obtained from elephant grass in the present study was in order. It was close to the original colour of the grass which was an indication of good quality silage that was well preserved (Oduguwa *et al.,* 2007). The pleasant smell could be attributed by good aroma from molasses of well fermented silages. The texture of the elephant grass silages was firm.

Silages with molasses at 5% level had higher ($p \leq 0.05$) sensoric scores than silages with molasses at 3% and 0% levels. Silages with molasses at 5% level possibly increased substrate for lactic bacteria which enhanced more lactic acid production resulting to good fermentation process. This was in agreementwith observation reported by Manyawu *et al.* (2003), Mtengeti and Urio, (2006) and Lyimo, (2010) who found well fermented silages after molasses was applied at 5% level. Kung and Shaver, (2002) reported that pleasant smell is accepted for good or well-made silage.

Table 3 Mean effect of grass specie and different levels of molasses on organoleptic of silage quality

Parameter (%)	Factors			SEM	p-value
	Effect of specie				
	EGS	**GGS**	**RGS**		
Appearance	3.33^{a}	2.67^{b}	2.00^{c}	0.192	0.0001
Smell	3.00^{a}	2.67^{ba}	2.17^{b}	0.193	0.0001
Texture	3.33^{a}	2.50^{b}	2.00^{b}	0.215	0.0001
	Effect of MOL additive levels				
	0%	**3%**	**5%**		
Appearance	1.83^{c}	2.67^{b}	3.50^{a}	0.192	0.0001
Smell	2.00^{b}	2.50^{b}	3.50^{a}	0.193	0.0001
Texture	1.67^{c}	2.67^{b}	3.50^{a}	0.215	0.0001

EGS - elephant grass silage GGS - guatemala grass silage RGS- rhodes grass silage, MOL- molasses, Score 1 = Poor Score 2=Moderate Score 3= good, 4= very good, SEM - Standard error of means. Means within row with different superscript letters are significantly different (P < 0.05).

Effect of grass species and different levels of molasses on chemical composition and in vitro dry matter digestibility

Elephant grass silages had higher ($p \leq 0.05$) CP and ash but lower DM and WSC than guatemala and rhodes grass silages (Table 4). This is related to the original chemical composition of individual grass specie before ensiling.

There was no difference among elephant, guatemala and rhodes grass silages on NDF. Silages with molasses at 5% level had higher ($p \leq 0.05$) DM, CP, WSC, ash, IVDMD but lower NDF than silages with molasses at 3% and 0% levels. More DM recovery with molasses at 5% level compared to other levels may be due to the addition of WSC that improves the fermentation characteristics. Once the silage gains the stability then there is no more fermentation and at very low pH the microbes become the part of medium and reduction in DM is prohibited. The results were inconsistent with those reported by Mtengeti *et al.* (2013). Observed high CP fermentation has been documented by McDonald *et al.* (1991). May be due to increased level ofmolasses that improved the fermentation process, increased lactic acid, lowering the pH and therefore decreased proteolysis or breakdown of the CP to ammonium nitrogen.

The results were in agreement with those found by Adesogan *et al.* (2004) who found higher CP in treated silages than in untreated silages. Observed high WSC contents could be attributed by increased energy for lactic bacteria due to increased substrate resulted to more lactic acid production, leads to rapid pH reduction and when the process stops WSC remains as recovery substrate. This was in agreement with McDonald *et al.* (2002) who observed good fermentation after adding more WSC to the herbage with high water and low WSC. In cases where forage has an insufficient amount of WSC, it is difficult to ensile satisfactory. Observed high ash could be attributed by high minerals found in molasses that can increase ash. This result was in consistent with those of (Gofeen and Khalifa, 2007; Aksu *et al.*, 2006; Donmez *et al.*, 2003) who found higher ($p \leq 0.05$) levels of ash after addition of molasses to the grasses. Increased IVDMD could be attributed to the provision of useful energy substrate for ruminal microbes and thus improve their effectiveness in digesting feed particles. The importance of molasses as useful energy substrate for ruminal microbes have been documented by McDonald *et al.* (1973).

Low NDF could be attributed to increased acidity which stimulated further hydrolysis of linked sugar molecules in the cell wall causing further breakdown of hemicelluloses. Breakdown of up to 50% of hemicelluloses during silage

Table 4 Mean effect of grass species and different levels of molasses on chemical composition and *in vitro* dry matter digestibility

Parameter (%)	Factors			SEM	p- value
	Effect of specie				
(%)	**EGS**	**GGS**	**RGS**		
DM	18.1^{c}	26.5^{a}	22.1^{b}	0.116	0.0001
CP	9.1^{a}	6.8^{c}	7.4^{b}	0.052	0.0001
WSC	1.68^{b}	1.76^{a}	1.4^{c}	0.014	0.0001
Ash	13.8^{a}	9.58^{c}	12.1^{b}	0.059	0.0001
NDF	68.8^{a}	68.5^{a}	68.9^{a}	0.147	0.0001
IVDMD	54.8^{b}	62.3^{a}	53.9^{b}	0.323	0.0001
	Effect of MOL additive levels				
	0%	**3%**	**5%**		
DM	21.5^{c}	22.3^{b}	22.9^{a}	0.116	0.0001
CP	7.70^{b}	7.73^{b}	7.98^{a}	0.052	0.0001
WSC	1.13^{c}	1.75^{b}	1.95^{a}	0.013	0.0001
Ash	11.9^{b}	12.1^{b}	12.5^{a}	0.059	0.0001
NDF	69.8^{a}	68.5^{b}	67.4^{c}	0.147	0.0001
IVDMD	56.2^{b}	56.7^{b}	58.2^{a}	0.323	0.0001

EGS - elephant grass silage, GGS -guatemala grass silage, RGS- rhodes grass silage, MOL – molasses, SEM- Standard error of means. ab least significant means and means within row with different superscript letters are significantly different ($P < 0.05$).

Combination effect of grass specie and different levels of molasses on composition of silage quality

The interaction of elephant grass and 5% level of molasses showed that elephantgrass produced silage with higher ($p \leq 0.05$) CP and WSC than guatemala and rhodes grasses (Table 5). Higher CP is related to the original CP of elephant grass compared to those of guatemala and rhodes grass. Higher WSC possibly was due to increased molasses level at 5% than at 3% and 0%. Thus, the interaction of elephant grass and molasses at 5% level resulted to efficient fermentation than other interactions in this study. The results implicated that nutrient contents of the grass silage vary depending on the specie and silage additives levels. The results are related to those of Baytok and Muruz, (2003) who found that, both nutrients and pH of the grass silage vary depending on the specie, vegetation period and silage additives. Thus, consideration of grass specie and silage additive level can be useful tools to improve silage quality.

Table 5 Mean Combination effect of grass specie and different levels of molasses on composition of silage quality

Par. (%)	MOL (%)	EGS	GGS	RGS	SEM	p- value
	0	8.99^{c}	6.8^{a}	7.31^{b}	0.091	0.0001
CP	3	9.06^{c}	6.8^{a}	7.33^{b}	0.091	0.0001
	5	9.21^{c}	6.81^{a}	7.35^{b}	0.091	0.0001
	0	1.02^{a}	1.35^{d}	1.03^{b}	0.023	0.0001
WSC	3	1.67^{e}	1.75^{f}	1.84^{g}	0.023	0.0001
	5	2.35^{i}	2.18^{h}	13.4^{c}	0.023	0.0001

Par-parameter, EGS -elephant grass silage, GGS -guatemala grass silage, RGS - rhodes grass silage, MOL - molasses, SEM-Standard error of means. Means within row and parameter with different superscript letters are significantly different (P < 0.05).

Effects of species and different levels of molasses on fermentative characteristics of grass silages

Elephant grass silage had higher ($p \leq 0.05$) lactic acid, acetic acid but lower ($p \leq 0.05$) pH, NH_3N, than guatemala and rhodes grass silages (Table 6). This indicated that, elephant grass was better option for silage preservation compared to guatemala and rhodes grasses. Low pH and NH_3N could be due to higher lactic acid in elephant grass which allows improved fermentation and increases acids that could preserve the grass silage well. Silages with 5% molasses had higher ($p \leq 0.05$) lactic acid and acetic acid but lower ($p \leq 0.05$) pH and NH_3N than molasses at 3% and 0% levels. This probably, could be due to additional energy supplied by the increased molasses which created more conducive environment for the anaerobic fermentation bacteria ('t Mannetje, 2000). According to Yang *et al.* (2004), attainment of low pH is one of the important determinants for final silage fermentation quality. The addition of any level of molasses could lower pH and it enhances the lactic acid and improves the fermentative quality of silage. Silage that has been properly fermented will have a much lower pH (be more acidic) than from the original forage. The addition of WSC additives (molasses or maize bran) at the ensiling process as a source of energy could stimulate the pH drop during ensiling. The results are in agreement with Aminah *et al.* (2000) and Baytok *et al.* (2005) who observed improved fermentation after an application of high levels of molasses.

The reduced NH_3N were observed for good grass silage by Kung, (2009). These could be due to readily satisfactory available energy provided by molasses at 5% level to the fermenting bacteria (Lyimo, 2010; Mtengeti *et al.*, 2013) to produce lactic acid which rapidly lowers pH and stops proteolysis resulted to reduced NH_3N. The proteolytic activities were merely restricted when the pH of the fermented silage is 4.3 or lower and in good silage the process will stop earlier and limit the loss of protein (Man and Wiktorsson, 2002). Molasses has high concentration of soluble carbohydrate that can stimulate heterofermentation process in silage (Aksu *et al.*, 2006). Butyrate was negligible at 5% level and indicated that high restriction of the development of yeast which could increase butyric acid. Clostridia can grow in silage that has high soluble carbohydrate.

Table 6 Mean effect of specie and additive levels on fermentative quality of grass silages

Par. (%)	Factors			SEM	p-value
	Effect of species				
	EGS	**GGS**	**RGS**		
pH	4.30^{c}	4.53^{b}	4.57^{a}	0.0091	0.0001
NH_3N	3.44^{c}	4.13^{b}	4.22^{a}	0.0085	0.0001
Lactic acid	1.39^{a}	1.08^{b}	0.47^{c}	0.0119	0.0001
Acetic acid	0.69^{a}	0.55^{b}	0.22^{c}	0.0041	0.0001
Butyric acid	0.0067^{a}	0.008^{a}	0.011^{a}	0.0019	0.008, 0.0029, 0.0003
	Effect of MOL additive levels				
	0%	**3%**	**5%**		
pH	5.09^{a}	4.28^{b}	4.07^{c}	0.0091	0.0001
NH_3N	4.18^{a}	2.95^{b}	2.74^{c}	0.0085	0.0001
Lactic acid	0.49^{c}	0.97^{b}	1.48^{a}	0.0119	0.0001
Acetic acid	0.26^{c}	0.463^{b}	0.741^{a}	0.0041	0.0001
Butyric acid	0.024^{a}	0.0013^{b}	0.00033^{b}	0.0019	0.0001, 0.52, 0.87

Par-parameter, EGS - elephant grass silage, GGS -guatemala grass silage, RGS- rhodes grass silage, MOL – molasses, SEM - Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different ($P < 0.05$).

Combination Effect of Grass Specie and Different Levels of Molasses on Fermentative Characteristics of the Grass Silages

The interaction of elephant grass and 5% level of molasses produced silage with lowest pH and NH_3N (Table 7). Low pH and NH_3N possibly was due to improved fermentation condition in elephant grass mixed with molasses at 5% level which leads to efficient fermentation than in the other interactions.

Table 7 Mean combination effect of grass specie and different levels of molasses on fermentative characteristics of silage

Par.	MOL (%)	EGS	GGS	RGS	SEM	P-value
	0	4.92^{g}	5.1^{h}	5.27^{i}	0.016	0.0001
pH	3	4.22^{d}	4.35^{f}	4.26^{e}	0.016	0.0001
	5	3.9^{a}	4.14^{b}	4.18^{c}	0.016	0.0001
	0	4.28^{h}	3.94^{e}	4.33^{i}	0.015	0.0001
NH_3N	3	1.78^{b}	2.85^{d}	4.22^{g}	0.015	0.0001
	5	1.50^{a}	2.6^{c}	4.12^{f}	0.015	0.0001

EGS - elephant grass silage, GGS -guatemala grass silage, RGS- rhodes grass silage, Mol - molasses, SEM- Standard error of means. Means within row and parameter with different superscript letters are significantly different ($P < 0.05$).

Effect of species and different levels of molasses on grass silages stability during feed out

Stability of pH at low values prevents silage from spoiling when exposed to air during feeding out and thus reduce feed losses. The results showed that, elephant grass silage was more stable than guatemala and rhodes grass silage as indicated by pH values (Table 8). pH value is one of the simplest and quickest way of evaluating silage quality. However, pH may beinfluenced by the moisture and the buffering capacity of the original materials. Silage that has been properly fermented will have a much lower pH (be more acidic) than the original forage. Kung and Shaver, (2002) observed that good quality grass silage pH values in the tropics ranges between 4.3-4.7. Menesses *et al.* (2007) found pH value of the silages which ranges between 3.5-5.5 classified to be pH for good silage. According to Lyimo, (2010) silage with pH below 5 was considered as stable silage.

In this present study, Elephant grass silage was stable up to fourth day. Guatemala grass silage up to third day and rhodes grass silage up to second day. Good condition in elephant grass allows fermentation and increases acids that could preserve grass and prevent growth of yeasts which could cause early deterioration of silage. According to Wilkinson and Davies, (2012) aerobic deterioration of silage occurs mainly during the feed out phase due togreater activity of yeasts and molds which develop on the residual carbohydrates and lactic acid as substrates, increasing the pH and favoring the growth of spoilage microorganisms in addition to yeasts and decreasing the nutritional value of the silage. Achieving a good silage fermentation that is dominated by the production of lactic acid will increase the stability of silages during the feed out.

The results indicated that, silages with molasses at 5% level were more stable (in terms of maintaining low pH value (<5) for longer period than those from molasses at 3% and 0% levels. The control silages had the pH values greater than 5 even before the feed out trial. The silages with molasses at 3% level maintained the pH values <5 up to the third day of feeding out and silages with molasses at 5% level maintained the pH values <5 up to the fourth day of feeding out. This implied that adding molasses in higher levels improves affects silage stability during feeding out. According to Jaurena and Pichard, (2001) molasses, a source of WSC, is often used to help preventing silage instability. Molasses has high concentration of soluble carbohydrate that can stimulate heterofermentation process in silage but could not inhibit proteolysis (Aksu *et al.*, 2006). Heterofermentation is a kind of fermentation which produce butyric acid and acetic acid, they have antimicrobials activity and eliminate growing fungi, mold and yeast but increase aerobic stability in feed out phase. The aerobic stability of the silage with molasses was increased thereby potentially preventing the growth of spoilage organisms (Danner *et al.*, 2003). This was in consistence with other workers elsewhere (Lyimo, 2010; Mtenget *et al.*, 2013) who found high stability after application of molasses at 5% level to the fodder grass. Thus, the inclusion of molasses at 5% level may be a successful strategy for improving grass silage stability.

Table 8 Effect of specie and molasses additive levels on stability of grass silages

Parameter	Factors			SEM	p-value
	Effect of specie				
	EGS	**GGS**	**RGS**		
Phdy0	4.28^{c}	4.39^{b}	4.45^{a}	0.0089	0.0001
Phdy1	4.47^{c}	4.64^{b}	4.85^{a}	0.0124	0.0001
Phdy2	4.54^{c}	4.79^{b}	4.96^{a}	0.0112	0.0001
Phdy3	4.78^{c}	4.92^{b}	5.23^{a}	0.0112	0.0001
Phdy4	4.99^{c}	5.48^{b}	5.50^{a}	0.0078	0.0001
Phdy5	5.79^{c}	5.92^{b}	6.26^{a}	0.0238	0.0001
	Effect of MOL additive levels				
	0%	**3%**	**5%**		
Phdy0	5.19^{a}	4.03^{b}	3.94^{c}	0.0089	0.0001
Phdy1	5.30^{a}	4.49^{b}	4.16^{c}	0.0124	0.0001
Phdy2	5.37^{a}	4.62^{b}	4.33^{c}	0.0112	0.0001
Phdy3	5.51^{a}	4.85^{b}	4.57^{c}	0.009	0.0001
Phdy4	5.94^{a}	5.28^{b}	4.75^{c}	0.008	0.0001
Phdy5	6.66^{a}	5.85^{b}	5.45^{c}	0.024	0.0001
Phdy6	6.60^{a}	5.98^{b}	5.67^{c}	0.011	0.0001
Phdy7	5.79^{a}	5.39^{b}	5.25^{c}	0.013	0.0001

EGS - elephant grass silage, GGS - guatemala grass silage, RGS- rhodes grass silage, MOL - molasses, SEM- Standard error of means. Ab least significant means and means within ro MOL - molasses, SEM- Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different (P < 0.05).

Conclusions

Elephant grass silage had higher appearance, smell and texture score, CP, ash, lactic and acetic acids, stability but lower DM, pH, NH_3N and butyric acid than guatemala and rhodes grass silage.

Grass silages treated with molasses at 5% level had higher appearance, smell and texture score, DM, CP, WSC, ash, IVDMD, lactic and acetic acids, stability but lower NDF, pH and NH_3N compared to silages with molasses at 3% and 0% levels. The interaction between grass specie (elephant, guatemala and rhodes grasses) and different molasses levels (0%,3%

and 5%) showed that, the interaction of elephant grass and molasses at 5% produced best silage as indicated by highest CP, WSC but lowest pH and NH_3N.

Therefore, it can be concluded elephant grass with molasses at level 5% was the most optimal combination technique to achieve high quality silage under smallholder farmers.

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CHAPTER FOUR

4.1 PAPER IV

Lyimo, B., Mtengeti, E.J., Urio, N.A and Ndemanisho, E.E. (2017). Effect of wilting, chopping length and maize bran levels on fodder grass silage quality. (Manuscript to be submitted in any reputable journal).

Effect of wilting, chopping lengths and different levels of maize bran on grass silage quality

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Abstract
Scarcity of feeds during dry season is one of the major constraints facing smallholder dairy production in Tanzania. Conserving excess fodder grasses available during wet season as silage, could increase dry season feed availability. However, appropriate technologies for conserving excess fodder grasses as silage in the wet season so as to reduce scarcity of feed in the dry season are still lacking among the smallholders dairy farmers in Tanzania. Therefore, the study was conducted to determine the effectiveness of wilting, chopping length and different levels of maize bran inclusion on elephant grass (*Pennisetum purpureum*) silage quality. Elephant grass was harvested when its regrowth reached a height of 1.5 m. The harvested grass was divided into two portions. One portion of grass was wilted for 24 hours prior to ensiling while the other portion was ensiled unwilted. Before ensiling each portion was divided into two sub-portions and the sub-portions chopped into either 2 or 4 cm pieces, respectively using a machete. Within each chop size (2 or 4 cm) the material was subdivided into four portions each of which were treated with four levels (0, 5, 10 and 15%) of maize bran. The experimental schedule comprised of two pre-ensiling treatments (wilted or unwilted), two chopping lengths and four additive levels which were arranged in a 2 x 2 x 4 factorial arrangement of treatments with two replicates. The silage was opened and sampled after 60 days, analyzed for sensoric qualities; chemical composition, in *vitro* DM digestibility, fermentation characteristics and stability. Wilted grass produced silages with higher ($p< 0.05$) appearance, smell and texture scores, DM, CP, water soluble carbohydrate (WSC), lactic and acetic acids, pH and stability but lower IVDMD, NDF, NH_3N and butyric acid than un-wilted grass silages. Silages produced from 2 cm chop showed higher ($p<0.05$) sensoric scores, DM, CP, WSC, IVDMD, lactic acid, acetic acid and stability but lower ($p<0.05$) NDF, pH, NH_3N and butyric acid than those from 4 cm chop. Silages treated with maize bran at 10 and 15% levels had higher DM, WSC and ash but lower ($p< 0.05$) NDF than the other levels (0 and 5). Silages treated with maize bran at 10% level had higher sensoric scores, CP, IVDMD, lactic acid, acetic acid and stability but lower NDF, pH, NH_3N and butyric acids than the other levels (0, 5 and 15%). The silage from wilted and chopped to 2 cm and treated with 10% maize bran had the highest IVDMD, CP and acetic acid. Wilted elephant grass, chopped to 2 cm and mixed with 10% maize bran seemed to be the appropriate combination techniques to improve fermentation and thus produce good grass silage under smallholder farmers.

***Key words**: Elephant grass, pre-ensiling treatments and Smallholder dairy farmers.*

Introduction

In the tropics, livestock production is often restricted by inadequate feed supply during prolonged dry seasons. Forage conservation in form of silage is an option to increase dry season feed availability. However, adoption of silage making among smallholders farmers in general has been limited (’t Mannetje, 2000). This is due to lack of better understanding of silage-making principles, not only by farmers but also by extensionists (Rangnekar, 2000). This becomes especially important when forages low in DM and WSC are to be ensiled. The main fodder grass established in East African highland which has been extensively adopted by dairy farmers due to its high productivity and persistence is elephant grass (Kitalyi *et al.*, 2005). Elephant grass can offer sufficient and good quality fodder, and the excess fodder can be conserved in form of silage, thereby ensuring availability of good quality feed for feeding dairy animals throughout the year. However, both the DM and WSC are considered to be too low for successful ensiling. Furthermore, the number of epiphytic lactic acid bacteria in elephant grass may be too low (Ohmomo *et al.*, 2002, Yahaya *et al.*, 2004) to ensure efficient fermentation process. Use of silage conservation technologies like, wilting, chopping and mixing additives to the fodder grass can improve fermentation process and therefore increase nutritional value of the silage. Wilting the forage before ensiling is recommended as a means of increasing DM, WSC and reducing losses from effluent and undesired fermentation (Nussio, 2005). Forage chopping may be alternative way to minimize *Clostridium* fermentation by promoting greater packing density and thus exclusion of air. Moreover, closer substrate contact with the fermenting bacteria, leads to higher lactate yield and faster pH reduction (Balsalobre *et al*., 2001). Adding of the carbohydrate-rich by products like maize bran promote the activity of epiphytic lactic acid bacteria. Despite of these useful technologies, lack of better understanding of silage-making principles becomes a barrier (Rangnekar, 2000). Farmers ensile their grasses without wilting, chopping or use any additives. Others chop and wilt grasses without using any additives, chop grasses mixing them with additives without wilting or wilt and mixing them with additives without chopping. Others may also use these techniques incorrectly like, chopping grasses without knowing exactly optimal chopping length or inclusive levels of additives. These unbalanced practices hinder production of high quality silages and demoralize farmers. Therefore, the current study aimed at assessing the effect of wilting, chopping lengths and different levels of maize bran on grass silage quality.

Materials and methods

Study area

The study was conducted in Magadu dairy farm at Sokoine University of Agriculture (SUA) in Morogoro municipal, Tanzania. The study site was located at about 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates). It is characterized by ambient temperature between 20-27^{o}C in the coolest months of April to August and 30 - 35^{o}C during the hottest month of October to February. The annual rainfall ranges from 600-1000 mm. Magadu farm was specifically selected because of its accessibily and its use for training University students and smallholder dairy farmers in the Easten zone of Tanzania.

Experiental design and treatments

The study adopted a completely randomized design with a 2 x 2 x 4 factorial treatment combination arrangement with two replicates. The experiment comprised of two wilting methods (wilted, unwilted), two chopping lengths (2, 4 cm) and four levels of maize bran (0, 5, 10 and 15%).

Source, harvesting, preparation of ensiling fodder grasses, ensiling procedure and storage

Elephant grass (*Pennisetum purpureum*) was harvested at 1.5 m tall, regrowth (Plate1). The harvested grass was divided into two portions. One portion of grass was wilted for 24 hours prior to ensiling while the other portion was ensiled unwilted. Before ensiling each portion was divided into two sub-portions and one sub-portion chopped into 2 cm and the other into 4 cm pieces by using a machete (Plate 2 and 3). Each chop portion was subdivided into four lots that were respectively treated with four levels (0, 5, 10 and 15%) of maize bran as additive (Plate 4).

The ensiling was done by filling the chopped grass materials in the ensiling plastic bag silos with 30 nm thickness. Air was squeezed out and the neck of the bag was twisted, turned over and tied with a rubber band. Thereafter, the ensiling plastic bag was labeled for treatment identity. Each bag was then inserted into a second empty shopping plastic bag (30 nm thicknesses) which was also tied, labeled and put in a hessian bag to protect it from rupturing (Plate 5). Hessian bags were then stored in thatched barn (Plate 6). Thatched barn is cheaper and affordable when compared with earth-pit (Lyimo, 2010). In the thatched barn, the hessian bags were carefully stacked on a wooden rack to allow ventilation and lower the temperature. Chicken wire mesh surrounded the wooden rack protecting the bags against rats, mice and birds, especially the crow who would view the bags as bin bags full of kitchen waste to consume.

Plate 1: Two portions of wilted and unwilted EG harvested.

Plate 2: Unwilted elephant grass was chopped either in 2 or 4 cm

Plate 3: Wilted elephant grass was chopped either in 2 or 4 cm

Plate 4: Elephant grass mixed with either 0,5,10 or 15% maize bran

Plate 5: Elephant grasswas ensiled

Plate 6: Ensiled grass was stored

Data collection procedures

After 60 days of fermentation, the plastic bag silos were opened and spoiled silage was separated from well preserved silage. Samples (weighing 500 g) from each bag were collected placed in polythene bags and immediately placed in a cool ice box and taken to the analytical laboratory. The sample was sub-divided into two samples. One sample was used for organoleptic test and pH determination. The other sub-samples were put in plastic bags and stored in a deep freezer at -10°C until they were used for chemical composition analysis and determination of *in vitro* dry matter digestibility (IVDMD).

The DM contents of the fresh ensiling material and silages were determined by drying in an oven at 65°C for 48 h (AOAC, 1984). The silages were freeze-dried in aLyphilizer maintained at -40 °C for 24 hrs according to Snowman (1988), so as to get a dry sample for ash, crude protein (CP), neutral detergent fibre (NDF), water soluble carbohydrates (WSC) analysis and IVDMD determination. Ammonia-nitrogen (NH_3N) was analyzed from fresh silage samples. The ash, CP and NH_3N were analyzed according to AOAC (2005) procedures while WSC was analyzed according to Thomas (1977). The NDF was analyzed according to Van Soest *et al*. (1991). A pH meter (model 219-MK 2; Pye Unicam) was used to measure the pH of the fresh silage samples. Samples of 40 mg from each silo were soaked in 200 ml of cool distilled water for 12 hours then filtered and the supernatant used for the determination of the pH. The *in vitro* dry matter of each of the silages were determined according to the two stage technique developed by Tilley and Terry (1963) and modified by Salabi *et al*. (2010).

The silages were analyzed for volatile fatty acids according to Shirlaw's (1967), procedure. Gas Chromatograph analyses were performed on a wide bore fused silica Cp-sil 19CB column, gas chromatograph equipped with a flame ionization detector (FID) $512x10^{-12}$ Afs. The technique used was gas chromatograph capillary column (10 m, 0.53 mm fused silica WCOT Cp-Sil 19CB (2.0 μm Cat. no.7647). The injector and detector temperatures were 275°C and 300°C respectively. The carrier gas was H_2 40kPa (0.4bar) 170 cm/s. The analyses were performed using a temperature programme: a linear gradient from 80°C to 280°C at 25°C min^{-1}. In each case a 0.1μL of sample was injected (a flow splitting 1:10). Silage stability was determined by observing the change of pH of exposed silage after sixty days of fermentation. Each day the pH of each treatment was recorded for 7 days consecutively.

Organoleptic Test

The organoleptic test was carried out at the Department of Animal, Aquaculture and Range Sciences laboratory of SUA by trained 30 assessors of Animal Science Undergraduate and Postgraduate Students. Each assessor assessed the silage from each treatment and scored its physical characteristics in terms of appearance, texture and smell. Appearance score No.1 (poor) indicated spoiled silage which was dark brown in color with mould growth, score No. 2 (moderate) olive green in colour with some mould growth, score No. 3 (good) light yellow or green brown colour and score No.4 (very good) indicated well pickled light green/yellowish green colour silage. Smell score No.1 (poor) indicated foul smell associated with putrefaction or tobacco like smell, score No. 2 (moderate) pungent smell of ammonia, score No. 3 (good) pleasant estery aroma and score No. 4 (very good) pleasant aroma typically silage smell. Texture score, No.1 (poor) slimy and watery, score No. 2 (moderate) firm, less slimy and wet No.3 (good) moderate firm, non-slippery and wet No. 4 (very good) very firm, non-slippery and slightly wet. The test was carried once after 60 days of fermentation, when ensiling bags (silos) were opened and spoiled silage separated from well preserved silage.

Data analysis

The General Linear Model (GLM) procedure of Statistical Analysis System (2008) used to analyze the data was based on the following statistical model: $Y_{ijklm} = \mu + W_i + C_j + A_k + (WC)_{ij} + (WA)_{ik} + (CA)_{jk} + E_{ijklm}$; whereby Y_{ijklm}= observation from the m^{th} sample drawn from the l^{th} replication within the k^{th} additive level, j^{th} chopping length and i^{th} wilting method; μ = general mean common to all observations in the experiment; W_i = effect of the i^{th} wilting method; C_j = effect of the j^{th} chop length; A_k =effect of the k^{th} additive level; $(WC)_{ij}$, $(WA)_{ik}$ and $CA)_{jk}$ are interaction effects of the factors indicated by the corresponding symbols; E_{ijklm}= random effects peculiar to each observation in the experiment.

Results and discussion

Chemical composition and digestibility of fodder grasses at the time of ensiling

Results on DM, CP, WSC, ash, NDF and IVDMD of elephant grass at the time of ensiling are summarized in (Table 1). Maize bran had relatively higher DM and CP than elephant grass. Effective ensiling relies on the fermentation of WSCs to lactic acid by lactic acid bacteria. WSC in the parent forage should be >2.5%, on a fresh forage basis, for good silage fermentation. If WSCs are <2.5%, the forage should be wilted or a silage additive used to reduce the risk of a poor fermentation.

Table 1: Mean chemical composition and digestibility of elephant and maize bran at the time of ensiling

Par. (%)	Elephant grass	Maize bran	Par. (%)	Elephant grass	Maize bran
DM	19.9	90.04	Ash	13.5	10.9
CP	10.1	11.9	NDF	73.9	61.6
WSC	3.19	4.51	IVDMD	59.3	66.3

Par.- parameter, DM –Dry matter, CP-Crude protein, WSC-Water soluble carbohydrates, NDF-Neutral detergent fibre IVDMD – in vitro-digestibility

Effect of wilting, chopping lengths and different levels of maize bran on grass silage organoleptic tests

Wilted grass silage had higher ($p< 0.05$) appearance, smell and texture scores than un-wilted grass silage (Table 2). This might have been due to reduced moisture which provided favorable fermenting condition to fermenting microbes resulting to good physical scoring. This also favours the growth of lactic acid bacteria and improved silage fermentation quality (Charmley, 2001).

Silages produced from 2 cm chop showed higher ($p< 0.05$) sensoric scores than those from 4 cm chop. This could be due to greater packing density promoted by 2 cm chop than 4 cm chop, thus excluded air in silage which resulted to good condition for fermentation process. The results were in consistence with those reported by O'Kiely (2001), who recommended 1-2 cm chopping length as best chop to achieve good fermentation. Shorter chop length increases rate of release of fermentation substrates and improves compaction. Silages treated with maize bran at 10% level had higher ($p< 0.05$) sensoric scores than silages treated with maize bran at other levels (0, 5 and 15%). The results might have been due to provision of optimal energy by maize bran at 10% level that created conducive environment for the anaerobic fermentation bacterialeading to efficient fermentation. This is in line with Ziggers (2003) who stated that, 'successful silage production depends on the promotion of fermentation by beneficial bacteria'. The results showed that, at 15% silage quality drops; this might be due to achievement of more than optimal maize bran level for satisfactory fermentation, which impaired the fermentation process.

Table 2: Mean effects of wilting, chopping length and different levels of maize bran on organoleptic tests of grass silage

Parameter	Effect of wilting				Effect of chopping length			
	Uwgs	**Wgs**	**SEM**	**p-value**	**2 cm**	**4 cm**	**SEM**	**p-value**
App.	2.94^{b}	3.81^{a}	0.073	0.0001	3.50^{a}	3.25^{b}	0.064	0.0001
Smell	2.88^{b}	3.75^{a}	0.035	0.0001	3.38^{a}	3.25^{b}	0.035	0.0001
Texture	3.00^{b}	3.69^{a}	0.067	0.0001	3.44^{a}	3.25^{a}	0.066	0.0001
	Effect of maize bran levels							
	MB 0%	**MB 5%**	**MB10%**	**MB 15%**	**SEM**	**p-value**		
App.	2.63^{b}	3.50^{a}	3.75^{a}	3.63^{a}	0.103	0.0001		
Smell	2.50^{c}	3.50^{b}	3.75^{a}	3.50^{b}	0.049	0.0001		
Texture	2.50^{b}	3.50^{a}	3.75^{a}	3.63^{a}	0.094	0.0001		

App-appearance, uwgs-unwilted grass silage, wgs- wilted grass silage, MB – maize bran, SEM - standard error of means. Means within row with different superscript letters are significantly different ($p < 0.05$).

Effect of wilting, chopping lengths and different levels of maize bran on chemical composition of grass silage

Wilted silage had higher ($p< 0.05$) DM, CP, WSC and ash but lower ($p< 0.05$) NDF and IVDMD than unwilted silages (Table 3). The observed high DM could be attributed to reduced moisture content in wilted than unwilted grass silages which favor fermentation process leading to more DM recovery. Wilted grass had DM over 20 percent which assured good fermentation. The results are in agreement with Gou *et al.* (2000) who stated that, 'DM should be over 20 percent to assure good silage quality'. Observed high CP could be due to decreased grass proteolysis by elevated external WSC by wilting and speed up lactic acid bacteria settlement. High WSC possibly was due to increased substrate for fermentation leading to rapid pH reduction and stops the process then WSC remains as recovery substrate. These results are in agreement with those reported by McDonald *et al.* (2002). Higher ash in wilted grass than in unwilted could be due to higher concentration of inorganic substances in wilted grass than in unwilted grass. Improved NDF possiblywas due to increased acidity stimulated further hydrolysis of linked sugar molecules in the cell wall causing further breakdown of hemicelluloses. Low digestibility could be due to loss of available nutrients and an increase in ash concentration. According to Keady (1998), wilting reduces silage digestibility due to a loss of available nutrients and an increase in ash concentration.

Two cm choppingsilageshad higher ($p < 0.05$) DM, CP and WSC and IVDMD but lower ($p < 0.05$) NDF than 4 cm chopping length (Table 3). Observed high DM in 2cm chopped silage could be due to greater packing density and thus exclusion of air than in 4 cm chopped silage. These results werealmost similar to those reported by O'Kiely (2001), who observed better results of short chop length than long chop length and recommended 1-2 cm chopping length. According to Piltz and Kaiser (2004) short chop length reduces fermentation losses of DM and energy. Too long chop make compaction more difficult. Observed higher CP may be due to efficient fermentation caused by closer substrate contact with the fermenting bacteria, leading to faster pH reduction and this decreased proteolysis. These results concur with those of Balsalobre *et al.* (2001) who observed closer substrate contact with the fermenting bacteria, leads to higher lactate yield and faster pH reduction. The results were also in agreement with Piltz and Kaiser (2004) who stated that, short chop length reduces degradation of the protein fraction.

Higher amount of WSC was retained in 2 cm chopped silages as compared with 4 cm chopped silages probably due to thorough compaction and thus expulsion of air and this stoped the aerobic process and then WSC remains as recovery substrate. These results agreed with Panditharatne *et al.* (1986) and Mushi *et al.* (2000) that chopping of forages prior to ensiling restricts losses of carbohydrates due to aerobic deterioration because of thorough compaction and thus expulsion of air. Observed lower NDF indicated that 2 cm chop enhance more breakdown of cell wall structure than 4 cm chop and thus favour fermentative process. These results are in line with those reported by Balsalobre *et al.* (2001) who reported that, chopping helps breakdown of cell wall structure which aid in fermentative efficiency. Higher digestibility in 2 cm chopped silages was probably due to closer substrates contact providing efficient fermentation process leading to adequate provision of useful energy substrate for ruminal microbes and thus strengthening their effectiveness in digesting feed particles. In contrast, Titterton *et al.* (2002) working with tropical forages in Southern Africa, found no effect of chop length on fermentation and nutritional quality of silages. Silages treated with maize bran at 10 and 15% level had higher ($p < 0.05$) DM and WSC and ash but lower ($p<0.05$) NDF than the other levels

(Table 3). Higher DM is probably due to ability of maize bran at 10 and 15% level to absorb moisture from silage than maize bran at 0 and 5% levels. Maize bran as an absorbent additive is used in crops with a low DM to prevent excessive effluent losses. Good results have been obtained with maize bran at 10% level as reported by Manyawu *et al.* (2003) and Lyimo (2010). On the other hand, silages treated with maize bran at 10% level had higher ($p < 0.05$) CP and IVDMD than the other levels (0, 5 and 15%). The possible reason of increase in CP may be due to protein sparing activity and pH has been reduced sufficiently to inactivate the plant proteolytic enzymes. Leibensperger and Pitt (1988) pointed out that a rapid decrease in pH inhibits clostridial fermentation and hydrolysis of plant proteins by plant enzymes.

Table 3: Mean effects of wilting, chopping length and different levels of maize bran on chemical composition of grass silage

	Effect of wilting				**Effect of chopping length**			
	Uwgs	**wgs**	**SEM**	**P-value**	**2 cm**	**4 cm**	**SEM**	**P-values**
DM	19.3[b]	21.9[a]	0.054	0.0001	20.9[a]	20.3[b]	0.054	0.0001
CP	9.46[b]	9.94[a]	0.039	0.0001	9.77[a]	9.63[b]	0.031	0.0001
WSC	3.03[a]	3.31[b]	0.029	0.0001	3.34[a]	3.01[b]	0.029	0.0001
Ash	12.4[a]	12.6[a]	0.049	0.0001	12.7[a]	12.3[b]	0.049	0.0001
NDF	73.5[a]	71.5[b]	0.147	0.0001	72.2[b]	72.8[a]	0.147	0.0001
IVDMD	55.9[a]	53.9[b]	0.135	0.0001	55.4[a]	54.5[b]	0.135	0.0001
	Effect of MB levels							
	MB 0%	**MB 5%**	**MB 10%**	**MB 15%**	**SEM**	**P-value**		
DM	19.9[c]	20.2[b]	21.3[a]	21.06[a]	0.076	0.0001		
CP	9.46[c]	9.62[b]	10.02[a]	9.69[b]	0.043	0.0001		
WSC	2.95[c]	3.1[b]	3.33[a]	3.31[a]	0.041	0.0001		
Ash	12.2[b]	12.3[b]	12.9[a]	12.8[a]	0.070	0.0001		
NDF	74.6[a]	73.4[b]	70.9[c]	71.3[c]	0.207	0.0001		
IVDMD	53.6[d]	54.5[c]	56.5[a]	55.1[b]	0.191	0.0001		

Uwgs-unwilted grass silage, wgs- wilted grass silage, MB – maize bran, SEM - Standard error of means.Means within row with different superscript letters are significantly different ($P < 0.05$).

Interaction of wilting, chopping length and different levels of maize bran on chemical composition of grass silage

Wilting and 2 cm chop produced silages with highest IVDMD (Table 4). Furthermore, wilting and maize bran at 10% produced silage with highest IVDMD and CP. Moreover, the interaction of chopping lengths (2 cm, 4 cm) and different maize bran levels (0%, 5% 10% and 15%) showed that 2 cm chop and maize bran at 10% produced silage with highest IVDMD and CP. Highest IVDMD possibly was due to sufficient provision of useful energy substrate for ruminal microbes and thus strengthening their effectiveness in digesting feed particles. Observed highest CP could be due to decreased proteolysis by elevated external WSC by wilting and maize bran.

Table 4: Mean interaction effect of wilting, chopping length and different levels of maize bran on chemical composition of grass silage

Effect of wilting and chopping lengths			Effect of wilting and MB levels				Effect of chopping lengths and MB levels			
wilt	**chop** (cm)	**IVDMD**	**wilt**	**MB (%)**	**CP**	**IVDMD**	**chop** (cm)	**MB (%)**	**CP**	**IVDMD**
Uw	2	54.3^{b}	uw	0	9.06^{a}	52.3^{a}	2	0	9.59^{b}	53.9^{b}
	4	53.6^{a}		5	9.42^{b}	53.9^{b}		5	9.68^{d}	54.7^{d}
w	2	56.4^{d}		10	9.85^{e}	55.1^{c}		10	10.1^{g}	57.4^{h}
	4	55.4^{c}		15	9.53^{c}	54.4^{c}		15	9.73^{e}	55.5^{f}
SEM		0.191	W	0	9.87^{f}	54.9^{c}	4	0	9.33^{a}	53.3^{a}
p-value		0.0001		5	9.82^{d}	55.1^{c}		5	9.55^{a}	54.4^{c}
				10	10.2^{g}	57.9^{e}		10	9.99^{f}	55.6^{g}
				15	9.86^{e}	55.8^{d}		15	9.66^{c}	54.7^{e}
			SEM		0.061	0.27	**SEM**		0.061	0.27
			p-value		0.0001	0.0001	**p-value**		0.0001	0.0001

MB – maize bran, uw – unwilted, w-wilted, SEM- Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).

Effect of wilting, chopping lengths and different levels of maize bran on fermentative quality of grass silages

Wilted silage had higher lactic, acetic acids and pH but had lower ($p< 0.05$) NH_3N and butyric acid than unwilted grass silage (Table 5). The high proportion of lactic and acetic acids for silages made from wilted herbage indicates the dominance of lactic acid bacteria. High pH in wilted grasses could be attributed to the lower water activity of the wilted herbage (Greenhill 1964) which would have created more inhibitory conditions for microbial fermentation (Woolford 1984). These findings concur with McEniry *et al.* (2008) and Keles *et al.* (2009), who found higher pH in wilted grasses. The lower NH_3N in wilted grasses indicated that, less proteolysis in wilted grass silage than in unwilted grass silage. The low butyrate value showed relative difficulty in clostridial growth in the wilted fodder grass material. McDonald *et al*. (2002) reported butyric acid values as low as 0.14% and 0.06 % in well preserved unwilted and wilted grass silages respectively.

The observed higher ($p< 0.05$) lactic and acetic acids but lower ($p< 0.05$) pH, NH_3N and butyric acid in 2 cm chopped than in 4 cm chopped silage could be attributed to greater packing density in 2 cm chopped silage 2 cm and thus exclusion of air which resulted to rapid pH drop leading to high lactic production. According to Piltz and Kaiser (2004), short length increases amount of lactic acid produced in wilted silages. The fermentation process reduced pH sufficiently to inactivate the plant photolytic enzymes which completely stopped at pH 4.5 to 3.8 leading to no more NH_3N production. According to Leibensperger and Pit (1988), a rapid decrease in pH inhibits clostridia fermentation and hydrolysis of plant proteins by plant enzymes. Reduced particle size by chopping grasses before ensiling reduced pH and NH_3N below the acceptable values of $\leq$4.2 and <10% respectively which denotes good silage fermentation. Neumann *et al.* (2007), evaluating the effect of particle size (small: 0.2 to 0.6 cm or large: 1.0 to 2.0 cm) and cutting height of corn plants (low: 15 cm or higher: 39 cm) on silage fermentation dynamics and opening period, found that small sized particles provide greater compression efficiency and consequently reduces pH. Low butyric acid showed relatively difficulty in clostridial growth in the 2 cm chopped silages.

The observed higher ($p < 0.05$) lactic and acetic acids but lower ($p < 0.05$) pH, NH_3N and butyric acids in silages mixed with maize bran at 10% than maize bran at 0, 5 and 15% could be due to optimal additional energy supplied by the additives that created more conducive environment for the anaerobic fermentation bacteria. This was in agreement with ‘t Mannetje (2000) who reported that additional energy supplied by the additives provided good environment for anaerobic fermentation bacteria. Lyimo (2010) and Mtengeti *et al.* (2013) had observed good silages at 10% maize bran for elephant grass. Lactic acids are relatively strong and their production in silo causes pH to drop, which is essential in the rush to kill-off less desirable organisms before they consume valuable nutrients and DM (McDonald *et al.*, 2002). Acetic acid was relatively high, but it has been indicated by Lima *et al.* (2010) that a good quality silage is associated with at least 70% but no more than 90% lactic acid and no more than 20% acetic acid (% of total short chain fatty acids). The ratio of lactic acid to acetic acid is a good indicator of the efficiency of the silage fermentation. The NH_3N concentrations were below the 12% of the total-N recommended by Molina *et al.* (2002) for good quality silage, indicating low proteolysis during fermentation, due to adequate soluble carbohydrates supply, that makes possible a rapid decline of pH.

Table 5: Mean effects of wilting, chopping length and different levels of maize bran on fermentative quality of grass silage

	Effect of wilt-ing				**Effect of chop-ping length**			
	Uwgs	wgs	**SEM**	**P-value**	**2 cm**	**4 cm**	**SEM**	**P-value**
pH	4.02^{b}	4.37^{a}	0.029	0.0001	4.11^{b}	4.28^{a}	0.029	0.0001
NH_3N	1.57^{a}	1.50^{b}	0.004	0.0001	1.51^{b}	1.57^{b}	0.004	0.0001
Lactic acid	1.014^{a}	1.13^{b}	0.004	0.0001	1.12^{a}	1.038^{b}	0.005	0.0001
Acetic acid	0.43^{a}	0.53^{b}	0.004	0.0001	0.495^{a}	0.46^{b}	0.004	0.0001
Butyric acid	0.095^{a}	0.00^{b}	0.018	0.0001	0.0103^{b}	0.084^{a}	0.018	0.0001

	Effect of maize bran levels					
	MB 0%	**MB 5%**	**MB 10%**	**MB 15%**	**SEM**	**P-value**
pH	4.33^{a}	4.25^{a}	4.08^{b}	4.13^{b}	0.040	0.0001
NH_3N	1.59^{a}	1.58^{a}	1.49^{b}	1.5^{b}	0.005	0.0001
Lactic acid	0.57^{c}	0.75^{b}	1.49^{a}	1.48^{a}	0.007	0.0001
Acetic acid	0.22^{d}	0.36^{c}	0.76^{a}	0.57^{a}	0.005	0.0001
Butyric acid	0.15^{a}	0.02^{b}	0.00^{b}	0.018^{b}	0.026	0.0001

Uwgs-unwilted grass silage, wgs- wilted grass silage, MB – maize bran, SEM - Standard error of means. Means within row with different superscript letters are significantly different (P < 0.05).

Interaction effect of wilting, chopping length and different levels of maize bran onfermentative quality of grass silage

Highest quantity of acetic acid have been reported in silages produced from interaction of wilted grass and 2 cm chop, interaction of wilted grass and maize bran at 10% and interaction of 2 cm chop and maize bran at 10% (Table 6). Observed highest acetic acid could be due to reduced moisture by wilting, increased closer substrate contact of grass by chopping grasses at 2 cm and increased WSC by adding optimal substrates for microbes. Production of acetic acid is considered positive because it has been reported by Danner *et al.* (2003) that acetic acid increases the aerobic stability due to the inhibition of spoilage organisms.

Table 6: Combination effect of wilting, chopping length and different levels of maize bran on fermentative quality of grass silage

Effect of wilting and chopping lengths			Effect of wilting and MB levels			Effect of chopping lengths and MB levels		
Wilt	**Chop** (cm)	**Acetic acid**	**Wilt**	**MB (%)**	**Acetic acid**	**Chop** (cm)	**MB (%)**	**Acetic acid**
Uwg	2	0.44^{a}	Uwgs	0	0.15^{a}	2	0	0.23^{b}
	4	0.42^{a}		5	0.31^{c}		5	0.39^{d}
Wgs	2	0.56^{c}		10	0.68^{g}		10	0.79^{h}
	4	0.5^{b}		15	0.56^{e}		15	0.58^{f}
SEM		0.191	Wgs	0	0.29^{b}	4	0	0.22^{a}
p-value		0.0001		5	0.4^{d}		5	0.33^{c}
				10	0.84^{h}		10	0.73^{g}
				15	0.58^{f}		15	0.57^{e}
			SEM		0.061	**SEM**		0.0071
			p-value		0.0001	**p-value**		0.0001

MB – maize bran, Uwgs-unwilted grass silage, wgs- wilted grass silage , SEM- Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).

Effect of wilting, chopping lengths and different levels of maize bran on stability of grass silages

After silos are opened for feeding, air penetrates the silages and promotes the growth of aerobic, acid-tolerant microorganisms and the oxidation of fermentation products in the silages. This so-called aerobic deterioration can cause spoilage of silages and may lead to potentially toxic substances or undesirable microorganisms (Lyimo, 2010). Silage with high pH values falling within the range of 5.0 to 7.0 results into poorly preserved silage (McDonald *et al*., 2002). Clostridia microbes prefer to grow at pH values of 7.0 to 7.4 (McDonald *et al*., 2002). The pH increase is a main indicator of aerobic deterioration due to lactic acid reduction. The results indicated that, silages with wilted grasses were more stable (in terms of maintaining low pH less than five for longer period) than un-wilted grasses (Table 7). Unwilted grass silages had pH greater than five from day 0 while wilted grasses maintained the pH less than five up to the third day of feeding out. This implied that wilting has an influence on the stability and it is important for high quality silage. This was in consistence with other workers elsewhere (Mtengeti *et al*., 2006) who found good fermentation after wilting the fodder grass.

The results indicated that, silages from 2 cm chopping were more stable (in terms of maintaining low pH value less than five for longer period) than those with 4 cm chopping. Those silages from 4 cm chopping had pH greater than five up to the second day while those from 2 cm chopping maintained the pH less than five up to the third day of feeding out. The observed higher stability in 2 cm chop than in 4 cm chop could be attributed to greater packing density in 2 cm chop and thus exclusion of air in silage than

4 cm chop. This resulted into a rapid pH drop leading to high lactic acid production which inhibits clostridia bacteria and acetic acid and thus prolonged silage stability. A basic principle of ensiling is to provide adequate compaction of the crop to minimize air infiltration (Coetzee, 2000). The results indicated that, silages with 10% maize bran additive were more stable (in terms of maintaining low pH less than five for longer period) than those with maize bran at 0%, 5% and 15% levels. At 10% maize bran silage was stable up to fourth day while at 15% stayed up to the third day and at 5% only up to the second day. Higher stability might be due to achievement of optimal maize bran level for satisfactory fermentation. This implied that optimal maize additive level was 10%. This observation was nearly similar to those observed by Jaurena and Pichard (2001),‘t Mannetje (2000), who reported an influence of additives on the stability of the silage quality during the feeding out.

Table 7: Mean effects of wilting, chopping length and different levels of maize bran on stability of fodder grass silages

pH	Effect of wilting				Effect of chopping length			
	Uwgs	**Wgs**	**SEM**	**P-value**	**2 cm**	**4 cm**	**SEM**	**P-value**
Phdy0	4.01^{a}	4.32^{b}	0.001	0.0001	4.11^{b}	4.23^{a}	0.046	0.0001
Phdy1	4.56^{a}	4.58^{a}	0.006	0.0001	4.51^{b}	4.64^{a}	0.034	0.0001
Phdy2	5.07^{a}	4.66^{b}	0.017	0.0001	4.76^{b}	4.97^{a}	0.071	0.0001
Phdy3	5.16^{a}	4.78^{b}	0.009	0.0001	4.89^{b}	5.05^{a}	0.009	0.0001
Phdy4	5.50^{a}	5.16^{b}	0.003	0.0001	5.27^{b}	5.39^{a}	0.003	0.0001
Phdy5	6.19^{a}	5.85^{b}	0.002	0.0001	5.96^{b}	6.09^{a}	0.048	0.0001
Phdy6	6.66^{a}	6.32^{b}	0.002	0.0001	6.42^{b}	6.56^{a}	0.002	0.0001
Phdy7	6.57^{a}	6.38^{b}	0.002	0.0001	6.41^{b}	6.54^{a}	0.002	0.0001
	Effect of maize bran levels							
	MB 0%	**MB 5%**	**MB 10%**	**MB 15%**	**SEM**	**P-value**		
Phdy0	5.02^{a}	4.43^{b}	4.18^{d}	4.28^{c}	0.0020	0.0001		
Phdy1	5.18^{a}	4.57^{b}	4.24^{d}	4.37^{c}	0.0120	0.0001		
Phdy2	5.28^{a}	4.78^{b}	4.49^{d}	4.66^{c}	0.0242	0.0001		
Phdy3	5.38^{a}	5.11^{b}	4.81^{d}	4.98^{c}	0.0125	0.0001		
Phdy4	5.58^{a}	5.25^{b}	4.96^{d}	5.11^{c}	0.0042	0.0001		
Phdy5	5.98^{a}	6.05^{b}	6.02^{d}	6.04^{c}	0.0042	0.0001		
Phdy6	6.53^{a}	6.44^{b}	6.34^{d}	6.25^{c}	0.0025	0.0001		
Phdy7	6.73^{a}	6.61^{b}	6.41^{d}	6.53^{c}	0.0025	0.0001		

Uwgs –unwilted grass silage, wgs- wilted grass silage, Phdy 0–7 is pH measured from day 1-7, MB- maize bran, SEM- Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different (P < 0.05).

Conclusions

Wilted grass had higher (P< 0.05) appearance, smell and texture scores, DM, CP, WSC, lactic and acetic acids, pH and stability but lower (P< 0.05) IVDMD, NDF, NH_3N and butyric acid than unwilted grass silages. Silages produced from 2 cm chop showed higher (P<0.05) sensoric scores, DM, CP, WSC, IVDMD, lactic acid, acetic acid and stability but lower NDF, pH, NH_3N and butyric acid than those from 4 cm chop. Silages treated with maize bran at 10% level had higher (P< 0.05) sensoric scores, CP and IVDMD, lactic acid, acetic acid and stability but lower NDF, pH, NH_3N and butyric acids than the other levels (0, 5 and 15%). Wilting and 2 cm chopping length produced silages with highest IVDMD and acetic acid. Wilting and 10% maize bran produced silage with highest IVDMD, CP and acetic acid. Chopping length of 2 cm with maize bran at 10% produced silage with highest IVDMD, CP and acetic acid.

Recommendations

It was therefore recommended that, wilted elephant grass, chopped at 2 cm and mixed with maize bran at 10% level was the most optimal combination of elephant grass silage making techniques to achieve high quality silage fermentation under smallholder farmers.

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4.2 PAPER V

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Effect of wilting, chopping lengths and different levels of molasses on grass silage quality

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Abstract

The productivity of dairy cattle under smallholder farmers has been small due to unavailability of adequate quality feeds. Silage can be an option to improve feed availability and quality to the animals. However, the effect of the iterraction of silage making technologies such as wilting, chopping length and different levels of molasses has rarely been documented. This study therefore, aimed at determining the effect of wilting, chopping lengths and different levels of molasses on grass silage quality**.** Elephant grass (*Pennisetum purpureum*) was harvested when its regrowth was 1.5 m tall. The harvested grass was divided into two portions. One portion of grass was wilted for 24 hours prior to ensiling while the other portion was ensiled un-wilted. Before ensiling each portion was chopped into either 2 or 4 cm pieces using a machete. Within each chop size (i.e. 2 or 4 cm) the material was subdivided into three portions each of which was treated with a three levels (0, 3 and 5%) of molasses as additive.Treatments combinations were assigned to a randomized factorial design (2 x 2x 3) as two pre-ensiling treatments (wilted and unwilted), two chopping treatments (2 or 4 cm) and molasses additive level (0, 3 and 5%) with two replications. The silage was opened and sampled after 60 days, analyzed for sensoric qualities; chemical composition, in *vitro* DM digestibility, fermentation characteristics and stability. Wilted grass produced silages with higher appearance, smell and texture scores, DM, CP, water soluble carbohydrate (WSC), ash, lactic acid, acetic acid, pH and stability but lower NDF, IVDMD, NH_3N and butyric acid than unwilted grass. Silages produced from 2 cm chop showed significantly higher sensoric scores, DM, CP, WSC, IVDMD, lactic acid, acetic acid and stability but lower NDF, pH, NH_3N and butyric acid than those from 4 cm chop. Silages treated with molasses at 5% level had higher ($p<0.05$) sensoric scores, DM, CP, WSC, ash, IVDMD, lactic acid, acetic acid and stability but lower ($p< 0.05$) NDF, pH, NH_3N and butyric acid than silages treated with molasses at 0 and 3% levels. Wilting and 2 cm chop, wilting and molasses at 5% and 2 cm chop and molasses at 5% produced silages with highest sensoric scores, DM, WSC, lactic acid, but lowest NDF, pH and NH_3N. Therefore, wilted elephant grass, chopped 2 cm and mixed with 5% molasses was the most optimal combination techniques to achieve high quality elephant grass silage fermentation under smallholder farmers.

***Key words:** Elephant grass, pre-ensiling treatments, Smallholder dairy farmers.*

Introduction

The dairy industry is among the most important components of the livestock sector which is used as a source of animal protein, income and employment (Njombe *et al.*, 2012). The sector has a great potential for improving the living standards of the people and contributing towards reduction of poverty. The Tanzanian dairy sector contributes roughly 30% to livestock Gross Domestic Product (NIRAS, 2010) and 1.53% to overall GDP (Makoni *et al*., 2014). Despite this, it has not developed substantially due to lack of quality pastures particularly during the dry season. This is an issue of serious concern and needs to be addressed in order to improve dairy production. Silage can be an option to increase the feed supply to the animals in unfavorable times. One of the tropical grasses that stand out for its good characteristics for ensilage is elephant grass, which presents a high productive potential and elevated phytomass production (Queiroz Filho *et al.,* 2000) and can be used for silage. Like other tropical grasses, the composition of elephant grass produces low quality silage (Mtengeti *et al.*, 2013, Lyimo, 2010). In order to improve crop preservation and its feeding value various technologies such as wilting, chopping and additives have been applied (Nussio, 2005; Balsalobre *et al.*, 2001; Aminah *et al.,* 2000; Lyimo, 2010, Lyimo *et al*., 2016). Various researchers (Keady *et al*., 2000; Yunus *et al*., 2000; Van Niekerk *et al.,* 2007; Nkosi *et al.*, 2009; Lyimo, 2010) have shown that additives such as molasses can be applied to improve the fermentation process and the quality of silage. Molasses has been reported to be used extensively in ruminants, both as a binder for compound feeds and source of additional energy to the diet (Weisbjerg *et al*., 2007). However, the effect of wilting, chopping lengths and different levels of molasses on grass silage quality has rarely been documented. Therefore, the current study, aimed at determining the effect of wilting, chopping lengths and different levels of molasses on grass silage quality so as to obtain the optimal silage making technique for smallholder dairy farmers.

Materials and methods

Study area

The study was conducted in Magadu dairy farm at Sokoine University of Agriculture (SUA) in Morogoro municipal, Tanzania. The study site was located at about 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates). It is characterized by ambient temperature between 20-27 ^{o}C in the coolest months of April to August and 30 - 35^{o}C during the hottest month of October to February. The annual rainfall ranges from 600-1000mm. Magadu farm was specifically selected because of its accessibily and its use for training University students and Smallholder dairy farmers in the Easten zone of Tanzania.

Experimental design and treatments

The study adopted a completely randomized design with a 2 x 2 x 4 factorial treatment combination arrangement with two replicates. The experiment comprised of two wilting methods (wilted, unwilted), two chopping lengths (2, 4 cm) and four levels of maize bran (0, 5, 10 and 15%).

Source, harvesting, preparation of ensiling fodder grasses, ensiling procedure and storage

Elephant grass (*Pennisetum purpureum*) was harvested at 1.5 m tall, regrowth (Plate1). The harvested grass was divided into two portions. One portion of grass was wilted for 24 hours prior to ensiling while the other portion was ensiled unwilted. Before ensiling each portion was divided into two sub-portions and one sub-portion chopped into 2 cm and the other into 4 cm pieces by using a machete (Plate 2 and 3). Each chop portion was subdivided into four lots that were respectively treated with four levels (0, 5, 10 and 15%) of maize bran as additive (Plate 4).

The ensiling was done by filling the chopped grass materials in the ensiling plastic bag silos with 30 nm thickness. Air was squeezed out and the neck of the bag was twisted, turned over and tied with a rubber band. Thereafter, the ensiling plastic bag was labeled for treatment identity**.** Each bag was then inserted into a second empty shopping plastic bag which was also tied, labeled and put in a hessian bag to protect it from rupturing (Plate 5). Hessian bags were then stored in thatched barn (Plate 6). Thatched barn is cheaper and affordable when compared with earth-pit (Lyimo, 2010). In the thatched barn, the hessian bags were carefully stacked on a wooden rack to allow ventilation and lower the temperature. Chicken wire mesh surrounded the wooden rack protecting the bags against rats, mice and birds, especially the crow who would view the bags as bin bags full of kitchen waste to consume.

Plate1: Grasses were established and harvested

Plate 2: Unwilted elephant grass chopped at 2 cm and 4 cm

Plate 3: Wilted elephant grass chopped at 2 cm and 4 cm

Plate 4: Elephant grass mixed with either 0, 3 or 5% molasses

Plate 5: Elephant grass was ensiled

Plate 6: Ensiled grass was stored

Data collection procedures

After 60 days of fermentation, the plastic bag silos were opened and spoiled silage was separated from well preserved silage. Samples (weighing 500 g) from each bag were collected placed in polythene bags and immediately placed in a cool ice box and taken to the analytical laboratory. The sample was subdivided into two samples. One sample was used for organoleptic test and pH determination. The other was put in plastic bags and stored in a deep freezer at -10°C until when they were used for chemical composition analysis and determination of *in vitro* dry matter digestibility (IVDMD).

The DM of the fresh ensiling material and silages were determined by drying in an oven at 65°C for 48h (AOAC, 1984). The silages were freeze-dried in aLyphilizer maintained at - 40ºC for 24 hrs according to Snowman (1988) so as to get a dry sample for ash, crude protein (CP), neutral detergent fiber (NDF), water soluble carbohydrates (WSC) analysis and IVDMD determination. Ammonia-nitrogen (NH_3N) was analyzed from fresh silage samples. The ash, CP and NH_3N were analyzed according to AOAC (2005) procedures while WSC was analyzed according to Thomas (1977). The NDF was analyzed according to Van Soest *et al*. (1991). A pH meter (model 219-MK 2; Pye Unicam) was used to measure the pH of the fresh silages samples. Samples of 40 g from each silo were soaked in 200 ml of cool distilled water for 12 hours then filtered and the supernatant used for the determination of the pH. The IVDMD of the silages were determined according to the two stage technique developed by Tilley and Terry (1963) and modified by Salabi *et al*. (2010). The silages were analyzed for volatile fatty acid according to Shirlaw's (1967) procedure. Gas Chromatograph analyses were performed on a wide bore fused silica Cp-sil 19CB column, gas chromatograph equipped with a flame ionization detector (FID) 512×10^{-12} Afs. The technique used was gas chromatograph capillary column (10m, 0.53 mm fused silica WCOT Cp-Sil 19CB (2.0 µm Cat.no.7647). The injector and detector temperatures were 275°C and 300°C respectively. The carrier gas was H_2 40kPa (0.4bar) 170 cm/s. The analyses were performed using a temperature programme: a linear gradient from 80°C to 280°C at 25°C min^{-1}. In each case a 0.1µL of sample was injected (a flow splitting 1:10). Silage stability was determined by observing the change of pH of exposed silage after sixty days of fermentation. Each day the pH of each treatment was recorded for 7 days consecutively.

Organoleptic Test

The organoleptic test was carried out at the Department of Animal, Aquaculture and Range Sciences laboratory of SUA by trained 30 assessors of Animal Science Undergraduate and Postgraduate Students. Each assessor assessed the silage from each treatment and scored its physical characteristics in terms of appearance, texture and smell. Appearance score No.1 (poor) indicated spoiled silage which was dark brown in color with mould growth, score No. 2 (moderate) olive green in colour with some mould growth, score No. 3 (good) light yellow or green brown colour and score No. 4 (very good) indicated well pickled light green/yellowish green colour silage. Smell score No.1 (poor) indicated foul smell associated with putrefaction or tobacco like smell, score No. 2 (moderate) pungent smell of ammonia, score No. 3 (good) pleasant estery aroma and score No. 4 (very good) pleasant aroma typically silage smell. Texture score, No.1 (poor) slimy and watery, score No. 2 (moderate) firm, less slimy and wet No. 3 (good) moderate firm, non-slippery and wet No. 4 (very good) very firm, non-slippery and slightly wet. The test was carried once after 60 days of fermentation.

Data analysis

The General linear Model (GLM) procedure of Statistical Analysis System (SAS, 2008) used to analyze the data was based on the following statistical model: $Y_{ijklm} = \mu + W_i + C_j + A_k + (WC)_{ij} + (WA)_{ik} + (CA)_{jk} + E_{ijklm}$; whereby Y_{ijklm}= observation from the m^{th} sample drawn from the l^{th} replication within the k^{th}additive level, j^{th} chopping length and i^{th} wilting method; μ = general mean common to all observations in the experiment; W_i = effect of the i^{th} wilting method; C_j = effect of the j^{th} chop length; A_k =effect of the k^{th}additive level; $(WC)_{ij}$, $(WA)_{ik}$ and $CA)_{jk}$ are interaction effects of the factors indicated by the corresponding symbols; E_{ijklm}= random effects peculiar to each observation in the experiment.

Results and discussion

The chemical composition and digestibility of elephant grass and molasses at the time of ensiling

Results on DM, CP, WSC, ash, NDF and IVDMD of elephant grass at the time of ensiling are shown in Table 1. Molasses additive had relative higher DM and WSC than fodder grass.

Table 1: Mean chemical composition and digestibility of elephant and maize bran at the time of ensiling

Parameter (%)	Elephant grass	Molasses	Parameter (%)	Elephant grass	Molasses
DM	19.9	65.30	Ash	13.5	10.6
CP	10.1	2.17	NDF	73.9	0
WSC	3.19	52.9	IVDMD	59.3	Nd

DM –Dry matter, CP-Crude protein, WSC-Water soluble carbohydrates, NDF-Neutral detergent fibre IVDMD – in vitro-digestibility, Nd –not determined

Effect of wilting, chopping lengths and different levels of molasses on grass silage organoleptic tests

Wilted grass silage had higher ($p<0.05$) appearance, smell and texture scores than un-wilted grass silage (Table 2). This might have been due to reduced moisture contents and increased concentration of WSC for the fermenting microbes that led to good fermentation process. The results are in agreement with those reported by Filya (2003) that, wilting process and molasses promote lactate production during the initial hours of fermentation in the silo. High lactate production reflected good fermentation and sensoric scoring.

The higher ($p< 0.05$) scores of appearance, smell and texture score in 2 cm chopped grass silages than 4 cm chopped grass silages could probably be due to greater packing density and thus exclusion of air and moisture in 2 cm silages than 4 cm silages which resulted to good condition for fermentation process. From this study, the particle size seems to have an influence on the compression and consequently the silage density leading to good condition for fermentation. Igarasi (2002) reported an inverse relationship between particle size and silage density, suggesting that the smaller the particle size the greater the packing density and thus there will be less oxygen remaining among the plant particles. Neumann *et al*. (2007) evaluating the effect of particle size (small: 0.2 to 0.6 cm or large: 1.0 to 2.0 cm) and cutting height of corn plants (low: 15 cm or higher: 39 cm) on silage fermentation dynamics and opening period, found that small sized particles provide greater compression efficiency and consequently reduces temperature and pH gradients in the silo. From this study also, the plant particle size after chopping was directly related to the success of fermentation.

Silages with 5% molasses showed higher ($p<0.05$) sensoric scores, manifested by good appearance and a pleasant smell sensed just after opening the silo compared to other molasses levels (0 and 3%). This could be attributed to the provision of adequate energy provided to fermenting bacteria by molasses at 5% leading to efficient fermentation. Fermentation with addition of molasses indicates good silage quality as well as colour, smell and no fungal growth (Snijders and Wouters, 2004). The results were in agreement with those reported by Lyimo (2010) and Mtengeti *et al.* (2013) who obtained good sensoric scores after applying molasses at 5% level to elephant grass. Snijders and Wouters (2004) reported that, addition of 3% molasses obtained good quality silage. The level of 5% molasses may be sufficient for producing good quality silage (Thanh *et al*., 2000). The presence of fungus in silage is undesirable because it uses silage nutrients and toxins are sometimes produced (Man and Wiktorsson, 2003).

Table 2: Mean effects of wilting, chopping length and different levels of molasses on organoleptic tests of grass silage

Parameter	Effect of wilting				Effect of chopping length			
	Unwilted grass silage	**wilted grass silage**	**SEM**	**p-value**	**2 cm**	**4 cm**	**SEM**	**p-value**
Appearance	2.33^b	3.42^a	0.124	0.0001	3.25^a	2.50^b	0.124	0.0001
Smell	2.50^b	3.42^a	0.111	0.0001	3.25^a	2.67^b	0.111	0.0001
Texture	2.42^b	3.33^a	0.124	0.0001	3.17^a	2.58^b	0.124	0.0001
	Effect of molasses levels							
	MOL 0%	**MOL 3%**	**MOL 5%**	**SEM**	**p-value**			
Appearance	2.25^c	2.88^b	3.5^a	0.152	0.0001			
Smell	2.13^c	3.0^b	3.75^a	0.136	0.0001			
Texture	2.25^c	2.87^b	3.50^a	0.152	0.0001			

MOL–molasses, Score 1 = Poor Score 2=Moderate Score 3= good, 4= very good, SEM- Standard error of means.Means within row with different superscript letters are significantly different (P < 0.05).

Combined effect of wilting, chopping length and different levels of molasses on organoleptic test of grass silage quality

Wilting and 2 cm chop, wilting and molasses at 5% and 2 cm chop and maize bran at 5% produced silage with highest appearance, smell and texture (Table 3). Highest sensoric scores werepossibly due to sufficient provision of useful energy substrate for microbes and satisfactory packing density leading to efficient fermentation.

Table 3: Mean combining effect of wilting, chopping length and different levels of molasses on organoleptic tests of grass silage

Wilt	chop (cm)	App	Smell	Text	chop cm	MOL%	App	Smell	Text
Unw	2	2.67^{b}	2.83^{b}	2.67^{c}	2	0	2.75^{a}	2.50^{b}	2.5^{b}
	4	2.00^{a}	2.17^{a}	2.17^{a}		3	3.25^{b}	3.25^{d}	3.25^{c}
W	2	3.83^{d}	3.67^{d}	3.67^{d}		5	3.75^{d}	4.00^{f}	3.75^{d}
	4	3.00^{c}	3.17^{c}	3.00^{c}	4	0	1.75^{a}	1.75^{a}	2.0^{a}
SEM		0.157	0.157	0.157		3	2.5^{a}	2.75^{c}	2.50^{b}
p-value		0.0001	0.0001	0.0001		5	3.25^{b}	3.5^{e}	3.25^{c}
						SEM	0.21	0.193	0.21
						p-value	0.0001	0.0001	0.0001

App **-** *appearance, Text* **-** *texture, MOL– molasses, unw – unwilted, w-wilted, SEM- Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).*

Effect of wilting, chopping lengths and different levels of molasses on chemical composition of grass silage

Wilted silage had higher (p< 0.05) DM, CP, WSC and ash but lower NDF and IVDMD than unwilted silages (Table 4). The higher DM of wilted silages than unwilted silages could be attributed to reduced moisture in wilted than unwilted grass silages which favor fermentation process leading to more recovery DM. According to Borreani *et al.* (2009) wilting is applied to reduce the moisture that has to be transported from the field to the silo. Increased CP means less proteolysis has taken place during fermentation, thus, wilting increases fermentation efficiency by reducing moisture content in silages, leading to favorite fermentation.Increased WSC was probably due to high content of WSC in wilted grass. Higher ash in wilted grass than in unwilted could be due to higher concentration of minerals or soil contamination, in wilted grass than in unwilted grass. According to Keady (1998) wilting increases ash concentration. Reduced NDF could be due to increased acidity stimulated further hydrolysis of linked sugar molecules in the cell wall causing further breakdown of hemicelluloses. The results were in consistent withKhan *et al.* (2006) and Rezaei *et al.* (2009) who reported reduced fibre in forage through ensiling. Wilting reduces silage digestibility due to a loss of available nutrientsand an increase in ash concentration (Keady, 1998). The author reported that, the rate of decline in digestibility due to wilting depends on the length of time between mowing and ensiling herbage and soil contamination due to tedding. Chopping length at 2 cm had higher (p< 0.05) DM, CP, WSC, IVDMD but lower NDF than 4 cm chopping length. The higher DM in 2 cm than those from 4 cm chopping silages could be could be due to greater packing density provided by 2 cm than 4 cm chopping silages grass which favor fermentation process leading to more DM recovery. This result was in agreement with those reported by O'Kiely (2001) who recommended 1-2 cm chopping length for well fermented grass silages. Good compaction exclude air from silages and thus favours anaerobic conditions, thus not only reducing losses caused by deterioration but also reducing storage costs, increasing DM recovery, aerobic stability and *in vitro* DM digestibility (Muck *et al.*, 2003). The higher CP may be due to efficient fermentation, preservation and stability of silagecaused by closer substrate contact with the fermenting bacteria, which restricts proteolysis. Higher amount of WSC retained in 2 cm chopped silage as compared with 4 cm chopped silage could be due to thorough compaction and thus expulsion of air and encouragement of early decline of the pH and thus impriving the recovery of WSC. This agreed with Mushi *et al.* (2000), that chopping of forages prior to ensiling restricts losses of carbohydrates due to aerobic deterioration because of thorough compaction and thus expulsion of air and encouragement of early decline of the pH of ensiled mass. The lower NDF indicated chop length of 2 cm led to more plant surfaces exposure for enzymatic hydrolysis of the linked sugar molecules in hemicelluloses than chop 4 cm. Increased digestibility could be attributed to sufficient provision of substrate close contact with fermenting microbes and thus strengthening their effectiveness in digesting feed particles.

Silages treated with 5% molasses had higher ($p< 0.05$) DM, CP, WSC, ash and IVDMD but lower NDF than silages treated with molasses at 0 and 3% levels. Increasing of molasses level increased silage DM because the DM content of molasses is higher than that of elephant grass. Moreover, the high DM could also be attributed to additional energy supplied by molasses at 5% level resulting to efficient fermentation hence more DM recovery. Increased DM at higher levels of molasses has been reported by Yunus *et al.* (2000). The high CP was in agreement with other reports in which molasses resulted in a positive influence on CP (Migwi *et al.,* 2000; Baytok *et al.,* 2005; Mahala and Khalifa, 2007). This is not surprising because molasses has been reported to have up to 44 g CP/kg DM (Xande *et al.,* 2010). Protein losses in the ensiling procedure might depend on the run off of proteolytic end products with the effluent (Man and Wiktorsson 2001). Extensive proteolysis occurs during the first few days of ensiling and if the pH can be reduced rapidly to 4.3 the proteolytic activity will be decreased. In the present study the DM content of herbage materials was sufficiently high to avoid seeping and silage pH went down quickly to prevent the loss of silage protein. It has been reported that biological additives reduced proteolysis during ensiling and resulted in improved efficiency of silage protein utilization and reduced N losses (Charmley, 2001).

Increased WSC could be due to high concentration of soluble carbohydrate in molasses (Aksu *et al.,* 2006). In practice, molasses is widely used as an additive to enhance the process of ensiling (Yunus *et al.,* 2000; Van Niekerk *et al.*, 2007) because of its high content of WSC. According to Baytok *et al.* (2005) molasses is a stimulant of silage fermentation. It is a stimulant additive because it contains sugar that is utilized by microorganisms as the nutrition matter and increases their fermentation activity (McDonald *et al*., 1991). Addition of molasses results in higher ash levels because molasses itself hashigh mineral contents which ultimately increaseashcontent (Gofeen and Khalifa, 2007). The reduction of NDF observed in all the experimental silages may be explained by low concentration of NDF in molasses which resulted into a dilution effect. According to Baytok *et al.* (2005) silage NDF decreased ($P<0.05$) with the addition of molasses, because enhancement of cell wall degradation due to increased silage fermentation caused by the sugars in molasses and the lower NDF of the molasses.Increased digestibility could be attributed to sufficient provision of useful energy substrate for microbes through molasses at 5% level and thus strengthening their effectiveness in digesting feed particles.

Table 4: Mean effects of wilting, chopping length and different levels of molasses on chemical composition of grass silage

	Effect of wilting				Effect of chopping length			
	Un-wilted grass silage	wilted grass silage	SEM	P-value	2cm	4cm	SEM	P-value
DM	19.1[b]	21.6[a]	0.063	0.0001	20.9[a]	19.8[b]	0.063	0.0001
CP	9.30[b]	10.1[a]	0.043	0.0001	9.9[a]	9.47[b]	0.043	0.0001
WSC	2.82[b]	3.41[a]	0.055	0.0001	3.33[a]	2.89[b]	0.055	0.0001
Ash	12.2[b]	12.5[a]	0.048	0.0001	12.5[a]	12.1[b]	0.048	0.0001
NDF	73.2[a]	70.9[b]	0.045	0.0001	71.4[b]	72.6[a]	0.045	0.0001
IVDMD	56.2[a]	53.7[b]	0.166	0.0001	55.5[a]	54.5[b]	0.166	0.0001

	Effect of MOL levels				
	0%	3%	5%	SEM	P-value
DM	19.5[c]	20.01[b]	21.5[a]	0.077	0.0001
CP	9.2[c]	9.62[b]	10.2[a]	0.053	0.0001
WSC	2.82[c]	3.1[b]	3.43[a]	0.068	0.0001
Ash	11.9[c]	12.2[b]	12.9[a]	0.059	0.0001
NDF	73.6[a]	71.9[b]	70.5[c]	0.055	0.0001
IVDMD	53.5[c]	54.9[b]	56.5[a]	0.204	0.0001

Score 1 = Poor Score 2=Moderate Score 3= good, 4= very good, SEM- Standard error of means. Means within row with different superscript letters are significantly different (P < 0.05).

Combined effect of wilting, chopping length and different levels of molasses on chemical composition of grass silage

The combined effect of wilting and 2 cm chop, wilting and molasses at 5% and 2 cm chop and molasses at 5% produced silage with highest DM and WSC but lowest NDF (Table 5). Highest DM and WSC possibly were due to sufficient provision of useful energy substrate for microbes and optimal packing density for efficient fermentation. Forage fibre (NDF) content has been regarded as an important factor in the regulation of forage intake. Reduced NDF could be due to hydrolysis of NDF-N bound during fermentation (Huisden *et al.*, 2009) and low concentration of NDF in molasses which resulted into a dilution effect. This agreed also with Guney *et al.* (2007) who reported a decrease in fibre in molasses treated sorghum silage compared to the control. Both studies recorded improved digestibility of DM compared to the control.

Table 5: Mean combined effect of wilting, chopping length and different levels of molasses on chemical composition of grass silage quality

Combined effect of wilting and different chopping lengths					Combined effect of wilting and MOL at different levels				
Wilt	**chop** cm	**DM**	**WSC**	**NDF**	**wilt**	**MOL (%)**	**DM**	**WSC**	**NDF**
Unw	2	19.6[b]	3.06 [b]	72.6[c]	unw	0	18.5[a]	2.28[a]	74.5[f]
	4	18.6[a]	2.57[a]	73.5[d]	unw	3	19.0[b]	2.9[b]	73.1[e]
W	2	22.3[d]	3.59[d]	70.2[a]	unw	5	19.8[c]	3.2[c]	71.8[c]
	4	20.9[c]	3.22[c]	71.6[b]	w	0	3.22[d]	72.8[d]	72.8[d]
SEM		0.088	0.078	0.06	w	3	21.02[e]	3.3[e]	70.7[b]
p-value		0.0001	0.0001	0.0001	w	5	23.10[f]	3.65[f]	69.2[a]
						SEM	0.108	0.096	0.077
						p-value	0.0001	0.0001	0.0001

Combined effect of chopping lengths and different levels of MOL				
Chop (cm)	**MOL (%)**	**DM**	**WSC**	**NDF**
2	0	20.0[c]	3.1[c]	73.2[e]
	3	20.7[c]	3.28[e]	71.3[c]
	5	22.1[e]	3.6[f]	69.8[a]
4	0	19.04[a]	2.53[a]	74.1[f]
	3	19.3[b]	2.91[b]	72.4[d]
	5	20.9[d]	3.25[d]	71.2[b]
	SEM	0.108	0.096	0.077
	p-value	0.0001	0.0001	0.0001

MOL– molasses, unw – unwilted, w-wilted, SEM- Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).

Effect of wilting, chopping lengths and different levels of molasses on fermentative quality of grass silages

Wilted silage had higher ($p < 0.05$) lactic acid, acetic acid and pH but had lower NH_3N and lower butyric acid than unwilted grass silage (Table 6). High proportion of lactic acid and acetic acid for silages made from wilted herbage indicates the dominance of lactic acid bacteria. The high pH could be attributed to lower water activity of the wilted herbage (Greenhill, 1964), which created more inhibitory conditions for microbial fermentation (Woolford 1984). Lyimo *et al.* (2016) also reported increased pH with wilting. Silage ammonia is reduced when plant enzyme activity, nitrate reduction and proteolysis decrease (Whiter and Kung, 2001).

Silages produced from 2 cm chop showed higher ($p < 0.05$) LA and AA but lower pH, NH_3N and BA than those from 4 cm chop. The lower ($p < 0.05$) pH 2 cm of chopped grass silage concurred closely with findings of other workers elsewhere for well preserved high moisture grass silages (Yakota *et al.*, 1998 and Mtengeti *et al.*, 2006). The lower pH and NH_3N values in 2 cm chopped than 4 cm chopped silage could be a result of increased affinity of the forage tissues for multiplication of LAB and rapid achievement of optimum anaerobic condition due to well compacted chopped pre-ensiling material that facilitated better exclusion of air. According to Piltz and Kaiser

(2004), short chop lengths can result in a lower silage pH, makes compaction of the forage in the silo easier, and reduces the volume of forage transported at harvest and storage space required. Lower butyric acid in 2 cm chopped grass silages than 4 cm chopped grass silages showed relative difficulty in clostridial growth. Clostridia adversely affect silage preservation because: - they compete with LAB for WSC needed to produce lactic acid; saccharolytic clostridia degrade WSC and lactic acid to butyric acid. This raises silage pH; proteolytic clostridia degrade proteins and amino acids to ammonia, amines and volatile fatty acids, reducing the utilisation of silage nitrogen by livestock; clostridia activity increases fermentation losses of DM and energy; and clostridia activity reduces silage palatability and lowers the nutritive value of the silage through the loss of energy and degradation of protein.

Silage from 5% molasses had higher ($p< 0.05$) lactic acid, acetic acid but had lower pH, NH_3N and butyric acid than silages treated with molasses at 0 and 3% levels. Zobell *et al.* (2004) stated that good silage has lactic acid levels ranging from 30 to 140 g/kg (0.03-1.4) and those of the present study were higher than that threshold, suggesting good fermented silages. This may be attributed to high WSC levels pre-ensiling. There are some reports that confirmed reduced acetic acid in silage with molasses (Baytok *et al*., 2005; Van Niekerk *et al*., 2007; Kwak *et al.*, 2009). In contrast, Gül *et al.* (2008) reported that adding molasses to grass silage increased the acetate. A likely explanation is the finding that the addition of molasses to wilted lucerne increased the acetate and decreased the lactate to acetate ratio, as reported by Hashemzadeh-Cigari *et al.* (2011). However, high concentrations of acetic acid could have been the result of poor compaction and retention of air pockets. Enterobacteriaceaehowever, are the main acetate-producing bacteria in silage and they strictly depend on fermentable carbohydrates for anaerobic growth (Buxton *et al.*, 2003), so added molasses can stimulate their growth during fermentation phases. Zhang *et al.* (2010) stated that a 2: 1 ratio of lactic acid to acetic acid is anindicator of strong homolactic fermentation. Since the grass silage lactate: acetate ratio (LA: AA) was more than 2:1, it suggests theyunderwent homolactic - fermentation. Otherwise, if the silagelactate: acetate ratio (LA: AA) was less than 2:1, it suggests they underwent hetero-fermentation. The concomitant production of lactic and acetic acids is considered positive because acetic acid increases the aerobic stability due to the inhibition of spoilage organisms (Danner *et al*., 2003). According to Filya (2003), molasses limiting clostridia growth and promotes lactate production during the initial hours of fermentation in the silo. This supported by others (Baytok *et al.*, 2005; Van Niekerk *et al*., 2007; Nkosi *et al*., 2009) who confirmed reduced butyric acid with molasses addition.

The reduced pH with addition of molasses probably was due to additional substrate levels for lactic acid bacteria. McDonald *et al.* (2002) reported that well-preserved silages had a pH range of 3.8 to 4.2; those of the present study were within the same range. Ammonia-N in silage reflects the degree of protein degradation, and extensive proteolysis adversely affects the availability of N to ruminants (Wilkinson, 2005). The low ammonia concentrations are indicative of minimal protein breakdown during the ensiling process. Well-preserved silages should contain less than 100 g NH_3-N/kg TN (McDonald, *et al.*, 2002). In this study, NH_3 content was good for all the molasses additive treatments. This can be explained by the fact that increasing molasses additive reduced pH in silage product rapidly, resulting in decreasing NH_3 production. Furthermore, this may be attributed also to the low CP available in the silages. Molasses is primarily an energy supplement, but is deficient in protein. Moreover, Clostridia can grow in silage that has high soluble carbohydrate and they can degrade protein to ammonia (Ward *et al.*, 2001) but with low pH clostridia are restricted. Molasses has high concentration of soluble carbohydrate that can stimulate heterofermentation process in silage (Aksu *et al.*, 2006) but due to low pH deamination process could be decreased (Slottner and Bertilsson, 2006). In contrast, Baytok *et al.* (2005) obtained higher ammonia-N in molasses treated silage compared to the control, citing high moisture content of forage and the level of molasses used. High concentrations of ammonia (>12% to 15% of CP) are a result of excessive protein breakdown caused by a slow drop in pH or clostridial action (Kung and Shaver, 2001).

Table 6: Mean effects of wilting, chopping length and different levels of molasses on fermentation characteristics of grass silage

Par.	Uwgs	Wgs	SEM	P-value	2 cm	4 cm	SEM	P-value
pH	3.94 [b]	4.13[a]	0.029	0.0001	3.92[b]	4.15[a]	0.029	0.0001
NH_3N	1.48[a]	1.42[b]	0.004	0.0001	1.41[b]	1.48[a]	0.004	0.0001
LA	0.99[b]	1.082[a]	0.006	0.0001	1.073[a]	1.007[a]	0.006	0.0001
AA	0.48[a]	0.61[a]	0.004	0.0001	0.569[a]	0.524[a]	0.004	0.0001
BA	0.11[a]	0.00[b]	0.023	0.0001	0.0062[b]	0.103[a]	0.023	0.0001
	Effect of MOL levels							
	MOL 0%	**MOL 3%**	**MOL 5%**	**SEM**	**P-value**			
pH	4.11[a]	4.08[a]	3.91[b]	0.036	0.0001			
NH_3N	1.49[a]	1.47[a]	1.39[b]	0.005	0.0001			
LA	0.668[c]	0.853[b]	1.59[a]	0.007	0.0001			
AA	0.319[c]	0.457[b]	0.862[a]	0.005	0.0001			
BA	0.147[a]	0.017[b]	0.000 [b]	0.028	0.0001			

Par.-parameter, LA-lactic acid, AA-acetic acid, BA-Butyric acid, MOL – Molasses, uwgs – unwilted grass silage, wgs-wilted gras silage, SEM- Standard error of means. Means within row with different superscript letters are significantly different (P < 0.05).

Combined effect of wilting, chopping length and different levels of molasses on fermentative quality of grass silage

The interaction of wilting and 2 cm chop, wilting and molasses at 5% and 2 cm chop and 5% molasses produced silage with highest lactic acid but lower pH and NH_3N (Table 7). This could be attributed to sufficient provision of useful energy substrate for fermenting microbes and optimal packing density leading to efficient fermentation. The useful energy might have been obtained from reduced moisture by wilting, leading to increased WSC, additional optimal WSC from 5% molasses and reduced grass chop length which put closer particles in contact with the fermenting bacteria for efficient fermentation.

Table 7: Combined effect of wilting, chopping length and different levels of molasses on fermentative quality of grass silage

Effect of wilting and chopping lengths					Effect of wilting and MOL levels				
Wilt	**Chop** cm	**pH**	**NH_3N**	**Lactic acid**	**wilt**	**MOL %**	**pH**	**NH_3N**	**Lactic acid**
Unw	2	4.05^c	1.46^c	1.02^b	unw	0	4.31^d	1.52^d	0.6^a
	4	4.5^d	1.51^d	0.97^a		3	4.03^c	1.503^c	0.74^b
W	2	3.8^a	1.39^a	1.12^d		5	3.86^a	1.44^a	0.9^d
	4	4.01^b	1.44^b	1.04^c	w	0	4.29^c	1.46^c	0.84^c
SEM		0.042	0.0052	0.008	w	3	3.93^b	1.45^b	1.55^e
p-value		0.0001	0.0001	0.0001	w	5	3.78^a	1.33^a	1.65^f
						SEM	0.0509	0.0063	0.0095
						p-value	0.0001	0.0001	0.0001

Effect of chopping lengths and MOL levels				
chop cm	**MOL (%)**	**pH**	**NH_3N**	**Lactic acid**
2	0	3.99^b	1.47^d	0.71^b
	3	3.91^a	1.46^c	0.86^d
	5	3.86^a	1.35^a	1.65^f
4	0	4.25^d	1.5^e	0.63^a
	3	4.23^c	1.49^d	0.85^c
	5	3.94^a	1.44^a	1.55^e
SEM		0.0509	0.0063	0.0095
p-value		0.0001	0.0001	0.0001

MOL– molasses, Mol – molasses, unw – unwilted, w-wilted, SEM- Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).

Effect of wilting, chopping lengths and different levels of molasses on stability of grass silages

Aerobic stability is a measure of the shelf life of silage aerobic stability is important because many (dairy) producers contract silage delivery for 2-4 days worth of feed. Silage removed, but not fed immediately, is exposed to air for an extended time period (Muck and Holmes, 2000). According to Lyimo *et al.* (2016), silage stability is determined by observing the change of pH of exposed silage for several days. In silages made from tropical grasses, a pH of 4.2 has been reported as the maximum to consider silage to be well-preserved (McDonald *et al*., 2002). In case of silage stability, because it takes several days, silage maintaining low pH value (<5) for longer period has been considered as more stable silage (Lyimo, 2010; Lyimo *et al.*, 2016). The results indicated that, silages with wilted grasses were more stable (in terms of maintaining low pH value (<5) for longer period) than unwilted grasses (Table 8). Unwilted grass silages had pH values > 5 from day 0 while wilted grasses maintained the pH values < 5 up to the third day of feeding out this implied that wilting have an influence on the stability and it is important for high quality silage. This was in consistent with other report by Mtengeti *et al.* (2006) who found good fermentation after wilting the grass.

The results indicated that, silages from 2 cm were more stable in terms of maintaining low pH value (<5) for longer period than those from 4 cm chop. Those silages from 4cm chop had pH values <5 up to the second day while those from 2 cm chop maintained the pH values <5 up to the third day of feeding out. This could be attributed to greater packing density promoted by 2 cm chop and thus exclusion of air in silage as compared to 4 cm chop. Greater packing density resulted to rapid decline in pH with high lactic production which prolonged the silage stability. It has been established that improved aerobic stability of silages is associated with higher concentrations of acetic acid compared to untreated silages (Danner *et al.*, 2003, Nkosi *et al.*, 2009). Silages with molasses at 5% level were more stable (in terms of maintaining low pH (<5) for longer period) than those from molasses at 0% and 3% levels. Those silages with molasses at 0% had pH > 5 from day 0 while those with molasses at 3% maintained the pH< 5 up to the third day whereas silages with molasses at 5% level maintained the pH< 5 up to the fourth day of feeding out. This implies that an additive level has an influence on the stability and it is important for high quality silage. The aerobic stability of the silage with molasses was increased thereby potentially preventing the growth of spoilage organisms (Danner *et al.*, 2003).

Table 8: Mean effects of wilting, chopping length and different levels of molasses on stability of fodder grass silages

	Effect of wilting				Effect of chopping length			
pH	**UWGS**	**WGS**	**SEM**	**p-value**	**2 cm**	**4 cm**	**SEM**	**p-value**
Phdy0	5.01[a]	4.32[b]	0.0059	0.0001	4.11[b]	4.23[a]	0.0459	0.0001
Phdy1	5.09[a]	4.58[a]	0.0171	0.0001	4.51[b]	4.64[a]	0.0337	0.0001
Phdy2	5.16[a]	4.66[b]	0.0088	0.0001	4.76[b]	4.97[a]	0.0705	0.0001
Phdy3	5.23[a]	4.78[b]	0.0030	0.0001	4.89[b]	5.05[a]	0.0088	0.0001
Phdy4	5.50[a]	5.16[b]	0.0018	0.0001	5.27[b]	5.40[a]	0.0030	0.0001
Phdy5	6.19[a]	5.85[b]	0.0018	0.0001	5.96[b]	6.09[a]	0.0480	0.0001
Phdy6	6.66[a]	6.32[b]	0.0018	0.0001	6.42[b]	6.56[a]	0.0018	0.0001
Phdy7	6.56[a]	6.38[b]	0.0018	0.0001	6.41[b]	6.54[a]	0.0018	0.0001

	Effect of MOL levels				
	MOL 0%	**MOL 3%**	**MOL 5%**	**SEM**	**p-value**
Phdy0	5.03[a]	4.11[b]	4.03[c]	0.0019	0.0001
Phdy1	5.11[a]	4.62[b]	4.41[c]	0.0083	0.0001
Phdy2	5.18[a]	4.93[a]	4.69[b]	0.0242	0.0001
Phdy3	5.25[a]	4.98[b]	4.72[c]	0.0125	0.0001
Phdy4	5.48[a]	5.35[b]	4.86[d]	0.0042	0.0001
Phdy5	5.98[d]	6.05[a]	5.53[c]	0.0042	0.0001
Phdy6	6.53[b]	6.54[b]	6.44[d]	0.0025	0.0001
Phdy7	6.53[a]	6.51[b]	6.41[d]	0.0025	0.0001

Phdy 0-7-is pH measured from day 1-7, MOL – molasses, SEM- Standard error of means. Ab least significant means and means within row with different superscript letters are significantly different (P < 0.05).

Conclusions

Wilted grass produced silages with higher (P<0.05) appearance, smell and texture scores, DM, CP, WSC, ash, lactic and acetic acids, pH and stability but lower (P< 0.05) NDF, IVDMD, NH_3N and butyric acid than unwilted grass silages. Silages produced from 2 cm chop showed higher (P<0.05) sensoric scores, DM, CP, WSC, IVDMD, lactic acid, acetic acid and stability but lower (P< 0.05) NDF, pH, NH_3N and butyric acid than those from 4 cm chop. Silages treated with 5% molasses had higher (P<0.05) sensoric scores, DM, CP, WSC, ash, IVDMD, lactic acid, acetic acid and stability but lower (P< 0.05) NDF, pH, NH_3N and butyric acid than silages treated with no or treated with 3%

molasses. Wilting and 2 cm chopping produced grass silages with highest sensoric scores, DM, WSC, lactic acid, but lowest NDF, pH and NH_3N. Wilting and 5% molasses produced silage with highest sensoric scores, DM, WSC, lactic acid, but lowest NDF, pH and NH_3N. Chopping lengths of 2 cm with 5% molasses produced silage with highest sensoric scores, DM, WSC, lactic acid but lowest NDF, pH and NH_3N.

Recommendations

It was recommended that, wilted elephant grass, chopped to 2 cm and mixed with 5% molasses was the most optimal combination techniques to achieve high quality grass silage fermentation under smallholder farmers.

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CHAPTER FIVE

5.1 PAPER VI

Lyimo, B.J., Mtengeti, E.J., Urio, N.A and Ndemanisho, E.E. (2017). Effect of grass specie, ensiled amount in shopping plastic bags and storage positions on grasssilage quality (Manuscript to be submitted in any reputable journal).

Effect of grass specie, ensiled amount in shopping plastic bags and storage positions on grasssilage quality

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Abstract

Smallholder production in Tanzania is constrained by inadequacy and seasonality of feed and its quality. During dry season, dairy cattle are underfed resulting to low milk production. Smallholder dairy farmers need to be equipped with simple but appropriate grass conservation technology which can be easily adopted. A study was conducted to determine the effect of fodder grass species, ensiled amount inplastic bag siloand storage positions on silage quality. Elephant (*Pennisetum purpureum*), guatemala (*Tripsacum laxum*) and rhodes grasses (*Chloris gayana*) were harvested when their regrowth were 120, 63 and 56 days old, respectively. Nutritive value declines quickly as plant matures thus were harvested at respective recommended stages of growth for each grass. The harvested grasses were chopped into 2 cm particle length before ensiling. The chopped materials were ensiled in portions of 5, 10 or 12 kg in plastic bag silos. The plastic bags were placed in hessian bags and stored either in a thatched barn or in a trench. The experimental design was completely randomized design under 3 x 3 x 2 factorial arrangement of three grass species (elephant, guatemala and rhodes grasses), three ensiled amount (5, 10 and 12 kg) and two storage positions with two replications. The silage was opened and sampled after 60 days, analyzed for chemical composition, fermentation and sensoric qualities, *in vitro* DM digestibility and stability. Elephant grass produced silages with higher ($p< 0.05$) sensoric scores, crude protein (CP), ash, lactic acid, acetic acid and stability but lower ($p< 0.05$) pH, NH_3N and butyric acid than the other two grasses. The 5 and 10 kg ensiled amounts showed higher appearance, smell and texture scores, DM, CP, WSC, ash, IVDMD, lactic acid, acetic acid and stability but lower NDF, pH, NH_3N and butyric acid than 12 kg ensiled amounts.There was no difference ($p>0.05$) between the two ensiled amounts (5 and 10 kg) in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, lactic acid, acetic acid and butyric acid. There were no differences ($p> 0.05$) between silages stored in thatched barn and trench in terms of sensoric scores, DM, CP, WSC, ash, NDF and IVDMD, pH, NH_3N, lactic acid, acetic acid, butyric acid and stability.Elephant grass ensiled either as 5 or 10 kg and stored either in thatched barn or trench showed highest CP, lactic acid but lowest pH and NH_3N. It was therefore concluded that, either 5 or 10 kg of elephant grass ensiled in shopping plastic bag silo, stored in either thatched barn or in trench was the most optimal combination technology to achieve high silage quality under smallholder farmers.

***Key words**: Chloris gayana, Pennisetum purpureum, smallholder dairy farmers,* thatched barn, trench and *Tripsacum laxum*

Introduction

Low availability of forage in the dry season reduces the dairy cattle productivity, making it essential to establish a strategy for forage conservation (Vilela and Carneiro, 2002). Silage is a feed for ruminants resulting in the preservation of fresh forage crops by acidification, which is achieved under anaerobic environment. The process of ensiling mainly depends upon the chemical and microbial composition of forage. During the fermentation process, changes in chemical composition of forage occur mainly due to bacterial activities. According to Lyimo (2010) limitation in silage production in tropics is lack of simple but optimal technologies for conserving excess forages in the wet season. The smallholder farmers are not able to utilize most of the forages biomass present in the rain season. If these forages are left to grow and mature in the fields they will lose their nutritive value thereby resulting in wastage of valuable feed resource (Lyimo, 2010). According to Machin (2000) important factors to improve adoption of silage by smallholders in the tropics are low investment costs, low risks, and the potential of rapid and significant returns on investments. Elephant, guatemala and rhodes grasses are the most predominant fodder grass species found in smallholder dairy farms in Tanzania and could be used for silage. These fodder grasses could be ensiled in plastic bag silos. Plastic bags are cheap and are available in the country and can be used as silos to ensile different amounts of grasses as has been reported by different authors in Pakistani, Benin, Zimbabwe, Kenya and Tanzania (Lane, 2000; Ashbell *et al.*, 2001; Delacollette *et al.*, 2005; Pariyar, 2005; Mtengeti and Urio, 2006; Lyimo, 2010). Morever, trench or thatched barn could be used as storage positions for those ensiled grasses as they have been reported by Lyimo (2010) and Mtengeti *et al.* (2013). However, the effect of fodder grass species, ensiled amounts and storage positions to achieve high quality silage for smallholder dairy farmers have rarely been documented. Therefore, this study intends to evaluate the effects of fodder grass species, ensiled amounts and storage positions on silage quality.

Materials and Methods

Study area

The study was conducted in Magadu dairy farm at Sokoine University of Agriculture (SUA) in Morogoro municipal, Tanzania. The study site was located at about 526 m.a.s.l (S 6° 50' 58.80" E 37°39'12.22" GPS coordinates). It is characterized by ambient temperature between 20-27 ^{o}C in the coolest months of April to August and 30 - 35 ^{o}C during the hottest month of October to February. The annual rainfall ranges from 600-1000 mm.

Experimental design and treatments

The experimental design was completely randomized design under a 3 x 3 x 2 factorial arrangement for three grass species (elephant, guatemala and rhodes grasses), three ensiled amounts (5, 10 and 12) kgs and two storage positions (thatched barn and trench) with two replicates. The experiment had 18 treatments combinations with two replications.Five, 10 and 12 kgs were chosen because, normally, smallholder farmer fed their dairy cows between 5 and 20 kg of silage per day so any amount between 5 and 20 kg could be appropriate for investigation. Furthermore, for a smallholder farmer with only one cow, a 5 kg of grass silage could be approximate since the animal may require only 5 kg of silage per day since it should be combined with other feeds such as hay and concentrates for a healthy rumen.

Source, harvesting, preparation of ensiled grasses and ensiling procedure

The ensiled grass species used in the study were elephant grass (*Pennisetum purpureum*) and guatemala grass (*Tripsacum laxum*) and rhodes grass (*Chloris gayana*). All grass species were harvested from well managed pasture plots (Plates 1). Each pasture grass species covered an area of about 400 m^2. Grasses were harvested (Plate 2). The elephant and Guatemala grasses regrowths were harvested at 1.5 and 1 m of tall, respectively. Rhodes grass regrowth on the other hand was harvested, at flowering stage of growth. According to Zanine *et al*. (2010) grasses can be stored if they are ensiled at the ideal stage of development. The harvested grass was chopped into 2 cm particle length (Plate 3) and ensiled in 5, 10 and 12 kgs shopping plastic bag silos. The ensiling was done by filling the chopped grass materials in the ensiling plastic bag silos with 30 nm thickness (Plate 4). Air was removed and the neck of the bag was twisted, turned over and tied with a rubber band. Thereafter, the ensiling plastic bag was labeled for treatment identity**.** Each bag was then inserted into a second empty shopping plastic bag (30 nm thicknesses) which was also tied, labeled and put in a hessian bag to protect it from rupturing.

Plate 1: The re-growth grasses were irrigated

Plate 2: Grasses were harvested

Plate 3: Grasses were chopped

Plate 4: Grasses were ensiled in shopping bags either in 5, 10 and 12 kg

Plate 5: Thatched barn

Plate 6: Trench

Plate 5 and 6: Ensiled grasses were stored either in thatched barn or in trenches

Hessian bags were then stored in either thatched barn or in a trench (Plates5 & 6). In the thatched barn, the hessian bags were carefully stacked on a wooden rack to allow ventilation and lower the temperature. Chicken wire mesh surrounded the wooden rack protecting the bags against rats, mice and birds, especially the crow who would view the bags as bin bags full of kitchen waste to consume.In the trench the hessian bags were covered by plastic sheet to protect them from termites and then the pit were re-filled with the soil to form an earth mould over the trench so as to clear rain water away from the pit. After 60 days of fermentation, silages were removed from thatched barn and trenches.

Data collection procedures

After 60 days of fermentation, silos were opened and spoiled silage was separated from well preserved silage. Samples (weighing 500 g) from each bag were collected placed in polythene bags and immediately placed in a cool ice box and taken to the analytical laboratory. The sample was sub-divided into two samples. One sample was used for organoleptic test and pH determination. The other sub-samples were put in plastic bags and stored in a deep freezer at -10°C until when they were used for chemical composition analysis and determination of *in vitro* dry matter digestibility (IVDMD).

The DM of the fresh ensiling material and silages were determined by drying in an oven at 65°C for 48h (AOAC, 1984). The silages were freeze-dried in aLyphilizermaintained at -40ºC for 24 hrs according to Snowman (1988) so as to get a dry sample for Ash, crude protein (CP), neutral detergent fiber (NDF), water soluble carbohydrates (WSC) analysis and IVDMD determination. Ammonia-nitrogen (NH_3N) was analyzed from fresh silage samples. The ash, CP and NH_3N were analyzed according to AOAC (2005) procedures while WSC was analyzed according to Thomas (1977). The NDF was analyzed according to Van Soest *et al*. (1991). A pH meter (model 219-MK 2; Pye Unicam) was used to measure the pH of the fresh silages samples. Samples of 40 g from each silo were soaked in 200 ml of cool distilled water for 12 hours then filtered and the supernatant used for the determination of the pH. The *in vitro* dry matter (IVDMD) of the silages were determined according to the two stage technique developed by Tilley and Terry (1963) and modified by Salabi *et al.* (2010). The silages were analyzed for volatile fatty acid according to Shirlaw‘s (1967) procedure. Gas Chromatograph analyses were performed on a wide bore fused silica Cp-sil 19CB column, gas chromatograph equipped with a flame ionization detector (FID) $512x10^{-12}$ Afs. The technique used was gas chromatograph capillary column (10 m 0.53 mm fused silica WCOT Cp-Sil 19CB (2.0 µm Cat.no.7647). The injector and detector temperatures were 275°C and 300°C respectively. The carrier gas was H_2 40kPa (0.4bar) 170 cm/s. The analyses were performed using a temperature programme: a linear gradient from 80°C to 280°C at 25°C min^{-1}. In each case a 0.1µL of sample was injected (a flow splitting 1:10). Silage stability was determined by observing the change of pH of exposed silage after sixty days of fermentation. Each day the pH of each treatment was recorded for 7 days consecutively.

Organoleptic Test

The organoleptic test was carried out at the Department of Animal, Aquaculture and Range Sciences laboratory of SUA by trained 30 assessors of Animal Science Undergraduate and Postgraduate Students. Each assessor assessed the silage from each treatment and scored its physical characteristics in terms of appearance, texture and smell. Appearance score No.1 (poor) indicated spoiled silage which was dark brown in color with mould growth, score No. 2 (moderate) olive green in colour with some mould growth, score No. 3 (good) light yellow or green brown colour and score No. 4 (very good) indicated well pickled light green/yellowish green colour silage. Smell score No.1 (poor) indicated foul smell associated with putrefaction or tobacco like smell, score No. 2 (moderate) pungent smell of ammonia, score No. 3 (good) pleasant estery aroma and score No.4 (very good) pleasant aroma typically silage smell. Texture score, No.1 (poor) slimy and watery, score No.2 (moderate) firm, less slimy and wet No.3 (good) moderate firm, non-slippery and wet No.4 (very good) very firm, non-slippery and slightly wet. The test was carried once after 60 days of fermentation, when ensiling bags (silos) were opened and spoiled silage separated from well preserved silage.

Experimental design and statistical analysis

GLM procedure of the SAS (SAS, 2008) was used to analyze the data based on the following statistical model: $Y_{ijkl}= \mu+ G_i + T_j + S_k+(GT)_{ij} + (TS)_{jk} + (GS)_{ik} + E_{ijkl;}$ whereby Y_{ijkl} = qualities attributes of grass species, ensiled amounts and storage positions; µ= general mean common to all observations in the experiment; $G_{i=}$ effect of the i^{th} grass species; T_j = effect of the j^{th} ensiled amount; S_k = effect of the k^{th} storage position; GT_{ij}= interaction of i^{th} grass and j^{th} ensiled amount ; TS_{jk}= interaction of j^{th} ensiled amount and the k^{th} storage position; $GS_{ik=}$ interaction of i^{th} grass species and k^{th} storage position and $E_{ijk=}$ random effects peculiar to each observation.

Results and Discussion

Chemical composition and digestibility of fodder grasses at the time of ensiling

Results on DM, CP, WSC, ash, NDF and IVDMD of elephant grass and guatemala grass at the time of ensiling are shown in Table 1. Elephant grass had relatively higher CP and ash but lower DM, IVDMD andWSC than guatemala and rhodes grasses. Rhodes grass had higher WSC compared to elephant and guatemala grasses which had however, nearly similar WSC and NDF.

Table 1: Mean chemical composition and digestibility of of grasses at the time of ensiling

Parameter (%)	Elephant grass (120 dys)	Guatemala grass (63 dys)	Rhodes grass (56 dys)	Parameter (%)	Elephant grass (120 dys)	Guatema-la grass (63 dys)	Rhodes grass (56 dys)
DM	19.4	29.3	21.8	**Ash**	13.5	9.5	9.2
CP	10.1	8.45	7.8	**NDF**	73.9	73.2	66.4
WSC	3.19	3.40	3.01	**IVDMD**	61.3	64.7	69.1

DM –Dry matter, CP-Crude protein, WSC-Water soluble carbohydrates, NDF-Neutral detergent fibre IVDMD-in vitro-digestibility

Effect of fodder grass species, ensiled amount and storage positions on organoleptic tests

Elephant grass silage had higher ($p < 0.05$) appearance, smell and texture scores than guatemala and rhodes grass silages (Table 2). Elephant grass showed good quality silages, guatemala moderate silages whereas rhodes grass showed poor silages. These differences might have been caused by improved fermentation condition in elephant grass silages which gave microbes'conducive environment during fermentative process than in guatemala and rhodes grass silage. It means that, elephant grass had better capability to complete a successful ensiling process than the other two grasses. This is in agreement with Lyimo (2010) who found good physical scoring of elephant grass silage after fermentation. The 5 and 10 kgs silages in plastic bag silo showed higher ($p < 0.05$) appearance, smell and texture scores than 12 kgs silages in plastic bag silo. This could be attributed to optimal ensiled amount which allows thorough compaction of grasses which promoted greater packing density and thus exclusion of air and culminating to good condition for fermentation process. There was no difference ($p > 0.05$) between the two ensiled amounts (5 and 10 kgs) on appearance, smell and texture scores and implying that, either of the two ensiled amount can produce moderate to good quality silages.

There were no differences ($p > 0.05$) between silages stored in thatched barn and trench in terms of appearance, smell and texture. The results showed moderate silages from both thatched barn and trench, this was in contray to Lyimo (2010) who found good silages stored in both thatched barn and trench. Lyimo (2010) reported thatafter chopping the grasses, some additives such as maize bran (10%), molasses (5%) were added during the ensiling process to enhance the fermentation process. According to the nature of this study, only chopping of the grasses was done as pre-ensiling treatment, no wilting, and no additives. Probably this could be the reason why the two storage positions produced moderate silages. This implies that, whenever, fermentation process is enhanced by pre-ensiling treatments, either of the two storage positions can be used to produce good quality silage.

Table 2: Mean effect of grass species, ensiled amount and storage positions on organoleptic tests

Par.(%)	Effect of specie					Effect of ensiled amount				
	EGS	**GGS**	**RGS**	**SEM**	**p-value**	**5kg**	**10kg**	**12kg**	**SEM**	**p-valu**
App.	3.17^{a}	2.5^{b}	1.92^{c}	0.160	0.0001	3.00^{a}	2.83^{a}	1.75^{b}	0.164	0.0001
Smell	3.17^{a}	2.5^{b}	1.92^{c}	0.137	0.0001	3.08^{a}	2.75^{a}	1.75^{b}	0.136	0.0001
Texture	3.08^{a}	2.5^{b}	1.92^{c}	0.146	0.0001	3.08^{a}	2.92^{a}	1.50^{b}	0.145	0.0001

	Effect of Storage positions			
	Thatch barn	**Tren ch**	**SEM**	**p-value**
App.	2.44^{a}	2.61^{a}	0.134	0.297
Smell	2.5^{a}	2.56^{a}	0.111	0.73
Texture	2.39^{a}	2.61^{a}	0.119	0.20

EGS -Elephant grass silage, GGS- Guatemala grass silage, RGS -Rhodes grass silage.App. -appearance, Score 1 = Poor Score 2=Moderate Score 3= good, 4= very good, SEM- Standard error of means. Means within row with different superscript letters are significantly different (P < 0.05).

Effect of fodder grass species, ensiled amount in shopping plastic bags and storage positions onchemical composition and digestibility

Elephant grass silages had higher (P<0.05) CP and ash but had lower DM and WSC than guatemala and rhodes grass silages (Table 3). This is related to the original chemical composition of individual grass specie before ensiling. There were no differences among elephant, guatemala and rhodes grass silages on NDF. The 5 and 10 kg silages showed higher (p< 0.05) DM, CP, WSC, ash and IVDMD but lower NDF than 12 kg silages. This could be attributed to decreased volume in ensiled amounts of 5 kg and 10 kg which provided reasonable compaction to the ensiled grasses culminating to good fermentation condition. Lyimo (2010) and Mtengeti *et al.* (2013) found good silage fermentation after ensiling 5 kgs of grass in plastic bag silos. On the other hand, there was no difference between the two ensiled amounts (5 and 10 kgs) with respect to DM, CP, WSC, ash, NDF and IVDMD. This implies that either of the two ensiled amount (5 and 10 kgs) can be used to produce good quality silage. There was an insignificant difference (p> 0.05) between thatched barn and trench storage positions in terms of DM, CP, WSC, ash, NDF and IVDMD (Table 3). This might be due to provision of conducive environment to fermenting microbes for efficient fermentation and suggesting that farmers may avoid expenses of digging trenches for storing shopping bags with ensiled grass material every year and thus build only once a thatched barn where they can store silage bags and even hay bales together.

Table 3: Mean effect of fodder grass species, ensiled amount in shopping plastic bags and storage positions on chemical composition and digestibility

Par (%)	Effect of grass specie					Effect of ensiled amount				
	EGS	GGS	RGS	SEM	p-value	5 kg	10 kg	12 kg	SEM	p-value
DM	18.2[c]	27.1[a]	21.4[b]	0.013	0.0001	22.23[a]	22.21[a]	21.9[b]	0.013	0.0001
CP	9.4[a]	7.01[b]	6.93[c]	0.003	0.0001	8.26[a]	8.26[a]	7.98[b]	0.003	0.0001
WSC	1.3[b]	1.4[a]	1.21[c]	0.004	0.0001	1.32[a]	1.32[a]	1.26[b]	0.004	0.0001
Ash	13.3[a]	9.21[c]	12.1[b]	0.006	0.0001	11.05[a]	11.05[a]	10.9[b]	0.006	0.0001
NDF	68.6[b]	67.5[c]	69.9[a]	0.003	0.0001	69.09[b]	69.1[b]	69.9[a]	0.003	0.0001
IVD	55.5[b]	65.6[a]	53.7[c]	0.019	0.0001	59.3[a]	59.3[a]	58.1[b]	0.019	0.0001

	Effect of storage position			
	Thatch barn	Trench	SEM	p-value
DM	22.2[a]	22.2[a]	0.010	0.31
CP	8.04[a]	8.05[a]	0.002	0.50
WSC	1.98[a]	1.99[a]	0.004	0.11
Ash	11.9[a]	11.9[a]	0.005	0.72
NDF	65.7[a]	65.7[a]	0.002	0.15
IVD	58.2[a]	58.3[a]	0.016	0.26

EGS - Elephant grass silage, GGS- Guatemala grass silage, RGS -Rhodes grass silage.Means within row with different superscript letters are significantly different (P < 0.05).

Combined effect of grass species, ensiled amount in shopping plastic bags and storage positions onchemical composition

The interaction of specie and ensiled amount, species and storage positions and ensiled amount and storage positions was observed as shown in Table 4. The results showed highest CP from elephant grass in either 5 or 10 kg ensiled amount stored in either thatched barn or in trench. This could be due to good condition for microbes provided by elephant grass during fermentation, optimal ensiled amounts for sufficient compaction and conducive environment provided by storage positions which led to less proteolysis.

Table 4: Combined mean effect of grass species, ensiled amount in shopping plastic bags and storage positions on chemical composition

Combined effect of species and ensiled amount			Combined effect of species and Storage positions		
spp	**Ensiled amount (kg)**	**CP**	**spp**	**Storage positions**	**CP**
EG	5	9.86^{f}	EG	Thatch	9.74^{c}
	10	9.86^{f}		trench	9.74^{c}
	12	9.71^{e}	GG	Thatch	7.45^{b}
GG	5	7.59^{d}		trench	7.47^{b}
	10	7.48^{c}	RG	Thatch	6.92^{a}
	12	7.44^{c}		trench	6.93^{a}
RG	5	6.99^{b}		**SEM**	0.0037
	10	6.93^{a}		**p-value**	0.0001
	12	6.91^{a}			
	SEM	0.0045			
	p-value	0.0001			

Combined effect of ensiled amount and Storage positions		
Ensiled amount (Kg)	**Storage positions**	**CP**
5	Thatch	8.25^{c}
	trench	8.25^{c}
10	Thatch	8.13^{b}
	trench	8.16^{b}
12	Thatch	8.01^{a}
	trench	8.02^{a}
	SEM	0.0037
	p-value	0.0001

Spp-species, EG-Elephant grass, GG-Guatemala grass, RG- Rhodes grass, CP- crude protein, SEM-Standard error of means. Means within column with different superscript letters are significantly different (P < 0.05).

Effect of fodder grass species, ensiled amount in shopping plastic bags and storage positions onfermentation quality of grasses

Elephant grass silage had higher ($p<0.05$) lactic acid and acetic acid but lower ($p\leq 0.05$) pH, NH_3N than guatemala and rhodes grass silages (Table 5). This could be due to favorable condition in elephant grass which enhances fermentation process for high quality silages. Low NH_3N indicated less proteolysis during fermentation.The rate of pH decline is important in determining the extent of proteolysis. If the rate of pH decline is slow, more protein will be hydrolysed (McDonald *et al*., 2002). Thus, in this study less proteolysis means that, the rate of pH decline was rapid. Low butyric acid showed relative difficulty in clostridial growth in elephant grass silage. These lower ($p<0.05$) lactic acid concentrations in guatemala and rhodes grass silages are an indication that the WSC concentrations at pre-ensiling were not sufficient enough to promote efficient fermentation (Yang *et al*., 2006).

The 5 and 10 kgs ensiled amounts showed higher ($p< 0.05$) lactic acid, acetic acid but lower ($p< 0.0 5$) pH, NH_3N and butyric acid than 12 kg ensiled amount. There was no difference between the two ensiled amounts (5 and 10 kgs) in terms of pH, NH_3N, lactic acid, acetic acid and butyric acid. This means that, the two ensiled amounts (5 and 10 kgs) provided good environment for lactic bacteria to stabilize the acidity in the silo which led to successful fermentation. As soon as favorable environment is provided during fermentation process there is a decline of pH. The decline in pH promotes increased populations of efficient homofermentative lactic-acid bacteria.These bacteria reduce silage pH faster and more efficiently by producing predominantly lactic acid (Niekerk *et al.*, 2007; Van Hiep *et al*., 2008). There was no difference between the two ensiled amounts (5 and 10 kgs) on pH, NH_3N, acetic acid and butyric acid.

There was no significant difference between grass silage stored in the thatched barn and those stored in trench in terms of pH, NH_3N, lactic, acetic and butyric acids. Thus, either of the two storage positions can be used to produce high quality silage. A thatched barn is chosen as an above ground storage place because it will always remain cool as compared to corrugated iron thatched barn (Mtengeti and Urio, 2006). Aksu *et al*. (2006) reported high quality silage stored in dark room with low room temperature (20 ºC). Weinberg *et al*. (2001) reported silage stored at elevated (37-41ºC) ambient temperatures resulting in unfavorable ensiling characteristics (higher pH and DM losses, and less lactic acid) and less aerobic stability when compared to silage stored at room temperature (< 33ºC). High temperatures lead to unsuitable fermentation of the silage (Gonzalez *et al*., 2003).

Table 5: Mean effect of grass species, ensiled amount and storage positions on fermentation of grass silage

Par. (%)	Effect of specie					Effect of ensiled amount				
	EGS	**GGS**	**RGS**	**SEM**	**p-value**	**5kg**	**10kg**	**12kg**	**SEM**	**p-value**
pH	4.50^c	4.69^b	4.85^a	0.0068	0.0001	4.56^b	4.56^b	4.63^a	0.0068	0.0001
NH_3N	3.45^c	4.21^b	4.32^a	0.0038	0.0001	3.31^b	3.31^b	3.42^a	0.0038	0.0001
LA	0.66^a	0.43^b	0.24^c	0.0053	0.0001	0.55^a	0.55^a	0.42^b	0.0053	0.0001
AA	0.28^a	0.21^b	0.16^c	0.0040	0.0001	0.25^a	0.25^a	0.19^b	0.0040	0.0001
BA	0.07^b	0.06^a	0.09^a	0.0045	0.0001	0.029^b	0.029^b	0.049^a	0.0045	0.0001
	Effect of storage positions									
	Thatch barn	**Trench**	**SEM**	**p-value**						
pH	4.62^a	4.61^a	0.0080	0.139						
NH_3N	3.32^a	3.32^a	0.0031	0.119						
LA	0.58^a	0.58^a	0.0043	0.419						
AA	0.28^a	0.28^a	0.0033	0.479						
BA	0.03^a	0.029^a	0.0037	0.339						

EG-elephant grass, GG-guatemala grass, RG- Rhodes grass. Par –parameter, LA - Lactic acid AA - Acetic acid BA - Butyric acid, Means within row with different superscript letters are significantly different (P < 0.05).

Interaction effect of fodder grass species, ensiled amount in shopping plastic bags and storage positions onfermentative quality

The interaction of specie and ensiled amount, species and storage positions, ensiled amount and storage positions was observed as shown in Table 6. The results showed highest lactic acid but lowest pH and NH_3N from interaction of elephant grass with either 5 or 10 kgs ensiled amount stored in either thatched barn or in trench. This could be due to provision of good condition for microbes by elephant grass during fermentation, optimal ensiled amounts for sufficient compaction and conducive environment provided by thatched barn or trench which leads to less proteolysis, low pH and lactic acid production.

Table 6: Combined mean effect of grass species, ensiled amount in shopping plastic bags and storage positions on fermentative quality

		Combined effect of species and ensiled amount		
spp	**amnt**	**pH**	**NH_3N**	**LA**
EG	5	4.57^{a}	3.10^{a}	0.75^{d}
	10	4.57^{a}	3.10^{a}	0.75^{d}
	12	4.64^{b}	3.23^{b}	0.72^{c}
GG	5	4.69^{c}	4.21^{c}	0.47^{b}
	10	4.71^{c}	4.22^{c}	0.46^{b}
	12	4.73^{c}	4.24^{c}	0.44^{b}
RG	5	5.08^{d}	4.61^{d}	0.35^{a}
	10	5.17^{d}	4.61^{d}	0.35^{a}
	12	5.28^{d}	4.63^{d}	0.33^{a}
SEM		0.017	0.0066	0.0091
p-value		0.0001	0.0001	0.0001

		Combined effect of species and storage positions		
spp	**Strg**	**pH**	**NH_3N**	**LA**
EG	thatch	4.63^{a}	3.22^{a}	0.83^{c}
	trench	4.63^{a}	3.22^{a}	0.83^{c}
GG	thatch	4.69^{b}	4.23^{b}	0.75^{b}
	trench	4.67^{b}	4.21^{b}	0.75^{b}
RG	thatch	4.74^{c}	4.52^{c}	0.54^{a}
	trench	4.75^{c}	4.51^{c}	0.55^{a}
SEM		0.0139	0.0053	0.0074
p-value		0.0001	0.0001	0.0001

		Combined effect of ensiled amount and storage positions		
amnt	**strg**	**pH**	**NH_3N**	**LA**
5	thatch	4.66^{a}	3.31^{a}	0.76^{b}
	trench	4.65^{a}	3.31^{a}	0.76^{b}
10	thatch	4.67^{a}	3.32^{a}	0.76^{b}
	trench	4.66^{a}	3.32^{a}	0.76^{b}
12	thatch	4.75^{b}	3.43^{b}	0.53^{a}
	trench	4.74^{b}	3.41^{b}	0.53^{a}
SEM		0.0139	0.0053	0.0074
p-value		0.0001	0.0001	0.0001

EG-elephant grass, GG-guatemala grass, RG- Rhodes grass, strg-storage, spp-species, LA-Lactic acid, amnt-amount, SEM- Standard error of means. Means within column with different superscript letters are significantly different ($P < 0.05$).

Effect of grass species, ensiled amount and storage positions on the stability of silage quality during feed out

Aerobic stability is a measure of the shelf life of silage. According to Lyimo *et al.* (2016b) silage stability is determined by observing the change of pH of exposed silage for several days. Aerobic stability is important because many dairy producers contract delivery for 2 - 4 day's worth of feed. Silage removed from silo, but not fed immediately, is exposed to air for an extended time period (Holmes and Muck, 2000) as aerobic deterioration can occur rapidly and lower the silage quality. Silage quality is not only characterized by its chemical composition but also by how long it will remain stable and resist deterioration once the silo has been opened and fed to livestock. In this study, silage was considered as stable when it has pH less than 5, so based on this criterion, elephant grass silage was stable up to the fourth day (Table 7). Guatemala grass silage up to the third day whereas rhodes grass silage up to the second day. The results indicated that, elephant grass allows fermentation and increases acids that could preserve grass and prevent growth of yeasts which could cause early deterioration of silage.

The two ensiled amounts (5 and 10 kgs) showed higher ($P< 0.05$) stability than 12kg ensiled amount. There was no difference between the two ensiled amounts (5 and 10 kg) in terms of stability. Silages from the two ensiled amounts (5 and 10 kgs) were stable up to the fourth day of feeding out whereas 12 kgs ensiled amount up to the second day of feeding out. This indicated that, silages from the two ensiled amounts (5 and 10kgs) had higher stability than those from 12 kgs ensiled amount and should be fed within three days after opening the silo, thereafter deterioration becomes unbearable and the silage becomes unsuitable for feeding the animals. There was no difference between the two storage positions (thatched barn and trenches) in terms of stability. Silages from the thatched barn and trenches had pH less than 5 up to the third day of feeding out. This indicated that, either of the two storage positions can be used to store silages and the silages should be fed within three days after opening the silo.

Table 7: Mean effects of wilting, chopping length and different levels of molasses on stability of fodder grass silages

	Effect of specie					**Effect of ensiled amount**				
pH	**EGS**	**GGS**	**RGS**	**SEM**	**p-value**	**5kg**	**10kg**	**12kg**	**SEM**	**p-value**
Phdy0	4.87[c]	4.92[b]	4.96 [a]	0.007	0.0001	4.83[b]	4.83[b]	4.93[a]	0.007	0.0001
Phdy1	4.93[c]	4.95 [b]	4.98 [a]	0.007	0.0001	4.88[b]	4.88[b]	4.95[a]	0.007	0.0001
Phdy2	4.95[c]	4.97[b]	4.99[a]	0.004	0.0001	4.93[b]	4.93[b]	4.98[a]	0.004	0.0001
Phdy3	4.97[c]	4.98[b]	5.39[a]	0.047	0.0001	4.65 [b]	4.65[b]	5.61[a]	0.047	0.0001
Phdy4	4.99[c]	5.43[b]	6.63[a]	0.020	0.0001	4.98 [b]	5.08[b]	5.96[a]	0.020	0.0001
Phdy5	5.72[b]	5.99[a]	6.09[a]	0.046	0.0001	6.21[b]	6.23[b]	6.56[a]	0.046	0.0001
Phdy6	6.86[c]	6.08[b]	6.28[a]	0.028	0.0001	6.8 [b]	6.8[b]	6.90[a]	0.028	0.0001
Phdy7	5.49[b]	5.85[a]	5.87[a]	0.105	0.0001	5.84[b]	5.85[b]	6.09[a]	0.105	0.0001

	Effect of storage positions			
	Thatch barn	**Trench**	**SEM**	**p-value**
Phdy0	4.89[a]	4.89[a]	0.006	0.701
Phdy1	4.92[a]	4.91[a]	0.005	0.132
Phdy2	4.95[a]	4.96[a]	0.004	0.552
Phdy3	4.98[a]	4.98[a]	0.038	0.552
Phdy4	5.22[a]	5.21[a]	0.016	0.776
Phdy5	6.8[a]	6.8[a]	0.037	0.415
Phdy6	6.88[a]	6.88[a]	0.023	0.247
Phdy7	5.92[a]	5.92[a]	0.086	0.881

Phdy0-7-is pH measured from day 1-7, EGS-Elephant grass silage, GGS-Guatemala grass silage, RGS-Rhodes grass silage, Means within row with different superscript letters are significantly different ($P < 0.05$).

Conclusions

Elephant grass silage produced higher quality and preserved better than guatemala and rhodes grasses as indicated by higher sensoric scores, crude protein, ash, lactic acid, acetic acid and stability but lower pH, NH_3N and butyric acid. The 5 and 10 kgs ensiled amounts showed higher appearance, smell and texture scores, DM, CP, WSC, ash, IVDMD, lactic acid, acetic acid and stability but lower NDF, pH, NH_3N and butyric acid than 12 kg ensiled amounts. There was no difference between the two ensiled amounts (5 and 10 kg) in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, lactic acid, acetic acid, butyric acid and stability. There were no differences between silages stored in thatched barn and trench in terms of appearance, smell and texture scores, DM, CP, WSC, ash, NDF, IVDMD, pH, NH_3N, lactic acid, acetic acid, butyric acid and stability. The interaction of elephant grass and either 5 or 10 kg ensiled amount in shopping plastic bag, stored in either thatched barn or in trench showed highest CP, lactic acid but lowest pH and NH_3N.

Recommendations

It was therefore recommended that, elephant grass ensiled at either 5or 10 kg shopping plastic bag silo and stored in either thatched barn or in trench was the most optimal combination technology to achieve high silage quality under smallholder farmers.

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