EFFECT OF FEEDING PRACTICE ON PERFORMANCE OF DAIRY CATTLE UNDER ZERO GRAZING SYSTEM IN TURIANI DIVISION

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN TROPICAL ANIMAL PRODUCTION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Two investigations were carried out in Turiani division to assess the feeding practices and their effect on the performance of lactating dairy cows kept by smallholder farmers under zero grazing system. Investigation 1, aimed at evaluating the nutritional values of the feeds commonly fed to dairy cattle and performance of lactating cows under different feeding practices. Twenty four lactating dairy cows within their 1^{st} to 2^{nd} month after calving were selected from smallholder dairy farmers whereby feed intake and milk yield were recorded for a period of 28 days. Investigation 2 aimed at testing an appropriate feeding practice for the lactating cows in the study area. A total of 24 lactating cows of similar status as above were randomly allocated to three feeding practices (P1, P2 and P3) in a completely randomized design (CRD). Cows on P1 were raised on a feeding practice normally used by the farmers whereas those in P2 were supplemented daily with 3.89 kg DM of a home made concentrate formulated to contain 16.26% CP and 13.67 MJ ME/kg DM on top of practice P1. Cows on P3 were fed similar to those on P2 plus 5 kg DM/d of fresh local forages. Feed intake, milk yield, body weight gain, costs of supplementation and income generated were recorded for a period of 45 days. The average CP (%) and ME (MJ/kg DM) of the available feeds were 11.54 and 6.94 for forages and 13.79 and 10.48 for concentrates, respectively. Performance of animals in Investigation 1 in terms of milk yield and average body weight gain were 6.5 l/cow/d and 16.5 g/d, respectively. The daily DMI (kg/d), CP (g/d) and ME (MJ/d) intake from both forages and concentrate in Investigation 1 were 10.79, 1306.11 and 85.98, respectively with the deficit of 49 ME/d and 671.9 g CP/d. In Investigation 2, the daily mean DMI was higher ($P < 0.05$) for cows on P3 (19.29 kg) than those on P1 (12.31 kg) and P2 (14.43 kg). The daily mean milk yield was higher ($P < 0.05$) for cows on P3 (13.68 l) than those on P1 (8.5 l) and P2 (10.9 l). The profit margins due to different feeding practices (Tsh/cow/d) were higher in P3

(4907.27) than P2 (3077.27) and P1 (1660). It is concluded that cross bred lactating cows under smallholder dairy farmers in Turiani are underfed for both basal and concentrate diets. The tested feeding practice (P3) where cows are fed 4.2 kg of concentrate and forage *ad libitum* could increase milk production and profitability of the dairy enterprise.

DECLARATION

I, **NICOSTRATUS KIGINGA MAGORI**, do hereby declare to the senate of Sokoine University of Agriculture that, this dissertation is my original work and that it has neither been submitted nor concurrently being submitted for a higher degree award in any other institution.

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The above declaration is confirmed by:

__________________ __________________

Prof. G.H. Laswai Date

(Supervisor)

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This work is dedicated to my father Magori Kiginga who valued and sacrificed a lot for my education and well being. May the Almighty God rest his soul in eternal peace, AMEN.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
^oC	Degree Celsius
/	per
ADF	Acid detergent fibre
AOAC	Association of Official Analytical Chemists
CF	Crude fibre
CIAT	Centre for International Tropical Agriculture
cm	Centimeters
CP	Crude protein
CRD	Completely Randomized Design
d	Day
DCP	Dicalcium phosphate
DM	Dry Matter
DMI	Dry matter intake
EE	Ether Extract
E	East
FCPI	Forage crude protein intake
FDMI	Forage dry matter intake
FMEI	Forage metabolizable energy intake
g	Gram
GLM	General linear model
h	Hours
HCL	Hydrochloric acid

HM	Hominy Meal
ILRI	International Livestock Research Institute
IVDMD	*in vitro* dry matter digestibility
IVOMD	*in vitro* organic matter digestibility
kg	Kilogram
km	Kilometres
LLM	Leucaena leaf meal
l	Litre
MAFF	Ministry of Agriculture, Fisheries and Food
MB	Maize bran
MDC	Mixed concentrate
ME	Metabolizable energy
MJ	Mega joule
ml	Millilitre
NBS	National Bureau of Statistics
NDF	Neutral Detergent Fibre
NP	Natural pastures
NRC	National Research Council
OM	Organic matter
Ph	Potential Hydrogen
RP	Rice polishing
S	South
SAS	Statistical Analysis System
SSC	Sunflower seedcake
SUA	Sokoine University Agriculture

TCPI	Total crude protein intake
TDMI	Total dry matter intake
TDN	Total digestible nutrient
TMEI	Total metabolizable energy intake
Tsh	Tanzania shillings

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Dairying under smallholder farmers is constrained with low milk yield ranging from 4 to 8 litres per cow per day during the dry and wet seasons, respectively (Mtui, 2004 and Mtengeti *et al*., 2008). The expected average milk yield is at least 15 litres per cow per day from crossbred dairy cows under tropical conditions (Msanga and Kavana, 2002). Such low milk yield is attributed to poor nutritive values of feeds and improper feeding practices, which supply inadequate nutrients to meet the maintenance, production and reproduction requirements of the animal. Feeding practice is defined by Wheeler (2011) as those activities which ensure supply of feed and water of suitable quantity and quality from sustainable sources as well as controlling the storage conditions of feeds brought to the animals. The majority of smallholder dairy farmers keep their animals indoor with zero grazing system. The animals are normally stall fed with combinations of forages with or without concentrate supplementation. Some farmers supplement concentrates, often maize bran during milking time.

Feeding practice has influence on milk yield of dairy cows (Gillah *et al*., 2012). Cows fed on forages alone cannot attain their genetic potential for milk production. Lukuyu *et al*. (2012) reported milk yield of 7 litres per cow per day from cows fed on Napier grass alone, while 9-12 litres were obtained when cows were fed on Napier-legume mixture. On the other hand, feeding forage to cows and supplement with maize bran during milking has been reported to lower milk yield by 50% in Tanga region (Urassa, 1999) and 23% in Morogoro urban and peri-urban areas (Mlay *et al*., 2001) relative to adequate feeding. In addition, seasonal variations in quantity and quality of the forages have considerable effect on performance of dairy cows. Dairy cows under zero grazing receive less forages of poor quality during the dry periods, hence reduced milk yield (Kavana and Msangi, 2005). It is therefore, vital to assess the feeding practices of dairy cows under smallholder farmers and identify appropriate intervention strategies for increased milk yield especially during the dry season.

In Turiani division however, little information is available on the mode of feeding and possible combinations of locally available feed resources to improve milk production from the cows. The main aim of the study was therefore to assess and test an appropriate feeding practice to improve milk yield from the cows in Turiani division.

1.2 Problem statement and justification

Dairy cows under smallholder production in Turiani division and other parts of Tanzania are performing sub optimally, probably due to poor feeding practiced by the farmers. The genetic potential of the cows in these areas is expected to produce at least 15 litres of milk per cow per day (Mtui, 2004 and Njombe *et al*., 2012). The level of milk production from the cows is quite low, ranging from 4 to 5 litres in the dry seasons to 6 to 8 litres in the wet seasons (Mtengeti *et al*., 2008). This situation is presumed to be caused by the poor nutritive values of the locally available feeds and inappropriate feeding, which fail to meet the required nutrients by the cows. Nevertheless, the smallholder dairy farmers in Turiani division perceived that the low milk yield from their cows is due to low genetic potential of the animals for milk production. Scant data is available to explain the cause for low milk yield from these cows and the possible intervention strategies. The present study was part of the ongoing collaborative research project between Sokoine University of Agriculture (SUA), the International Livestock Research Institute (ILRI) and the Centre for International Tropical Agriculture (CIAT), under the MilkIT project entitled

"Enhancing Dairy-based Livelihoods in India and Tanzania through Feed Innovation and Value Chain Development Approaches". The present study aimed at assessing and evaluating the effects of feeding practices on milk yield and body weight changes of lactating dairy cows kept by smallholder farmers in Turiani division. The obtained information from the study is useful to the smallholder dairy farmers, project implementers and other stakeholders in improving dairy cattle productivity in Tanzania.

1.3 Objectives of the study

1.3.1 General objective

To develop a feeding practice for improved milk production from the dairy cows under smallholder farmers in Turiani division, Mvomero district.

1.3.2 Specific objectives

i To evaluate the nutritional values of common feedstuffs fed to dairy cows under zero grazing system in Turiani division,

ii To monitor and assess the feeding practices and performance of stall fed lactating dairy cows,

iii To test an appropriate feeding practice for improved milk yield and body weight changes of lactating cows.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

Milk yield from the dairy cows under smallholder farmers is far below the expected genetic potential of the cows due to several factors, one of them being improper feeding practice, which deprive nutrients supply to the animals (Mtengeti *et al*., 2008). Most of the feeds provided to dairy cows by the smallholder farmers are forage based with little or without concentrate supplementation. Maize bran is mostly used as a major supplementary feed to lactating cows without considering the nutrient requirements of the animals. This situation suggests that there is a need to put in place a proper feeding practice in order to improve performance of dairy cattle under smallholder farmers.

This chapter reviews four main topics, namely, the available feeds and their quality for dairy cattle under smallholder production, common feeding practices under zero grazing system, performance of lactating dairy cattle under zero grazing system and nutrient requirements of lactating dairy cows. The chapter intends to identify knowledge gaps in relation to dairy cattle feeding practices and existing opportunities for increased milk production from the cows under smallholder farms.

2.2 Quality of available feeds for smallholder dairy cattle production

Quality feeds are able to supply the most nutrients required to meet the animals' requirements for maintenance and production. Feed quality, which is influenced by its nutrient composition, determines the intake and availability of ingested nutrients for utilization by the dairy cattle because high quality feeds offer greater dry matter intake (DMI) and digestibility than low quality feeds.

In most of the tropical areas where there is a distinguishable wet and dry seasons, a wide seasonal fluctuation in availability, chemical composition, digestibility and nature of digested products of feeds particularly forages is very common. The common feedstuffs used by smallholder dairy farmers for feeding animals are forages, crop residues and concentrates. The amount of feed consumed by the animal is very important as it affects the total nutrient intake and hence animal performance.

2.2.1 Forages and crop residues

Forages are bulky feeds cut and fed to animals particularly cattle kept under zero grazing system either as fresh green fodder or conserved as hay or silage. Common forages used to feed dairy cattle under smallholder farmers in Turiani division are natural pastures (NP), such as grasses (*Rottboellia cochinchinensis* – itch grass or ‘‘Mbayaya’’, *Panicum maximum*, *Pennisetum purperium*); legumes (*Vigna pubescens,* commonly known as “Kunde pori”, *Neonotonia wightii*, *Clitoria tenatea* and *Macroptilium atropurperium*) and crop residues. The common crop residues are maize stover, rice straws, bean hauls and sugarcane tops (Temi, 1991).

The crude protein (CP) content of *P. maximum* and *P. purperium* was observed to vary with season, ranging from 6.5 to 8.5% and 7.8 to 10.2% during dry and wet seasons, respectively (Mtengeti *et al*., 2008). The CP content of *P. purpureum*, was found to be higher than that of *P. maximum* (Table 1). However, the two grasses had CP levels lower than the required level of 12% DM for a dairy cow producing at least 10 litres of milk per day (McDonald *et al*., 2010). Legumes, such as *V. pubescens* and leaf meals of multipurpose trees, such as *Leucaena leucocephala* and *Gliricidia sepium* were reported to have CP ranging from 17-27% and 22-30% DM, respectively (Machibula, 2000 and Kakengi *et al*., 2001). The reported CP values of NP under smallholder farmers are below the requirement of a dairy cow (12% DM) producing at least 10 litres of milk per day. According to McDonald *et al*. (2010), the chemical composition of forages in East Africa particularly native grasses or introduced species in a particular environment normally tends to vary widely not only by species but also with maturity, soil and climate.

Table 1: Nutritional values of some tropical grasses and crop residues used by smallholder farmers in Tanzania

Forage/crop residue	Parameters (g/kg DM)							Source
	DM	CP	ADF	NDF	IVOMD	IVDMD	ME (MJ/kgDM)	
P. maximum	302.0	72.2	495.9	786.5	484.2	470.4	-	Mtengeti *et al.* (2008)
P. purpureum	194.0	102.0	487.5	759.0	519.2	499.7	-	Mtengeti *et al.* (2008)
R. cochinchinensis	324.0	47.3	408.0	753.0	508.0	-	6.18	Laswai *et al.* (2013)
Mixed forage	188.5	119.0	411.6	539.0	515.4	574.8	8.25	Urassa (2012)
Banana leaves	214.0	127.0	443.0	738.0	233.0	-	4.50	Laswai *et al.* (2013)
Banana pseudostem	50.0	51.2	381.0	527.0	406.0	-	4.39	Laswai *et al.* (2013)
Rice straw	839.0	40.7	516.0	739.0	424.0	-	4.19	Laswai *et al.* (2013)
Maize stover	910.0	56.5	390.0	685.0	554.0	-	7.27	Lukuyu *et al.* (2012)

When plants grow require more fibrous tissues to maintain their structure where by the main structural carbohydrates namely cellulose and hemicelluloses and lignin increases and the concentration of protein (CP) and total ash content decreases.

Soil type affects mineral content of pasture as soil acidity has influence on the uptake of many trace elements by plants (McDonald *et al*., 2010). Also the amount of rainfall affects mineral composition of pasture, for example, calcium accumulate more in plants during period of drought while phosphorus seems to be in higher concentrations during rainy than dry season. A study by Mtengeti *et al*. (2008) in Turiani division revealed that during the dry season grasses supply more mineral than during the wet season possibly due to high DM content of the grasses observed during the dry season. For example, *P. purpureum* which forms bulk of the animals' feed was observed to have relatively low DM (14.7%) content during wet season. The low DM content may lead to low intake of protein and minerals contained in it and thus resulting into poor animal performance. In Kibaha, Pwani region, Nkenwa (2009) reported values of *in vitro* dry matter digestibility (IVDMD) and energy content of mixed forages, such as natural grasses and legumes to be 48.09% and 7.02 MJ ME/kg DM, respectively. These values were below those values reported for medium quality forages, which contains more than 55% IVDMD and 10 MJ ME/kgDM (Meissner *et al*., 2000).

Inadequacy of high quality forages under smallholder dairy farmers is one of the major constraints limiting dairy cattle production. Mtui (2004) in a study on available feed resources and seasonal variation under smallholder dairy production in Turiani division revealed that there was a seasonal variation in availability and quality of feeds used by farmers for their dairy cattle. In dry season, forages were obtained in areas, such as river banks and flood plains far away from homestead. The collected forages are of low quantity and poor quality. The species *R. cochinchinensis* was observed to be the most preferred grass during wet season, whereas *P. purpureum* followed by *P. maximum* were the most preferred in both wet and dry seasons, due to their abundance and availability throughout the year.

Mixing the grasses with legumes has been reported to result in higher intakes of energy, protein and weight gain (Lukuyu *et al*., 2012). Legumes fix atmospheric nitrogen in the soil and thereafter the released nitrogen is utilised by the accompanying grass. However, smallholder dairy farmers have not been able to adopt the innovation of mixing grasses and legumes while feeding cows for a number of reasons, one of them being the difficulties associated with establishing and managing such stands particularly when legumes are planted with vigorous grasses such as *P. purpureum* and *Tripsacum laxum.* On the other hand, mixing grasses and legumes for feeding stall fed cows where farmers depend on NP as the major feed sources for their dairy cattle is a challenge (Mtui, 2004). Abundance and availability, particularly of the leguminous species was reported to limit their use by smallholder farmers as feed for their dairy cattle.

Other feed resources used for feeding dairy cattle are crop residues, such as maize stover and rice straws. These are mainly plant materials remained after food crops have been harvested. They are important part of feed resources available under smallholder dairy production for feeding animals especially during the dry season. Crop residues are generally high in fibre, low in digestibility and protein content. Massawe *et al*. (1998) reported that the extent of use of crop residues as feed for dairy cattle vary from place to place depending on the major crops grown in a particular area.

Maize stover and rice straw have been reported to contain poor nutritional values (McDonald *et al*., 2010). When dry period extends, farmers are forced to use other crop residues, such as wheat straw, bean straw, banana leaves, banana pseudo stems and sugar cane tops (Lukuyu *et al*., 2012). All of these feeds are low in quality as shown in Table 1. Most of tropical forages and crop residues are low in nutritional quality due to high temperature, which leads into low digestibility and hence low energy values (Gillah *et al*., 2013).

2.2.2 Concentrates

Concentrates are feeds rich in nutrients particularly energy, protein or both and provide far more nutrients than an equivalent weight of roughage. Therefore, they are fed in relatively small amounts together with the bulk feeds, which are forages to productive animals such as lactating or pregnant cows. They are usually low in crude fibre and high in total digestible nutrients.

Concentrates are classified as energy concentrates when energy is the major nutrient contained in it and protein concentrates when protein is the major nutrient in it. Energy rich concentrate sources available to dairy cattle under smallholder farmers in the tropics are cereals or cereal by-products such as maize, hominy meal (HM), maize bran (MB), rice polishing (RP) or roots and tubers. Liquid feeds such as molasses, fats and oils are added to a ration primarily to increase its energy density. Energy rich concentrate sources also contains proteins, minerals and vitamins in small quantities (Lukuyu *et al*., 2012). The use of whole cereals for feeding dairy cows is uncommon in Tanzania due to their high cost and competing use as food for humans. Therefore, their by-products are more commonly used. In Turiani division, the most preferred cereal by-products for use in animal feeds by smallholder dairy farmers are HM, MB and to less extent RP.

Hominy meal is a by-product of the maize milling industry obtained in the production of maize grits by the dry milling process, whereby maize bran is mixed with broken kernels, germ residue and inseparable fractions of germ, pericarp and endosperm (Stock *et al*., 1999). HM is comparable to MB but less variable and richer in protein as it contain 15% CP, 40% starch and 6.5% CF compared to 12% CP, 35% starch and 12% CF for maize bran (AAFCO, 2002). HM is primarily used as a source of energy for ruminants. It is less expensive than maize grain and its nutritional value may allow performance slightly lower, identical or even higher than that obtained with maize grain (Boyd *et al*., 2008). The author also suggested that due to its composition being close to that of maize grain, HM could be used as an energy source alone. Tahir *et al*. (2002) reported a higher milk yield of 18.05 l/day in HM based diet compared to wheat bran (14.65 l/day) and rice bran (12.87 l/day) based diet when supplementing lactating cows. Maize bran (MB) is another by-product of maize processing industries used as a source of energy for feeding animals and is less expensive than HM. It consists of the bran coating removed in the early steps of processing maize usually with a mixture of the bran fraction and other by-products. Mulumpwa *et al*. (2009) reported that high variability in cell wall content of MB results in variation in digestibility and energy content. On the other hand, Cardenas *et al*. (2002) and Tahir *et al*. (2002) reported that for cows with medium level of production, MB can be used fully to replace maize in their concentrate mixture without affecting milk quantity and quality.

However, during the dry season, MB has to be combined with protein sources like sunflower seedcake for increasing milk yield (Mlay *et al*., 2005). MB has been reported to have an advantage of providing energy without causing negative digestive interactions with other ingredients. For example, Muinga *et al*. (1995) in Kenya reported that supplementation of *P. purpureum* with 1 kg DM of MB did not significantly reduce the rumen degradation of the forage, rather it increased the molar proportions of propionate, which increased the efficiency of utilization of ME and therefore milk production. Variations in the nutritional values of different concentrates used by smallholder farmers to feed their animals are noted across urban and peri urban areas of Tanzania (Table 2). Various factors contribute to the variations in nutritional values across the areas. These include stage of harvest, processing methods, storage condition and method used to analyse the concentrate feeds.

Table 2: Nutritional values of different concentrates used by smallholder dairy farmers reported in different sources

	Parameters (g/kgDM)									
Concentrate type	DM	CP	ADF	NDF	IVOMD	IVDMD	Ca	P	ME MJ/kgDM	Source
Hominy meal	885	125	102	461	-	-	1.4	7.7	12.6	Laswai *et al*. (2013)
	893	152	89	307	-	-	-	-	12.9	Sauvant *et al*. (2015)
	899	115	63.5	400.2	864.6	931.2	-	-	12.97	Urassa (2012)
Maize bran	889	114	154	383	716	-	3.08	6.95	12.7	Laswai *et al*. (2013)
Sunflower seedcake	878	312	378	468	733	-	2.4	8.8	11.9	Laswai *et al*. (2013)
	932	219	459	519	-	-	-	-	12.6	Bwire (2002)

Protein concentrate are feedstuffs high in protein content. According to McDonald *et al*. (2010) the CP content of protein concentrates range from 200 to 500 g/kg DM and even higher than 600 g/kg DM for those of animal origin. The main sources of protein concentrate are animal, marine and plants (Lukuyu *et al*., 2012).

Animal products such as meat, bone, blood and feather meal are used in limited amounts as sources of protein to ruminants and non ruminants because they are expensive, which make their large scale use uneconomical (McDonald *et al*., 2010). Plant sources of protein preferred for ruminant feeding are leaf meals, such as *Leucaena leucocephala*, *Gliricidia sepium* and *Moringa oleifera* and oilseed by-products. Oilseed processing by-products such as cotton seedcake and sunflower seedcake are important sources of protein to ruminants under smallholder farmers. Digestibility and CP content of these oil processing by-products vary depending on the nature of the original seed, the oil extraction techniques and the content of the hulls mixed in the product (Golob *et al*., 2002). Availability and cost of the feedstuff dictate the choice for use as a source of protein supplement to ruminants. Sunflower seedcake (SSC) is a by-product of the extraction of oil from sunflower seed by hydraulic pressure. The quality of SSC depends on the plant characteristics such as seed composition, hulls to kernel ratio, dehulling potential, growth and storage condition and on the processing whether dehulled, mechanical or solvent extraction (Golob *et al*., 2002).

In most developing countries, such as Tanzania, extraction of oil from sunflower seeds is done mechanically without dehulling the seeds. This leads to production of low protein and high fibre SSC contrary to decorticated ones yielding high protein and low fibre SSC. Though it contains less protein and more fibre than soya bean meal, SSC is valuable livestock feed particularly ruminants (Blair, 2011). When it was used to replace soya bean meal in dairy cow diets, milk production was similar. Furthermore, Heuzé *et al*. (2015) reported that SSC does not have anti nutritional factors; therefore, it does not require special attention before being fed. Grompone (2005) reported that SSC is a valuable source of calcium, phosphorus and B-vitamins. Lactating dairy cows supplemented with a MB-SSC concentrate mixture containing 31% SSC fed at a rate of 4 kg/d were reported to have higher milk yields of 8.1 l/d/cow compared to 6.6 l/d/cow for those supplemented with the same amounts of MB alone (Mlay *et al*., 2005).

2.3 Performance of dairy cattle under different feeding practices

Feeding practices in dairy cattle production involves all the activities of securing feed and water supplies from sustainable sources and the amount of feed to be fed to dairy cows. Smallholder farmers in Turiani division keep crossbred dairy cattle under zero grazing system. They mainly practice either of the following feeding practices; Firstly, forage feeding depending mainly on NP and crop residues obtained from communal areas, fallow lands, road sides and river banks. Secondly, forage with MB as sole supplement during milking and thirdly, forage feeding with mixed concentrate (MDC) supplementation, chopped banana pseudo stem and leaves, potato peals, weeds and crop residues. Zero grazing is an intensive milk production system in which herbage is cut in the field and carried to indoor animals. Feeding system has an influence on dairy cattle productivity due to differences in management.

2.3.1 Forage feeding

Smallholder dairy farmers depend on forages, mainly NP as main basal diet for their animals. Forage availability and their nutritional values in most tropical areas differ with seasons. During the wet season, forage materials are abundant with reasonable quality in terms of nutritive values for feeding dairy cattle. On the other hand, in the dry season the quantity and quality of forages are low. This fluctuation in feed availability causes seasonal variability in productivity of dairy cows under smallholder farmers in the tropics (Mtui, 2004). Several authors have reviewed seasonal variation in milk yield in relation to the availability of tropical forages. In a study done in Kenya by Kayongo (1991), revealed that there was abundant growth of pasture and fodders which was in excess of requirement during the rain season. The 'excess' goes to waste since most farmers are not familiar or do not own facilities to conserve the excess herbage for dry season feeding.

On the other hand, in Morogoro peri urban it has been reported that nutritional value of forages decline with advancing dry season (Mlay *et al*., 2001). This condition results into fluctuation in milk production from dairy cows due to low intake of essential nutrients, such as energy, protein, minerals and vitamins required for rumen microbial activities. High performance of lactating dairy cow depends on availability of good quality feeds, clean water and proper feeding practice. Extensive work has been done to assess performance of dairy cattle kept in different feeding systems under different feeding practices. Earlier findings from the dairy units of Nakuru in Kenya (Lanyasunya *et al*., 2001) revealed that a feeding practice which depends only on forage or pasture without supplementation, milk production will depend on quality and quantity of the pasture. Nevertheless, it is difficult to realise the full genetic potential of a cow fed in that way. Lukuyu *et al*. (2012) reported that a cow fed on *P. purperium* alone can produce 7 l/d whereas 9-12 l/d was obtained when fed on a *P. purperium*-legume mixture. The authors also reported that when Rhodes grass was fed alone the average milk yield ranged from 5-7 l/d, whereas 7-10 l/d was obtained when grass-legume mixture was used. Normally a feeding practice which leads to underfeeding of dairy cows results into low performance, which eventually climaxes into economic losses to smallholder farmers. Therefore, a thorough assessment of the existing feeding practices could provide insight on the problems hampering productivity of dairy cattle in Turiani division.

2.3.2 Concentrate supplementation

Concentrate supplementation in the tropics is a feeding practice employed by some smallholder farmers, mostly to their stall fed lactating cows. According to Gillah *et al*. (2012), dairy farmers rarely feed concentrates at recommended levels and required quality. They supplement MB or MDC to relax the cows when milking at a rate of 2-3 kg/cow/d without considering the actual requirements based on the level of production of the animals (Richards and Godfrey, 2003). In addition, the types of concentrate mixture offered to dairy cows differ among farmers within the same location (Mtui, 2004). Most smallholder farmers prefer using MB singly as a concentrate to supplement their lactating cows while others use a mixture of more than one concentrate ingredients, such as MB and SSC; MB, SSC and RP and a mixture of MB, SSC, RP, mineral mixture and to a less extent leaf meals. However, the type of concentrate mixture and amount offered per cow per day differ from one household to another (Mtui, 2004). A survey by Kiruiro (1999) in central Kenya revealed that smallholder farmers feed concentrates to their lactating cows below the recommended level that is 2 kg dairy meal/cow/d instead of 4 kg dairy meal/cow/d as recommended by the manufacturer regardless of the level of milk production or status of the animal.

Feeding of concentrates to lactating dairy cows have been reported to improve performance of the animals in terms of milk yield. Lanyasunya *et al*. (2001) and Nkya *et al*. (2008) observed that in the dairy units of Nakuru in Kenya and Morogoro in Tanzania, respectively where concentrate feeding practices were introduced, daily milk yield (litres/cow/d) improved from 7 to over 24 litres and 6.7 to 8.0, respectively. On the other hand, Scheinman *et al*. (1992) reported an extra milk yield of 2-3 l/cow/d from supplemented dairy cows under zero grazing over the non-supplemented cows.

Basing on the fact that most of NP used by smallholder dairy farmers in the tropics are low in their nutritive value, adequate concentrate supplementation practice is of great importance in order to improve performance of dairy cows to reach their genetic potential. This is in agreement with the observation made by Abate *et al*. (1995) who observed that in sub-Saharan Africa the DMI of basal diets is usually inadequate because a wide range of selected genera and species of forages available for feeding dairy cows have low nutritive values, which also tend to vary with season. Therefore, to maintain higher levels of DMI in order to improve performance of dairy animals, various vegetative and concentrate supplementation is more essential. According to Gillah *et al*. (2013) the level of milk yield in Eastern and Central Africa dairy units range from 5.7 to 17 litres/cow/d (Table 3). A number of factors have been reported to contribute for the variation in milk production, among them feeding practices have greater influence on milk yield (Epaphras, 2004).

Table 3: Daily milk yield of crossbred dairy cows in some tropical African countries from different sources

Country	City/Town	Milk yield (litres/cow/d)	Reference
Tanzania	Morogoro	8.1	Mlay *et al*. (2005)
	Morogoro	7.4	Kavana and Msangi (2005)
	Korogwe	6.6	Bee *et al*. (2006)
	Tanga	5.7	Lyimo *et al*. (2004)
	Kibaha	10.0	Urassa (2012)
	Arumeru	10.1	Urassa (2012)
	Dar es Salaam	7.1	Epaphras *et al*. (2004)
	Dar es Salaam	8.0	Kivaria *et al*. (2006)
	Dar es Salaam	10.4	Gillah *et al*. (2013)
Kenya	Kiambu	7.2	Omore (2003)
Ethiopia	Addis Ababa	7.8	Ayenew *et al*. (2009)
Sudan	Khartoum	17.0	Idris *et al*. (1999)
Uganda	Kampala	10.0	Prain *et al*. (2010)

2.3.3 Crop residue feeding

Feeding of crop residues, mainly maize stover and rice straws is another feeding practice done by smallholder dairy farmers especially during the dry season. Masama *et al*. (2005) reported that farmers use a variety of crop residues to feed their animals because they are cheap and locally accessible. Utilization of alternative feed resources such as crop residues during period of forage scarcity is of importance under smallholder dairy production. However, the extent of use of crop residues to feed dairy cattle varies from place to place depending on the major crops grown, cost of collection and transportation, cost of storage and processing (Massawe, 1999 and Mpairwe, 2005). Because of their high fibrous content, low digestibility and low protein content, crop residues remain in the rumen for a long time leading to limited intake. Also they do not have enough crude protein to support adequate microbial activity in the rumen. The crude protein content of maize stover has been reported to range from 2.31 to 6.25% of dry matter (Mtui, 2004).

Feeding practice, physical processing and chemical treatment are the ways used to improve utilization of crop residues. In Thailand, Wanapat *et al*. (1998) reported that lactating dairy cows fed on a combination of urea-treated rice straw and whole sugar cane crop as roughage sources during the dry season improved the feeding values of these forages and increased dry matter intake (7.6 kg/d) and milk yield (4.47 l/d). The study by Masimbiti (2001) reported that lactating dairy cows fed on urea treated maize stover yielded higher milk (10.1 l/d) than those fed untreated maize stover (9.5 l/d) in Zimbabwe. Hence, dairy cattle fed on especially untreated crop residues need to be supplemented with readily available energy and degradable protein to supply nitrogen to the microbes in the rumen.

2.4 Feeding strategies during dry season

Smallholder farmers in most tropical countries particularly Tanzania are faced with a number of challenges, among them been seasonal variability of feeds. Various strategies have been developed for improving productivity during the dry seasons, notably feed conservation, treatment of low quality forages and concentrate supplementation.

2.4.1 Feed conservation

In the tropics there are times of plenty and times of scarcity of forages because both forages and fodder are rain-fed. This situation of seasonal availability stresses the importance of conserving the excess forage during rainy periods for use in dry season. Forages may be conserved either in form of hay, standing hay or silage.

Hay is conserved green crops cut after attaining 50% flowering, a stage at which levels of protein and digestibility are at maximum (Lukuyu *et al*., 2012). The cut crops are then dried to reduce the moisture content to a level low enough to inhibit action of plant and microbial enzymes and fungal growth. According to McDonald *et al*. (2010) the moisture content of green crops depends on season and stage of growth and normally range from about 650 g/kg to 850 g/kg DM tending to fall as plant matures. In order for the hay bale to be stored satisfactorily, the moisture content should be reduced to 150 – 200 g/kg DM. Drying to reduce moisture can be either manually by sun drying, use of field machinery and barn drying. Manual drying and baling is more economical for smallholder dairy farmers. However, hay making in the tropics is not widely used because grasses are abundant in the rain season that interrupt drying process in the field, vigorous growth of grasses which leads to rapid decline in protein content and digestibility as a result it becomes very difficult to combine a good yield with satisfactory nutritive value (Lukuyu *et al*., 2012).

Standing hay are forage stands left to dry on the field for use during period of scarcity. Forages conserved in that way are normally exposed to direct sunlight and rainfall for their whole time of conservation as a result deteriorate continuously leading to low quality (Lukuyu *et al*., 2012). They are poorly digestible, low in protein, energy and minerals and therefore when fed alone do not meet the animal nutrient requirement for maintenance and production.

Silage making is another method of conserving forages whereby high moisture fodder are preserved through fermentation in the absence of air (McDonald *et al*., 2010). Silage can be made from grasses, such as *P. purpureum,* fodder sorghum and green maize. The crops should contain an adequate level of fermentable sugars in the form of water soluble carbohydrates. Dry matter content in the fresh crop should be more than 200 g/kg DM and a physical structure that will allow it to compact readily in the silo. It requires a container or pit in which crop is ensiled after harvesting (Lukuyu *et al*., 2012).

Grass should be harvested when is about 1m high while maize and sorghum are harvested at dough stage where the protein content of the grass is about 10% and the grain for maize and sorghum is milky.

However, according to McDonald *et al*. (2010), tropical grasses and legumes are difficult to ensile as they have a low water soluble carbohydrate content and are more highly buffered. Thus, for satisfactory ensilage; wilting of very wet crops, mixing of legumes with cereal crops and addition of molasses to provide a source of water soluble carbohydrates is important. On the other hand, Lukuyu *et al*. (2012) reported that in order to increase the level of crude protein and quality of the silage, poultry waste and legumes such as *Lucerne* and *Desmodium* may be mixed with the material to be ensiled but at a rate of not more than 5% and 25% respectively of the total material ensiled. This is because protein has a buffering effect that increases the amount of acid (Muhammad *et al*., 2014), therefore if used in large amount tend to lower pH below the recommended value of 4.0 (McDonald *et al*., 2010).

Nevertheless, the economies of scale in terms of materials and labour intensive make silage making to be low under smallholder farming systems. Mannetje (2000) reported that silage making in the tropics is low because of limited know how among farmers, lack of finance and labour intensive. Silage making is considered to be cumbersome. In a study by Lyimo (2010), in-bag grass silage quality within small scale farmers in Mvomero district revealed that smallholder dairy farmers could easily use strong plastic bags. The plastic bags having capacity from 5 kg fresh chopped green fodder grass could be easily used, a technology employed in Zimbabwe, Benin and Kenya highlands. This technique allows conservation of available forage in small quantities over a long period compared to the pit method. In Turiani division, however, only a small proportion of farmers are aware on silage making. Similarly in central Uganda, Muhammad *et al*. (2014) reported only 10% of smallholder farmers knew about silage making as one of the methods of feed conservation. However, Kaiser *et al*. (1993) reported that when lactating dairy cows were fed on silage containing 11 MJ ME/kg DM as the sole feed, the cows produced 1.28 l/kg silage DM.

2.4.2 Treatment of low quality roughages

In most tropical countries crop residues, mature hay and over grown *P. purpureum* which are used to feed animals especially during dry season, are of low quality. Because of their high fibre content and low digestibility which tend to limit both their intake and utilization, several methods have been developed to ameliorate their quality. The common methods used to improve the quality of forage are physical, chemical and biological treatments.

Physical treatment of low quality forages such as chopping to about 5cm before feeding even though it does not improve digestibility, it increases its intake, reduce wastage and make it easy to be mixed with other feed components, such as legumes (Lukuyu *et al*., 2012). Grinding and pelleting are physical treatment of forages which improve its intake but when forages are finely ground (1mm) and fed to animals, it has been reported to result into less sorting, higher intake, less gut fill, higher passage rate and consequently lower digestibility (3% legumes and 15% grasses) (Chenost and Kayouli, 2003). On the other hand, Massawe (1999) suggested stripping as an alternative method for effective use of crop residues under smallholder units as it increases the level of intake but require supplementation of protein rich concentrate. The use of chemicals such as alkali and urea to treat low quality forages have been reported to increase their feed intake and digestibility (Mtamakaya, 2002). Alkaline improves the quality of low quality forages by increasing their digestibility through swelling the cellulose and hydrolysis of the hydrogen bonds between the lignin and hemicelluloses which makes it easier for the enzymes to work (Walker, 2013). Shem (1986) reported an increase of up to 50% in milk yield from cows fed on maize stovers treated with alkali. According to Kimambo *et al*. (2002) when maize stem, leaf sheath, air bract and rice straw were treated with alkali particularly Sodium hydroxide (NaOH), they were observed to improve their dry matter digestibility by 64.6%, 33.9%, 63.5% and 59% respectively. Mlay *et al*. (2001) revealed an improvement in microbial protein synthesis and NDF digestibility when hay was treated with Sodium carbonate, an alkali commonly known as Magadi. Contrary to the previous observation, Massawe (1998) revealed that chemical treatment of crop residues was not appropriate technology to smallholder farmers because it requires some technicalities which once miss-handled may lead to loss of the animal. However, in Tanzania the use of NaOH and Magadi is low because of high cost and availability, respectively and also the later is required in bulky when selected as an alkali for treating crop residues.

Another alkali that could be used for treating low quality forages under smallholder production system is wood ash. Wood ash is locally produced in households where woods and charcoal are used for cooking. Nkenwa (2001) and Mtamakaya (2002) in their studies using wood ash for treating rice straws and maize stover observed an increase in rumen dry matter and organic matter digestibility and a decrease in NDF content of rice straw. This was due to weakening of the bonds between the hemicelluloses, cellulose and lignin by the alkali which makes them to be susceptible to the action of microbes in the rumen.

Urea treatment of crop residues is done by sprinkling the chopped materials with urea solution mixed at a rate of 4 kg fertilizer grade urea in 100 litres of water. The mixing of the chopped material with urea-water solution can be done in a pit or on a plastic sheet on the ground before packing in a pit. This improves the nutritive value by increasing the digestibility, palatability and crude protein content (Lukuyu *et al*., 2012).

The pit remains closed for one month during which urea is being converted to ammonia which then breaks down some of the bonds in the fibrous material making them accessible to microbial enzymes. Urea treatment was reported to be the most practical significant in tropical countries like Tanzania. It acts both as alkali and a source of nitrogen to materials which are low in crude protein (Kimambo *et al*., 2002). Urea treated rice straws were observed to increase their CP content by 1%, that is from 6% to 7% and a decreased in NDF from 60.96 to 56.97% (Mtamakaya, 2002). Masimbiti (2001) in a study on utilization of urea treated maize stover in rations for dairy cows in Zimbabwe reported that lactating dairy cows fed on treated maize stover produced extra 0.6 litres of milk than those fed on untreated maize stover, that is 10.1 l/cow/d versus 9.5 l/cow/d.

On the other hand, feeding urea-molasses block together with crop residues is another technique which provides both nitrogen and energy to the microorganisms in the rumen and therefore improves the digestion of the crop residues (Walker, 2013). Ideally the urea-molasses block provides protein, energy and minerals to ruminants. It can be made from carefully weighed ingredients such as molasses, urea, dicalcium phosphate, salt, binding agent (cement) and MB. According to Pandey and Voskuil (2011), for a quantity of 100 kg the ingredients should be molasses (38), urea (12), dicalcium phosphate (2), salt (3), binding agent (13) and MB (32) kg respectively. Careful measurement of the ingredients is important because urea and binding agent are toxic when fed in excess. Recommended quantities of urea-molasses block to be fed per cow per day are 2 kg for cows weighing over 400 kg and 1 kg for cows weighing less than 400 kg. Biological treatment of low quality forages involves the use of fungi. White rot fungi (WRF) such as *Phanerochaete chrysosporium* are selective lignin degrading microorganisms which were reported to be the most effective for biological pre-treatment of low quality forages for enhancing their utilization by animals (Villas-Boas *et al*., 2001). They degrade (solubilise) lignin to the extent of 65 to 70% (Yu *et al*., 2009). Fungi (WRF) can decrease lignin by 50% and increase digestibility by 50 to 80% (Chenost and Kayouli, 2003). Therefore, this microbial conversion appears to be a practical and promising alternative for increasing the nutritional value of poor quality forages by transforming them into animal feed and producing a value-added product. Such observations and others indicate that if crop residues and poor quality hay are efficiently utilized there is a potential to improve milk production by crossbred lactating cows under smallholder farmers in the tropics.

2.4.3 Supplementation

Low quality forages when supplemented with good quality grasses, legumes or concentrate feeds significantly improve feed intake and animal performance. During the dry season where forages are scarce and of low quality, supplementation of the basal diet with good quality forage or concentrates helps to reduce the problem of low palatability and intake. Different studies have reported high milk production when poor quality forages are fed with different levels of concentrates and/or supplemented with multipurpose trees. A study by Nkya *et al*. (2002) revealed that supplementation of forages with concentrates at a rate of 0.8 kg per litre of milk produced was linked with an increase in milk yield of 1.26 l/cow/d and a body weight changes of 0.25 kg.

The same results were reported by Fike *et al*. (2003) who observed an increase in milk yield by 11.3% on lactating cows supplemented with 0.8 kg of concentrate per litre of milk produced compared to un-supplemented group. Supplementation of basal diets with good quality forage or concentrates in the tropics particularly during dry season improve intakes of low quality forage as well as milk yield of dairy cows. In a study with lactating Mpwapwa breed cows receiving 6.8 kg/cow/d of hay and supplemented with 4 kg DM/cow/d concentrate, Bwire and Wiktorsson (2003) observed higher milk production of 6.2 l/cow/d compared to 5.0 l/cow/d produced by those supplemented with 2 kg DM/cow/d of concentrate. Other results by Bwire (2002) on a study with dual – purpose lactating cows reported a higher milk yield of 5.3 l/cow/d from cows fed on grass and supplemented with 3.1 kg DM/cow/d compared to 4.8 l/cow/d obtained from cows fed on a combination of grasses without supplementation.

Supplementation of lactating dairy cows with 4 kg/cow/d of a concentrate (68% MB, 31% SSC and 1% cattle mix) in peri-urban and urban areas of Morogoro was reported to improve live body weight by 0.63 kg/d, body condition score and milk yield by 1.5 l/cow/d in a 12 weeks period (Mlay *et al*., 2005). Urassa (2012) in a study on supplementation strategy for improving milk production of crossbred dairy cows under smallholder farmers in Kibaha district observed that lactating cows receiving 5 kg/cow/d of hay made of *P. maximum* on top of basal diet and supplemented with a home made concentrate at a rate of 5 kg/cow/d produced 4.66 l/cow/d more than the un-supplemented cows. Other finding by Nkya and Swai (1999) revealed that supplementation with urea molasses mineral blocks to lactating dairy cows supplied with grass hay *ad libitum* and MB at a rate of 6 kg/cow/d for a period of 49 days during the dry season increased milk yield from 6.7 to 11.2 litres of milk per cow per day and DMI from 10.1 to 12.0 kg per day. However, as the population of rumen microorganisms depends on the composition of feedstuffs consumed, feeding of high-energy feedstuffs should consider the required roughage: concentrate ratio as excess of concentrate may have a negative associative effect on the degree of utilisation of roughage. The end products of fermentation of high-energy feedstuffs in the rumen are propionate and lactate which are both strong acids relative to acetate. Acetate is obtained after digestion of forages by cellulolytic bacteria. As the rate and extent of digestion are high for high-energy feedstuffs the resultant pH of the rumen is reduced. Low pH (< 6) has a negative effect on the microorganisms responsible for digestion of roughages. Therefore, high rate of incorporation of high-energy none fibrous carbohydrate feedstuffs decreases the utilization of roughages.

Supplementation with tree legumes has been reported to gain importance in improving performance of dairy cattle in most developing countries. Common tree legumes used in the tropics are *Leucaena leucocephala, Gliricidia sepium, Moringa oleifera* and *Calliandra* (Temi, 1999).Tree legumes are good source of protein. In the tropics they are of potential especially during the dry period as they have deep root systems that can withstand drought and hence serve as main source of forage during the dry season (Temi, 1999). Kakengi *et al*. (1999) reported that 2.6 kg DM of *leucaena* leaf meal (LLM) can substitute 1.8 kg DM of cotton seedcake without affecting cattle performance. The author observed that lactating dairy cows supplemented with LLM based concentrate showed more weight gain and high milk yield compared to those supplemented with cotton seed cake based concentrate at the same rate of 1.8 kg DM/cow/d.

According to McDonald *et al*. (2010), the crude protein (CP) content of tree legumes range from 200 to 300 g/kg DM. Due to their high CP and mineral contents, tree legumes can be suitable alternative to concentrates in forage based diets. They can be easily established and maintained under farmers' condition. They are relatively cheaper compared to agro-industrial by-products used as source of protein for ruminant animals. However, tree legumes are high in neutral detergent fibre (NDF) ranging from 500 to 600 g/kg DM. Together with tannins, both reduce palatability of tree legumes and hence it's nutritional value making them as a food reserve to be consumed when grass herbage is limited, particularly during the dry season. The form in which the tree legumes are fed may influence how tannins affect feed intake (Reed, 1995). Drying before feeding reduces solubility of tannins and, hence, reduces their ability to complex protein as they become more polymerized resulting in a lower number of free hydroxyls available for binding the proteins. Sarwatt *et al*. (2004) on a study with crossbred lactating cows fed on elephant grass (*P. purpureum*) based diet and supplemented with a concentrate in which cotton seedcake was substituted with *Moringa oleifera*, observed an increase in milk yield from 7.8 to 9.2 l/cow/d. On the other hand, Urassa (2012) observed an extra average milk gain of 5.39 l/cow/d from lactating cows supplemented with 4.7 kg DM/cow/d of a concentrate in which LLM substituted 15.9% of sunflower seedcake and 1.87 kg DM of *Chloris guyana* hay compared to milk gain of 0.73 l/cow/d obtained from unsupplemented group.

Supplementation of essential minerals particularly calcium and phosphorus has positive impact on milk yield of lactating cows. Gimbi *et al*. (2006) observed a difference of 2.5 litres (10.13 l/cow/d versus 7.63 l/cow/d) in milk yield between lactating cows supplemented with concentrate and the unsupplemented group due to additional phosphorus in the diet. Therefore, good feeding strategy especially during the dry season may be a useful tool for improving milk yield from dairy cows.

2.5 Nutrients requirement of lactating dairy cows

The aim of feeding dairy cows is to maximize milk yield by meeting the cow's nutrient requirements. The nutrient requirements largely depend on the amount of milk produced, which in turn depends on the stage of lactation, that is the period from calving to dry period, when milk production stops (Nelson and Knowlton, 2003; Pandey and Voskuil, 2011 and Heinrichs, 2014). All the nutrients required by the cow for milk production (except water) are in the dry material of the feed. High dry matter intake (DMI) results in high nutrient intake and high milk yield (Wheeler, 2011).

The amount of energy, protein and mineral required by lactating cows depends on maintenance, milk produced, growth and pregnancy (Lukuyu *et al*., 2012). The nutrients required for maintenance is largely affected by the cow's weight, environmental temperature and activity. Deficiency of any nutrient may reduce microbial protein synthesis in the rumen which in turn affects amino acid passage to the small intestine and hence in milk production by dairy cow.

Under zero grazing system where the forages are opportunistically obtained from communal areas, fallow lands, road sides and river banks, the animals are in most cases underfed especially in the dry season. Feeding of lactating cows should aim to provide nutrients for maximum milk yield, fast growing foetus and deposition of an energy reserve and regeneration of the mammary gland (Lukuyu *et al*., 2012). Furthermore, according to MAFF (1984), metabolizable energy (ME) and crude protein (CP) requirement for milk production by dairy cows depends on milk composition. For the milk with 3.0% fat and 2.6% protein the values are 4.5 MJ ME/l and 0.081 kg protein/kg of milk, respectively. The ME and CP requirements of a dairy cow weighing 400 kg live weight and producing at least 20 litres of milk per day as indicated in Table 4 were calculated basing on these values.

Minerals are nutrients required to be supplied in the diet all the time in order for the animal body to function properly, that is, remain healthy, reproduce and produce milk

(Lukuyu *et al*., 2012). Some minerals are required in large quantities (macro-minerals such as Calcium and Phosphorus) while others are required in small quantities (microminerals such as Iodine and Iron).

Table 4: Daily requirements of a dairy cow weighing 400 kg live weight and producing at least 20 litres of milk per day

Nutrient requirement	ME (MJ)	CP (g)	Ca (g)	P (g)
Maintenance for a cow with 400 kg live weight	45	358	-	-
For production of 20 kg of milk per day	90	1620	-	-
Total	**135**	**1978**	**68**	**44**

Source: MAFF 1984 and Laswai *et al*. (2013)

2.6 Conclusions from the review

From the review, it can be concluded that productivity of dairy cattle under smallholder farmers in the tropics is still low, being constrained by a number of factors, the major one presumed to be poor feeding practices. Smallholder dairy farmers depend mainly on forages particularly natural pastures (NP) to feed their animals. However, most of tropical forages are low in nutritive values and when fed alone do not meet the nutrients requirement of the cows for both maintenance and production. Furthermore, in the tropics the quantity and quality of forages depend on rainfall, causing fluctuation in milk production. The use of different feeding strategies, such as forage conservation, treatment of low quality forages and use of supplements have been observed to improve productivity from dairy cattle. Poor feeding practices to lactating cows, such as sole feeding of NP, use of single concentrate ingredient, use of imbalanced concentrate and inadequate amounts of supplemented concentrate and forages offered are the major constraints to production as reflected by low milk yield. Limited information is available on the amount of forage and concentrate to be fed in order to meet the nutrients required by lactating animals under smallholder zero grazing dairy production system in Turiani division and elsewhere. Therefore, a thorough assessment of existing feeding practices and performance of dairy cattle could assist in the formulation of appropriate feeding practice for improving dairy cattle productivity.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Overview

Two investigations were carried out to assess the effect of feeding practice on milk yield of crossbred dairy cows in two villages of Turiani division, Mvomero district. Investigation 1 involved monitoring of different feeding practices and measuring the amounts of different feeds offered to lactating cows in different farms. The investigation was carried out during the dry season between September and October, 2014 for a period of 28 days. Investigation 2 was a planed feeding experiment, which was undertaken towards the end of dry season in January and February, 2015 to test an appropriate feeding practice for improved milk yield of the lactating cows in the study area.

3.2 Description of the study area

The study was carried out in Manyinga and Madizini villages in Turiani division, Mvomero district. Turiani division is located 100 km North of Morogoro town along Kilosa – Handeni road at altitude between 800 to 1200 metres above sea level, latitude $5^{o}5'$ to $7^{o}41'$S and longitude $37^{o}10'$ to $38^{o}31'$E, surrounded by Nguu Mountains. The area receives bimodal type of rainfall with long rains between March and May and short rains in November and December. The average annual rainfall range is 900 mm to 1200 mm and temperature ranging between 15^{o} to 29^{o}C. The population of the division is 108 490 with considerable variation between and within wards (NBS, 2012). Small businesses, farming (crop integrated with livestock production) and employment in the Mtibwa sugar industry are the major economic activities of the habitants in the division. The major farming systems include maize-rice, agro-pastoralism and banana-vegetables.

3.3 Investigation 1 - Assessment of feeding practices and performance of lactating cows

3.3.1 Nature of the investigation

The lactating dairy cows were monitored for a period of 28 days between September and October 2014. Information on the existing feeding practices and performance of the stall fed animals were obtained through observations and measurements of different parameters. Farmers were supplied with stationery, pocket spring balances and calibrated milk measuring jars and trained on how to use them during a group meeting conducted one day before the onset of the investigation. In addition the nutritional values of the common feeds used by smallholder dairy farmers for their animals in the study area were evaluated.

3.3.2 Direct observation

Direct observations were made to examine the type and amount of feeds offered to the animals, existing feeding practices and animal housing conditions. Factors relating to housing design such as presence and adequacy of roofing, floor type, nature and adequacy of feeding bunks and drinkers were visually examined.

3.3.3 Investigation design

A cross sectional study design was employed to assess the existing feeding practices and performance of the 24 lactating dairy cows between the 1^{st} and 2^{nd} months after calving from 18 farms in Manyinga and Madizini villages, Turiani division.

3.3.4 Source of experimental animals and their management

The selected lactating dairy cows were 24 of mixed aged, breed (Zebu-Friesian and Zebu-Ayrshire crosses) and between 1^{st} and 3^{rd} parity that calved between July and August

2014, managed under zero grazing system. The animals were obtained from 18 smallholder farms basing on the stage of lactation. A weekly control of ticks and other ectoparasites was performed by hand spraying using knapsack in the morning after milking. The accaricide used for tick and other ectoparasites control was Parannex^R 100EC containing 100gm Alphacypermethrin per litre as an active ingredient produced by Farmbase Limited. Control of endoparasites was done using a wide spectrum anthelmintic - Albendazole 10% three days before the onset of the experiment. Isometamidium chloride hydrochloride (Samorin) was injected five days before the onset of the experiment for prevention and control of trypanosomiasis. Body temperature was taken weekly using a digital thermometer for the purpose of detecting fever condition. Each cow moved freely in individual partitioned pen. Milking was done by hand twice a day, in the morning between 0500 and 0630 h and in the evening between 1800 and 1930 h. Calves were bucket fed twice per day at a rate of 3 litres per calf, after every milking. The barns were cleaned every morning before milking and feeding.

3.3.5 Source of feeds and feeding

The animals were fed on natural pastures (NP), crop residues and local concentrates. The forages were cut and carried from roadsides, uncultivated land and riverbanks while crop residues mainly maize stover and rice straw were collected from the farms after crop harvest. The local concentrates commonly used were cereal and oil seeds by-products obtained from the milling machines and oil refinery plants situated nearby the study area. In some farms the animals were fed on mixed forages alone and others on mixed forages with supplementation of sole maize bran (MB) or with a mixture of different concentrate ingredients such as MB plus sunflower seed cake (SSC), MB plus SSC plus rice polishing (RP), RP plus SSC and MB plus dried Moringa leaf meal that were supplied during milking. Each animal was fed individually from the feeding and watering troughs. To ensure individual animal feeding, the cow's barns under farmer condition were modified to allow individual feeding and watering troughs. Forages were fed twice to three times a day and in most cases presented to animals without chopping. Weighing of feeds offered, feeding, collection and weighing of refusals were done by farmers.

3.3.6 Parameters measured

3.3.6.1 Feed offered and refusals

The forage used for feeding the experimental animals either chopped or not chopped was packed into bags and weighed daily using spring balance. Concentrates offered to the animals were also weighed separately at every meal during milking. Each morning before feeding the feed refusals of the previous day feeding were collected and weighed using similar spring balances.

3.3.6.2 Milk yield

The milk produced by each cow in every milking was measured using calibrated milk measuring jars and recorded on designed sheets, whereby the volumes of morning and evening milk yield were added together to obtain total daily milk yield per cow. Measurements of milk yield were taken by the farmers with assistance from the researcher and research assistants.

3.3.6.3 Live weight

The body weight of each lactating cow was estimated weekly after morning milking by taking the circumference at heart girth using weighing tape band, which is calibrated in centimetre with associated weight in kilograms. Measurement was carried out only after ensuring the animal is thoroughly restrained, standing on all four legs with the head maintained in an upright position. The weighing tape was wrapped snugly around the brisket just behind the forelegs and the reading obtained in kilograms was recorded as the live weight of the animal.

3.3.7 Sample collection and preparation

Forage samples for laboratory analysis were collected from each farmer's feed bundle twice per week. About 0.3 kg of mixed forages and 0.3 kg of refusals per cow from each farm were sampled twice per week, weighed and packed in polythene bags to control moisture loss before being transported to SUA laboratory for analysis. The collected samples were taken to SUA laboratory twice a week. A total of 192 mixed forage samples and 192 refusal samples were collected for the whole experimental period.

Concentrate samples were collected once for the whole experimental period from each farmer who provided concentrate to her cow. About 0.25 kg of concentrate per cow from each farm was sampled for analysis. A total of 24 concentrate samples were collected.

At the laboratory, forage and refusal samples were chopped into small pieces of 3-5cm and oven dried at 70^0 C to constant weight. The samples were then milled to pass through a 2mm sieve. The respective ground mixed forage, concentrates and refusal samples from each cow were again ground to pass through 1mm sieve, bottled and then stored for subsequent chemical analysis.

3.3.8 Chemical analyses

Representative ground samples were analysed for dry matter (DM), crude protein (CP) and ash using Weende scheme of analysis (AOAC, 2006). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest method (Van Soest, 1991).

3.3.8.1 Dry matter and ash determination

Approximately 1gm (W1) of each sample in duplicate was weighed and dried in the oven at 105°C to constant weight for 24 hrs then reweighed (W2). The percentage dry matter (DM) was determined as

DM = W2/W1 * 100%. ……………………………………………………..……….. (1)

The ash content was determined by ignition of the samples at 550° C for 3 hours in which the organic matter was burnt and the residue obtained was crude ash or mineral matter.

3.3.8.2 Crude protein determination

Crude protein was analysed according to kjeldahl technique using block digestion and steam distillation, whereby the proteins and the nitrogenous compounds from the feed sample materials were converted into Ammonium Sulphate by boiling with concentrated Sulphuric acid in the presence of catalysts. The Ammonium Sulphate formed was further decomposed by excess Sodium Hydroxide to form Ammonium Hydroxide and on boiling using hot steam the Ammonia was liberated. The Liberated Ammonia vapours were pushed to pass through a cold condenser and liquid where was trapped and collected in a week boric acid containing mixed indicators of Bromocresol green and Methyl Red. The actual amount was determined by titration with another standardized week acid, hydrochloric acid. Then the amount of Nitrogen or CP was calculated by the following equation;

$$\%N = \frac{14.01(\text{Titre value mls} - \text{blank value mls})\ \text{Molarity of acid used}}{\text{Sample weight} * 10} \quad \text{……………… (2)}$$

Therefore

%CP = %N * Factor

Where, factor = 6.25 for plant materials

3.3.8.3 Fibre analysis

The neutral detergent fibre (NDF) content of the samples was determined using digestion apparatus (Ankom fibre analyzer). The process involved boiling of the samples in the neutral buffer detergent solution at 100^{o} C for 75 minutes to partition the cell contents (non structural) and cell wall constituents (structural). The samples were packed in the filter bags. The bags with residues were then completely dried in the oven at 105^{o} C for 24 hours after being rinsed 3 times using hot distilled water at 100^{o} C for 5 minutes each and soaked in acetone for 3 minutes to remove fats. The bags were removed from the oven, cooled to ambient temperature, weighed and the percentage of NDF was calculated.

The acid detergent fibre (ADF) determination procedure was a rapid method of hemicellulose determination in the samples by using Ankom fibre analyzer whereby the sample materials was boiled with standardized acid detergent solution at 100^{o} C for 60 minutes, rinsed 3 times with distilled water at 100^{o} C for 5 minutes and soaked in acetone for 3 minutes. Then, the bags with residues were completely dried in the oven at 105^{o} C for 24 hours. The dried bags with residue were removed from the oven, cooled to ambient temperature and weighed to calculate the percentage ADF.

3.3.9 Determination of *in-vitro* digestibility

In vitro dry matter (IVDMD) and organic matter (IVOMD) digestibility of feeds offered to the animals and refusals were determined in the laboratory using two stage techniques according to Tilley and Terry (1963). The rumen liquor was obtained from four fistulated steers available at Magadu farm,SUA.

$$IVOMD = \frac{\text{Sample OM} - (\text{Residue OM} - \text{Residue OM blank})}{\text{Sample OM}} * 100 \quad \text{.............. (3)}$$

3.3.10 Parameters derived

3.3.10.1 Metabolizable energy (ME)

The ME contents of the feed samples were estimated according to the following equation by MAFF (1976);

For forages given to ruminants:- ME (MJ/kg DM) = 0.16 IVOMD; …………..…….. (4)

For concentrates given to ruminants:- ME (MJ/kg DM) = 0.15IVOMD, ………..…… (5)

where IVDMD was the *in vitro* dry matter digestibility per kilogram of dry matter and IVOMD was the *in vitro* organic matter digestibility per kilogram of dry matter.

3.3.10.2 Dry matter intake (DMI)

The daily dry matter intake by each cow was estimated by taking the difference between the amount of feed dry matter offered and the quantity of dry matter refused.

3.3.10.3 Nutrients intake

Daily crude protein (CP) intake by lactating cows were estimated by calculating the CP in feeds offered less that in the refusals. The contents of Calcium (Ca) and Phosphorus (P) in feedstuffs were obtained from the Eastern and Central Africa feedstuffs table for ruminants (Laswai *et al*., 2013). The nutrients deficit was calculated by taking the total individual nutrient offered to the animals by the farmers minus the total individual nutrient requirement by the cows.

3.3.10.4 Metabolizable energy intake

Daily ME intake by lactating cows was determined by calculating the total ME in feeds offered less that in the refusals. The amount of ME (MJ/d) deficit was calculated by taking the total ME offered to the animals by the farmers minus the total ME requirement by the cows.

3.4 Data analysis

The data collected was summarized and coded using Microsoft excel 2003 data sheet for arrangement and computation of descriptive statistics for generating totals, means and frequencies.

3.5 Investigation 2- Testing of an appropriate feeding practice

3.5.1 Experimental design and treatments

A total of 24 lactating dairy cows were randomly allocated to three feeding practices (P1, P2 and P3) in a completely randomised design (CRD). In feeding Practice 1 (P1), the cows were left to feed on the normal feeding style practiced by the farmers. In Practice 2 (P2), the cows were fed as P1 and supplemented with 3.9 kg DM per cow per day of home-made test concentrate diet, whereas cows in feeding Practice 3 (P3) were fed similar to those in P2 plus 5.01 kg DM per cow per day of *P. purpureium*.

3.5.2 Source of animals and their management

The 24 cows were purposively selected from 18 smallholder farmers keeping crossbred dairy cows under zero grazing system. They were of mixed age, breed and between 1st and 3rd parity and within the 1st and 2nd month's post-partum and managed as explained in Section 3.3.4.

3.5.3 Source of feeds and feeding

The experiment was conducted during the dry season, January to February, 2015. It was set on farm under the farmers' condition. The normal feeding by farmers included feeding lactating cows on either natural pasture (NP) alone or NP supplemented with maize bran (MB) or NP supplemented with mixed concentrate (MDC) mixture. Natural pastures (forages) were collected from roadside, river banks and uncultivated land by family or hired labour. Bicycles were the major means of transport for carrying feeds from different sources to the barns. The test concentrate diet was formulated using a computer based feed formulation employing Microsoft excel 2003 data sheet to select appropriate inclusion levels of various feed ingredients. It was based on supplying the nutrients deficient in the feeds offered to the cows by the farmers as derived in Investigation 1, which was daily deficit of 49.02 MJ ME, 671.89 g CP, 10.02 g Ca and 5.53 g P per cow. The physical composition of the test concentrate is given in Table 5.

Table 5: Physical composition and calculated components of the test concentrate

Ingredient	**Amount**
Physical composition (g/kg as fed)	
Hominy meal	705
Sunflower seed cake	280
Limestone	5
Super lick	5
Dicalcium phosphate (DCP)	2.5
Salt	2.5
Total	**1000**
Calculated components (g/kg DM)[1]	
CP	162.6
Ca	4.86
P	8.38
ME (MJ/kg DM)	13.67

1 Ca and P contents of the feed ingredients were obtained from feed-stuff tables (Doto *et al*., 2004 and Laswai *et al*., 2013)

The Hominy meal (HM) and sunflower seedcake (SSC) were obtained from the milling machines in Morogoro town while limestone, super lick, dicalcium phosphate and salt were bought from livestock input shops situated in Turiani town. Weighing of feed ingredients and compounding of the test concentrate was done by both male and female farmers under supervision of the researcher. Forages were offered by farmers twice to three times a day that is around 0700-0730 h, 1300-1430 h and 1800-1900 h while concentrates were fed twice a day during milking time (0500-0630 h and 1800-1930 h). Animals were subjected to a preliminary period of seven days for acclimatization with the experimental feeds. The formulated test concentrate diet was fed to cows in feeding practices P2 and P3 in individual feeders at a rate of 4.2 kg per cow per day. Half of the concentrate was offered in the morning at 0500-0630 h and the other half in the afternoon at 1800-1930 h. In addition, after evening milking, lactating cows on P3 received intake of *ad libitum* additional forage of *P. purpureum* type. Weighing of feeds offered and refusals was done daily by farmers using similar spring balances for the whole period of experiment.

3.5.4 Parameters measured

The amounts of feeds offered and refusals, milk yield and live weight were measured as described under Sections 3.3.6.1, 3.3.6.2 and 3.3.6.3, respectively.

3.5.5 Feed Sample collection, preparation and evaluation

Feed samples for laboratory analysis were collected from each farmer's forage bundles and concentrate from each farmer who provided concentrate to her cow twice and once per week, respectively for the whole experimental period as explained under Section 3.3.7 above. Also feed refusals were collected from feed banks in the morning before feeding twice per week for laboratory analysis. The samples were prepared as described in Section 3.3.7 and transported to the laboratory where at the end of experiment were bulked, mixed thoroughly and sub sampled to obtain representative sample for forages and the farmers concentrate. Determinations of the chemical composition and *in vitro* digestibility of feed samples were done as described under Sections 3.3.8 and 3.3.9, respectively.

3.5.6 Parameters derived

Estimation of metabolizable energy, dry matter intake, nutrient intake and metabolizable energy intake were done as described under Sections 3.3.10.1, 3.3.10.2, 3.3.10.3 and 3.3.10.4, respectively. Deficits in nutrients intake and metabolizable energy was not calculated during Investigation 2.

3.5.7 Gross margin analysis

The costs of extra concentrate and forages supplemented to the cows were calculated. Cost of the test concentrate was based on the costs of the ingredients. It included the costs of purchasing the feed ingredients, transportation, cost of compounding the concentrate and extra labour cost of supplementation. Likewise, the total milk yield, extra milk yield due to supplementation and the price of milk were recorded. The revenue realised was based on sale of the extra milk obtained due to supplementation and additional forage supplied.

The marginal profit of using the test concentrate and extra forage was calculated based on the extra expenses incurred when these feeds are used as diet for the cows in relation to the revenue realised from sale of the extra milk obtained due to the supplement and extra forage. Calculation of profit margin per each feeding practice was based on milk yield gain per practice multiplied by milk price, which was 1000 Tsh minus the cost of the additional concentrate and forages for P3. No attempt was made to estimate the overall profitability of the dairy enterprise such as construction and cleaning of barns, veterinary services, labour and cost of buying lactating cows were assumed to be constant and were not considered during the gross margin analysis.

3.5.8 Statistical data analysis

The data collected were analysed using the General Linear Model (GLM) of Statistical Analysis System (SAS, 2004). The following model was used; $Yi = \mu + Pi + ei$

Where:

Yi = Milk yield or nutrient intake as affected by i^{th} feeding practice

μ = Overall mean of the population

Pi = Effect of feeding practice

ei = Random error due to feeding practice

CHAPTER FOUR

4.0 RESULTS

4.1 General observations

Smallholder dairy farmers in Turiani division practiced zero grazing as a major system of production. They kept improved dairy cattle which were crosses of Zebu with Friesian or Ayrshire. The animals were totally confined in animal houses whereby feeds and drinking water were offered to them mostly by family members and in few farms by hired labour since most of the farmers depended on dairy cattle keeping as their main income generating activity.

Indigenous people in Turiani division are traditionally not livestock keepers. They are engaging in crop production. Crop-livestock farming started after introduction of improved dairy cattle by different none governmental organisations (NGOs) such as Heifer-in-Trust (HIT), foundation for Sustainable Rural Development (SURUDE) and Heifer Project International (HPI) in 1990s. The aim was to support low income families and enable farmers particularly women to acquire means of production and generate income through dairying by sale of milk, live animals and other livestock products.

Other animals kept are local dual purpose cattle and pigs. Currently, livestock is the major income generating activity in the area followed by crop agriculture mainly maize, rice, sugar cane and sweet potato. Other crops grown are cassava, banana and common beans. Rice is both food and cash crop, whereas maize is used as a cash crop only when it is in excess. Farmers also get income from selling sugar cane to the nearby factory (Mtibwa Sugar Factory). Businesses such as small shops and carpentry were also observed to contribute to the income of the family. The area experience a single long rainy season in a year which falls between March and May while short rains period begins in November to December. January to February is a short dry period and July to October is usually long dry period. The rainfall patterns have shown great variability and unreliability whereby dry seasons have become much longer than the rainy seasons. The amount of rainfall was relatively lower (28.3mm) during the period of Investigation 2 than in Investigation 1 (31.2mm). The levels of temperature (28.3^{o}C) and relative humidity (72.5%) during the period of Investigation 2 (January and February 2015) were relatively higher compared to those of Investigation 1 (September and October 2014). The common cattle diseases in the study area were reported to be infectious diseases, such as East Coast Fever (ECF) and Trypanosomiasis. Other problems were mastitis and worm infestation. The required inputs such as veterinary drugs were readily available when in need in the farm input shops situated in Turiani town. All farmers were able to treat their cows whenever they fell sick because of the readily available inputs, but it was difficult because extension staffs hardly visit the farmers to provide services or information.

4.2 Investigation 1-Assessment of feeding practices and performance of lactating cows

4.2.1 Nutritive values of available feeds for dairy cattle

The chemical composition of different forages available for feeding lactating dairy cows in Turiani division is shown in Table 6. The DM contents of fresh or green forages were generally low with an average of 25%. Among the grasses the CP content was observed to be higher in *P. purpureum* than in *R. cochinchinensis* whereas it was higher for legumes such as *Vigna spp.* than in forbs such as *Ipomoea spp*. The results indicated that among the grasses, *P. maximum* contained higher fibre (NDF and ADF) contents than *R. cochinchinensis* while for the crop residues, rice straw contained higher fibre contents compared with maize stover.

Table 6: Chemical composition of forages and crop residues commonly used for feeding cows

	Parameters (% DM)				
Feed type	DM	CP	NDF	ADF	Ash
Panicum maximum	31.91	8.40	74.69	41.83	12.66
Pennisetum purpureum	21.71	8.82	66.26	35.35	16.64
Rottboellia cochinchinensis	28.92	8.16	62.44	28.10	7.59
Vigna spp.	23.48	21.02	43.36	30.17	10.70
Ipomoea spp.	18.92	11.32	49.23	31.98	11.41
Rice straw	89.86	6.31	74.70	46.25	21.28
Maize stover	90.72	6.02	71.84	45.82	5.19

Table 7 shows the chemical composition and metabolizable energy (ME) of the concentrates used in feeding lactating cows in the study area. The concentrate mixture containing maize bran (MB) and sunflower seedcake (SSC) showed higher CP contents than other concentrate mixtures. The fibre (NDF and ADF) and ash contents were observed to be higher in the concentrate mixture containing MB and dried *Moringa* leaf meal than in the other concentrate mixtures. However, it was observed that MB contained lower fibre contents than all concentrate mixtures. The ME contents were more less similar in all of the concentrates used to feed the animals.

Table 7: Chemical composition (% DM) and Metabolizable energy contents (ME MJ/kg DM) of different concentrates used to feed dairy cows in Turiani

	Parameters					
Concentrate type	DM	CP	NDF	ADF	Ash	ME
Maize bran (MB)	89.01	13.16	34.61	7.57	4.71	10.85
MB + Sunflower seedcake (SSC)	89.58	15.42	37.19	14.78	8.24	10.00
MB + SSC + Rice polishing (RP)	92.76	14.23	38.40	17.40	7.00	10.89
RP + SSC	91.23	12.40	34.75	7.77	6.45	10.45
MB + Dried Moringa leaf meal	92.47	13.77	42.77	21.61	13.39	10.21

The values of *in vitro* dry matter (IVDMD) and organic matter (IVOMD) digestibility of forages offered to the animals are presented in Table 8. The values were higher in *R. cochinchinensis* than in *P. maximum*. Similarly, maize stover showed higher values than rice straw. The ME values of the forages (Table 8) followed similar trend to those of digestibility values.

Table 8: *In vitro* Dry Matter digestibility (IVDMD %), Organic Matter Digestibility (IVOMD %) and Metabolizable energy (ME, MJ/kg DM) values of forages

	Parameters		
Feed type	IVDMD	IVOMD	ME
Panicum maximum	30.95	30.67	4.60
Pennisetum purpureum	46.87	45.93	6.89
Rottboellia cochinchinensis	61.75	61.27	9.19
Vigna spp.	55.95	54.33	8.15
Ipomoea spp.	40.53	39.00	5.85
Rice straw	30.39	28.60	4.29
Maize stover	36.47	35.80	5.37

4.2.2 Condition of the animal housing

Table 9 shows the condition of the animal housing in the study area. In the animal housing it was observed that 77.8% (14) of the houses were roofed by corrugated iron sheets while there was no lactating dairy cows kept under un-roofed house. About 44.4% (8) of the smallholder farms had poorly finished concrete floor. In addition it was observed that in most of the animal houses 66.6% (12) used partially completed wooden feeding bunks while in most farms 83.33% (15) animals were observed to be supplied with drinking water through buckets.

Table 9: Condition of the animal housing in the farms

Parameters	Farms (n=18)	Percentage (%)
Roofing materials		
Corrugated iron sheet	14	77.8
Thatch grass	4	22.2
Floor type		
Concrete	7	38.9
Poorly finished concrete	8	44.4
Earthen	3	16.7
Type of feeding bunks		
Completed wooden	3	16.7
Partially completed wooden	12	66.6
Completed concrete	3	16.7
Drinkers		
Built in drinkers	3	16.67
Bucket	15	83.33

4.2.3 Feeding practices

Dairy farmers depended largely on natural pasture (NP) as feed source for their animals. Natural grasses and legumes were collected from the roadside, river banks and uncultivated land. The common forages used by smallholder farmers to feed their stall fed cows were *P. maximum, P. purpureum, R. cochinchinensis*, *Vigna spp.* and *Ipomoea spp.* with *P. purpureum* being the most fed. Forages and crop residues fed to the animals were observed to be at their late stage of growth (matured) and that 11 farmers (61.11%) out of 18 presented forages to their lactating cows without chopping while the rest chopped. Availability of the natural grasses and legumes was limited during the whole study period due to dry season. Hired labour for livestock activities was mostly required mainly for cutting and collecting forages from the field. Only three 16.67% (3) farms were observed to have storage barns which allowed them to collect the crop residues and store in bulky for further feeding during prolonged dry season. Table 10 shows the common feeding practices practiced by smallholder dairy farmers in feeding their lactating cows and the amount of feeds offered to the animals. Half of the farms (9) were observed to feed their lactating cows on NP and supplemented with a single concentrate ingredient mainly MB, whereas 27.78% (5) with a mixture of different concentrate ingredients and few of them 22.22% (4) fed pastures only. Most farmers who supplemented their animals gave milking cows a flat rate of 2-3 kg per cow per day (1-1.5 kg morning and evening) regardless of the animal's body condition.

Table 10: Common feeding practices and amount of feeds offered to lactating cows

Parameter	Frequency	Percentage (%)
Feeding practice	**Farms (n=18)**	
NP alone	4	22.22
NP supplemented with sole MB	9	50.00
NP supplemented with mixed concentrates	5	27.78
Amount of feeds offered		
Forages (kg/cow)	(n=24)	
10-20	2	8.33
21-30	16	66.67
31-40	5	20.83
41-50	1	4.17
Concentrates (kg/cow)	(n=19)	
1-2	2	10.53
2.1-3	14	73.68
3.1-4	2	10.53
4.1-5	1	5.26

NP = Natural pasture and MB = Maize bran

4.2.4 Nutrients intake by the cows

The average dry matter intake by the cows is presented in Figure 1. The total DMI was higher for lactating cows on NP and supplemented with mixed concentrate (MDC) than those on NP and supplemented with sole MB and NP.

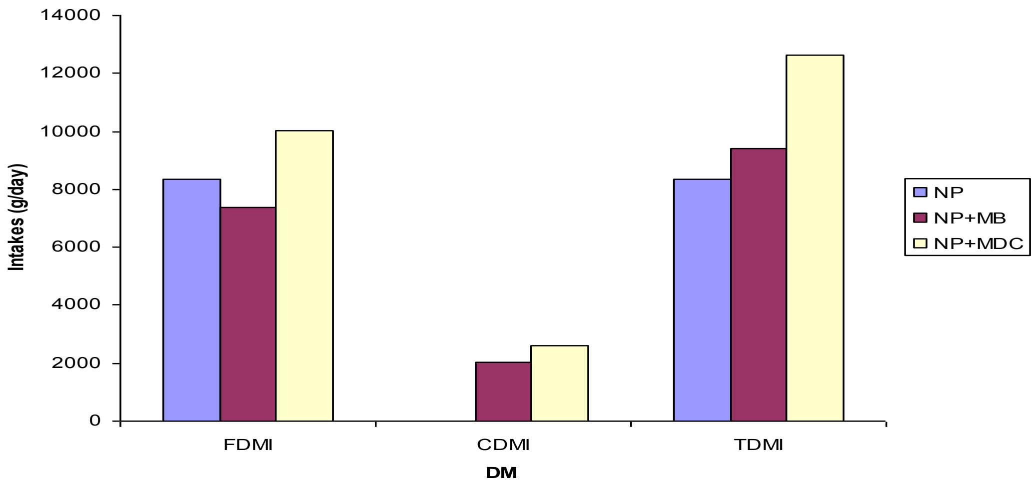

Figure 1: Average Dry matter intake for forage (FDMI) concentrate (CDMI) and total (TDMI) intake during Investigation 1

The average crude protein (CP) intake is shown in Figure 2. The total CP intake (TCPI) was higher for cows on NP + MDC than those on NP + MB and NP alone. On the other hand, the CP intake from forage (FCPI) source was higher for animals on NP and NP + MDC than those on NP + MB.

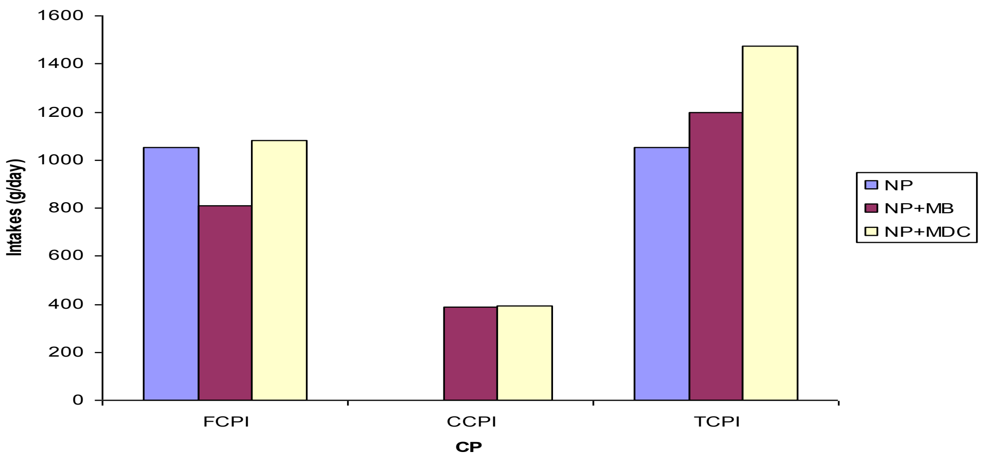

Figure 2: Average CP intake for forage (FCPI), concentrate (CCPI) and total CP intake (TCPI) during Investigation 1

The ME intake by the cows is presented in Figure 3. The total ME intake (TMEI) was higher for cows on NP + MDC followed by those on NP + MB and lowest in those on NP alone.

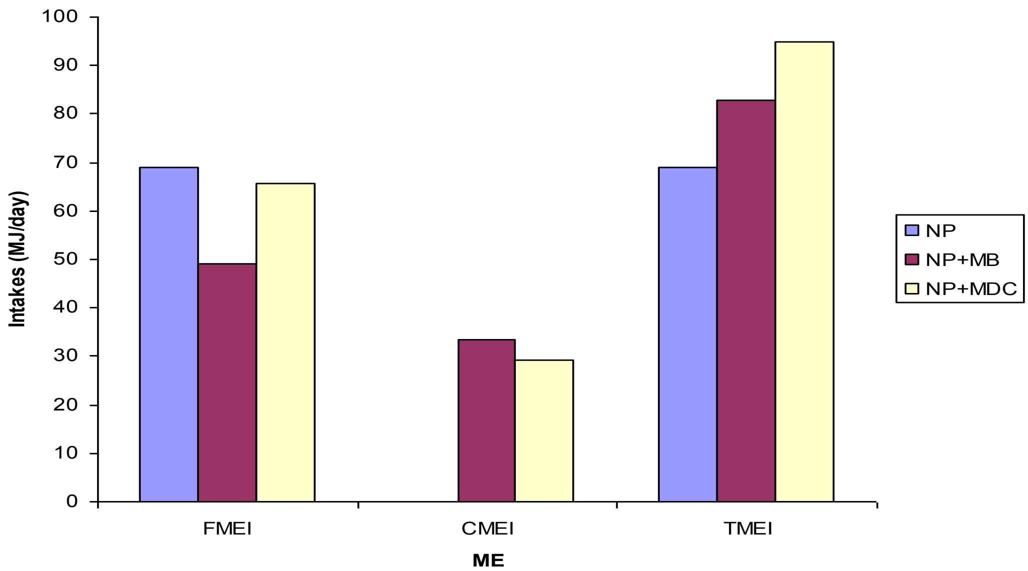

Figure 3: Average metabolizable energy intake for forage (FMEI), concentrate (CMEI) and total (TMEI) intake during Investigation 1

4.2.5 Performance of lactating cows

Performance in terms of milk production by the lactating cows in the study area is shown in Figure 4. The average milk yield from the cows was 6.1 litres per cow per day. However, milk yield from cows fed on NP was observed to be lower than in those supplemented with sole MB (NP + MB) and mixture of different concentrates (NP + MDC), the average yield been 4.6, 6.4 and 7.4 l/cow/d, respectively.

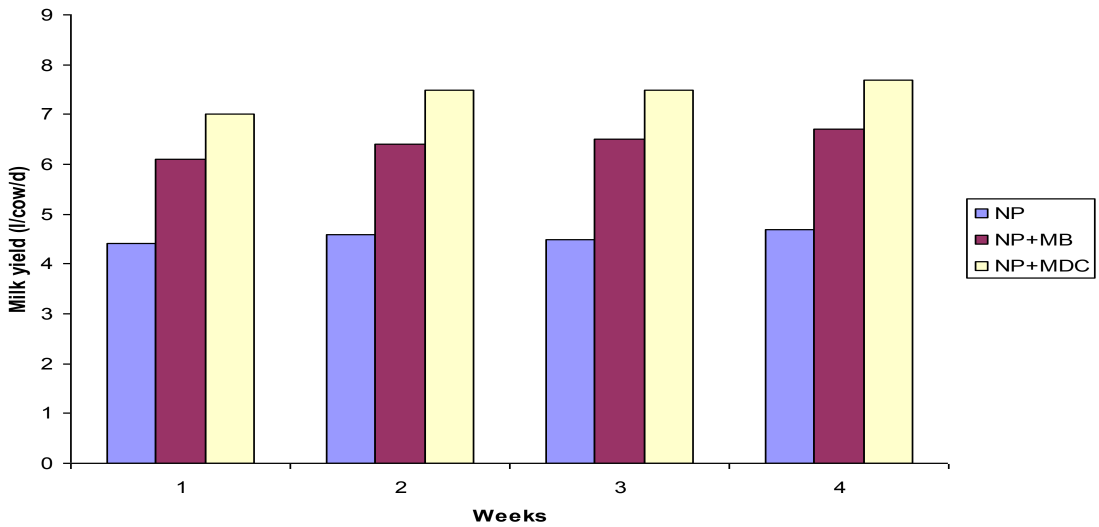

Figure 4: Average milk yield of lactating cows during Investigation 1 in Turiani

Body weight gain of the lactating cows in both feeding practices is shown in Figure 5. Animals fed on natural pastures and supplemented with mixture of different concentrates showed higher average body weight gain than those fed on natural pastures alone (0.06 vs. 0.22 g/d).

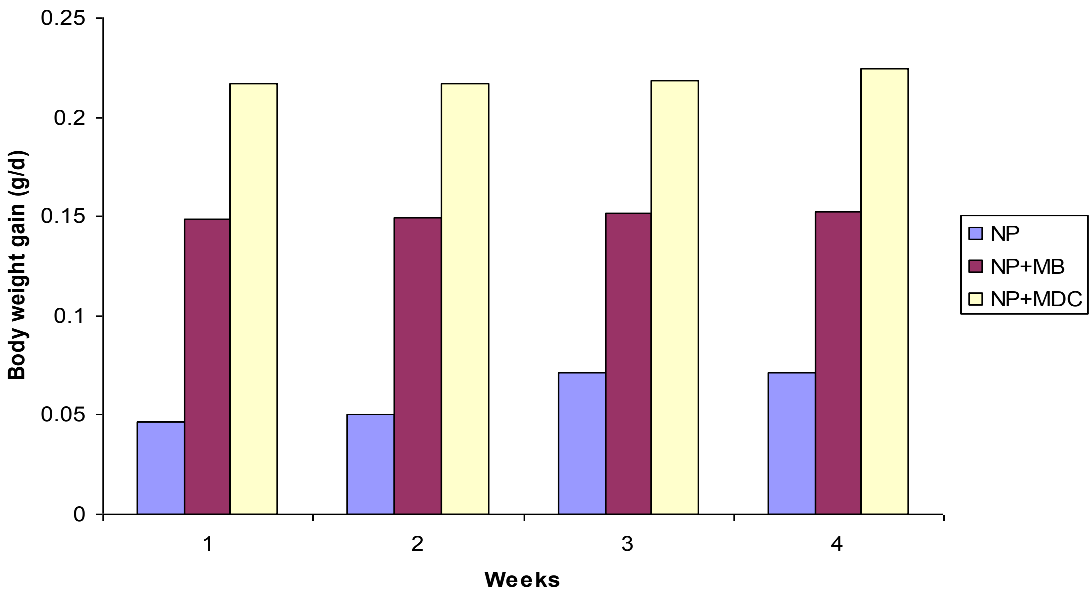

Figure 5: Average body weight gain of the cows under different feeding practices

4.3 Investigation 2 - Testing of an appropriate feeding practice

4.3.1 Nutritional values of feeds used in Investigation 2

The chemical composition of forages, concentrate ingredients and concentrate mixture fed to lactating dairy cows in Investigation 2 are presented in Table 11. The DM content of the forages was generally low. Among the forages, *P. maximum* showed relatively higher DM content than other forages. The average CP content of forages was observed to be 10.7% DM whereby *Vigna sp*. contained the highest value. As expected the CP content of SSC was higher than those of other ingredients. The test concentrate showed higher CP content than the farmers' concentrate. The contents of NDF and ADF were higher in *P. maximum* and lower in *Vigna sp.* than other forages. *R. cochinchinensis* contained lowest values of ADF among the forages. The ash contents of forages were higher in *Ipomoea spp*. and *P. purpureum* and lower in *Vigna spp*. than in other forages. The farmers' concentrate was observed to contain higher ash content than the test concentrate. Sunflower seedcake showed higher ash content than HM and MB.

Table 11: Chemical composition of the different feedstuffs used to feed dairy cows in Investigation 2

	Component (% DM)				
Type of feedstuffs	DM	CP	NDF	ADF	Ash
Forages					
Panicum maximum	32.28	6.79	74.69	41.83	11.44
Pennisetum purpureum	22.77	10.61	66.24	35.35	13.00
Rottboellia cochinchinensis	25.96	8.16	62.44	28.18	10.32
Mixed forage	27.05	7.61	67.14	39.27	12.18
Vigna sp.	19.93	19.85	43.36	30.17	10.01
Ipomoea sp.	15.15	11.01	49.23	31.96	13.01
Concentrates and ingredients					
Test concentrate	92.82	16.30	NA	NA	5.43
Farmers concentrate	91.99	14.16	NA	NA	7.07
Hominy meal	92.47	11.42	NA	NA	3.57
Sunflower seedcake	93.21	29.32	NA	NA	5.59
Maize bran	87.47	11.59	NA	NA	4.02

NA = Not analysed

The *in vitro* dry matter digestibility (IVDMD), *in vitro* organic matter digestibility (IVOMD) and ME contents of the forages and concentrates fed to lactating cows in Investigation 2 are presented in Table 12. The values of IVDMD and IVOMD for forages were highest in *Ipomoea spp*. and lowest in *Vigna spp*. than in other forages. The contents of IVDMD and IVOMD were highest in the test concentrate and lowest in SSC compared to other concentrate and ingredients. The ME contents of both forages and concentrates followed similar trends as digestibility values.

Table 12: Average values of *in vitro* (%) Dry Matter digestibility (IVDMD), Organic Matter digestibility (IVOMD) and Metabolizable energy (ME, MJ/kg DM) of the feeds

	Parameters		
Feed type	IVDMD	IVOMD	ME
Forages			
Panicum maximum	39.35	37.28	5.96
Pennisetum purpureum	45.11	42.20	6.75
Rottboellia cochinchinensis	54.88	53.47	8.56
Mixed forage	41.75	41.43	6.63
Vigna sp.	37.75	35.73	5.72
Ipomoea sp.	68.87	66.86	10.69
Concentrates and ingredients			
Test concentrate	78.34	77.93	11.69
Farmers concentrate	69.83	68.97	10.35
Hominy meal	69.84	69.68	10.45
Sunflower seedcake	59.31	58.99	8.85
Maize bran	68.53	67.35	10.10

4.3.2 Effect of feeding practice on nutrients intake by the cows

The least square means for the effect of feeding practice on the dry matter, protein, energy, calcium and phosphorus intake by the cows are shown in Table 13. The individual animal values are shown in Appendix 1 and the summaries of the analysis of variance (ANOVA) are shown in Appendices 2-17. The DMI was higher (P < 0.05) for lactating cows on P3 than those on P2 and P1. However, the DMI by animals on P1 was not significantly (P > 0.05) different from those on P2.

Table 13: Least Square Means for the effect of feeding practice on total dry matter (TDMI), nutrient intakes (g/d) and energy (ME, MJ/d) intake by the cows

	Feeding practice				
Parameters	P1	P2	P3	SEM	P- values
Number of observations (n)	8	8	8		
DMI					
Forage	8568[b]	7324[b]	11676[a]	985.74	0.0149
Concentrate	3744[b]	7105[a]	7616[a]	271.06	0.0001
Total DMI	12312[b]	14429[b]	19292[a]	1032.45	0.0003
CP intake					
Forage	671.56[b]	571.26[b]	1015.86[a]	68.79	0.0004
Concentrate	443.57[b]	1025.13[a]	1130.29[a]	36.22	0.0001
Total CP intake	1115.13[c]	1596.39[b]	2146.16[a]	79.40	0.0001
ME intake					
Forage	51.69[ab]	46.81[b]	70.62[a]	6.78	0.0512
Concentrate	40.33[c]	81.36[b]	97.32[a]	4.34	0.0001
Total ME intake	92.02[c]	128.16[b]	167.94[a]	7.69	0.0001
Calcium intake					
Forage	8.91[b]	7.62[b]	12.14[a]	1.03	0.0149
Concentrate	1.15[b]	3.45[a]	3.70[a]	0.12	0.0001
Total calcium intake	10.06[b]	11.07[b]	15.84[a]	1.03	0.0016
Phosphorus intake					
Forage	2.91[b]	2.49[b]	3.97[a]	0.34	0.0149
Concentrate	2.60[b]	5.95[a]	6.38[a]	0.21	0.0001
Total phosphorus intake	5.52[c]	8.44[b]	10.35[a]	0.40	0.0001

[a, b, ab, c] Means with the same letter within the row are not significantly different

The total dry matter intake (TDMI) from both forage and concentrate sources was significantly higher (P < 0.05) for cows on P3 than those on P2 and P1. However, the

DMI intake from concentrate source was lower for cows on P1 than those on P3 and P2, which had similar ($P > 0.05$) intake of concentrate. The total crude protein (CP) intake from both forage and concentrate sources was higher ($P < 0.05$) for lactating cows on P3 than those on P2 and P1. The CP intake from forages was not significantly different between cows on P2 and those on P1. However, the CP intake from concentrate source by animals on P2 was not significantly ($P > 0.05$) different from those on P3, but was higher than those on P1. The metabolizable energy (ME) intake from concentrate source was significantly higher ($P < 0.05$) for cows on P3 followed by those on P2 and lowest in those on P1. The ME intake from forages was higher ($P < 0.05$) for cows on P3 followed by those on P2 which was similar to those on P1. The total calcium (Ca) and phosphorus (P) intake was significantly higher ($P < 0.05$) for cows on P3 than those on P2 and P1.

4.3.3 Effect of feeding practice on body weight gain and milk yield

Least Square Means for the effect of feeding practice on body weight changes and milk yield from the cows are presented in Table 14 and the summaries of the analysis of variance (ANOVA) in Appendices 19–25. The initial body weight of the cows was not significantly ($P > 0.05$) different between practices. The final body weight was higher ($P < 0.05$) for animals on P3 than those on P1 but was similar to those on P2. The mean live weight gain was highest ($P < 0.05$) for animals on P3 than their counterparts. The difference between those on P2 and P1 was however not significant ($P > 0.05$). The initial milk yield was not different between treatments. The average final milk yield was higher ($P < 0.05$) for cows on P3 than those on P1. However, the average final milk yield from the cows on P2 was not significantly ($P > 0.05$) different from those on P1 and P3. The average milk gain after supplementation was higher ($P < 0.05$) for cows on P3 than those on P2 and P1. The average milk gain by cows on P1 was not significantly ($P > 0.05$) different from those on P2.

Table 14: Least Square Means for the effect of feeding practice on body weight gain (g/d) and milk yield (l/d/cow) of the cows

	Feeding practices				
Parameters	P1	P2	P3	SEM	P-values
Number of observation (n)	8	8	8		
Initial live weight (kg)	365.88	378.88	379.25	12.73	0.7032
Final live weight (kg)	369.88^{b}	387.63^{ab}	416.63^{a}	13.83	0.0416
Body weight gain	0.09^{b}	0.19^{b}	0.83^{a}	0.07	0.0001
Initial milk yield	5.99	6.56	6.63	0.71	0.7932
Final milk yield	8.50^{b}	10.90^{ab}	13.68^{a}	1.15	0.0158
Milk gain	2.50^{b}	4.34^{b}	7.05^{a}	0.79	0.0020

$^{a, b, ab}$ Means with the same letter within rows are not significantly different

4.3.4 Effect of feeding practice on gross margins

The additional cost of production and revenue accumulated from sale of milk are summarised in Table 15 and Appendix 27.

Table 15: Estimates of extra production costs due to supplementation and profits (Tshs/cow/d) from milk sales in different feeding practices

	Feeding practice		
Item	P1	P2	P3
Number of observations (n)	8	8	8
Additional cost/cow			
Farmers' supplements	840		
Test supplements		1262.73	1262.73
Extra forage			880
Total	**840**	**1262.73**	**2142.73**
Extra milk yield (l/cow)	2.5	4.34	7.05
Extra revenue (Tsh/cow)[1]	2500	4 340	7 050
Gross marginal profit (Tshs/cow)[2]	**1660**	**3077.27**	**4907.27**
Extra profit per day due to provision of extra supplements		1417.27	3247.27
Extra profit per day due to provision of extra forage			1830

[1]The price of milk in Turiani during the period of study was 1000 Tsh per litre

[2]Gross margin profit = Revenue – Total variable costs

The total costs of farmers' and test concentrates were 840 and 1262.73 Tsh per cow per day, respectively. The extra cost of production due to extra supplementation was highest for feeding practice P3 followed by P2 and provision of extra forage to animals on P3 was 880 Tsh per animal per day. The extra milk yield was higher for feeding practice P3 followed by P2 and P1. Similarly, the gross marginal profit in monetary terms per cow per day as a result of extra supplementation over the un-supplemented cows was higher in P3 followed by P2.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Nutritional values of commonly used feedstuffs

The observed CP content (7.61% DM) of the mixed forages offered to cows by farmers in Turiani was within the minimum range of 6-8% DM for ruminant animals. Generally the chemical composition of forages depends on the plant species or cultivar, the plant part and age. Mixed forages comprising of grasses and legumes will contain high CP values than a mixture of different grass species and that CP is higher in leaves than in stems while plant CP decreases with maturity. The observed values for CP of mixed forages are reasonable for ruminants because feed intake and digestibility could not be affected. However, for high production of milk, the dietary protein value should be higher than the observed in the present study. The current results were attributed to species composition as the pastures used were a mixture of different types of grasses at different stages of growth.

The observed mean CP content (19.85% DM) of legumes was higher than the value (13.4%) reported by Mtui (2004) and slightly higher than that (18.85%) reported by Mtengeti *et al*. (2008) in the same division for the same species of legumes. It is well known that variation in chemical composition of most forages in the tropics depends on several factors, including plant species, maturity of the plants, soil characteristics and climate. Therefore, the differences between studies for the CP content of legumes could be due to different stages of maturity at which the legume was harvested and soil characteristics. Doto *et al*. (2004) and Nkenwa (2009) reported that the CP content of legumes, grasses and crop residues range from 15-23%, 8-18% and 2- 6% of DM, respectively. The observed lower CP value for mixed forage (7.61% of DM) than that reported by Kimambo *et al*. (1990) in Arusha which was 12.6% of DM could be due to the fact that mixed forages in Turiani division had poor grass-legume mixture than those in Arusha. On the other hand, the observed protein level for mixed forages was in agreement with the earlier findings by Doto *et al*. (2004) who reported that forages with protein level greater than 7.5% of DM are adequate to lactating dairy cows. The observation can also be attributed to differences in the stage of growth at which the forages were harvested. The minimum CP content of forage suitable for the requirement of body maintenance for cattle is about 7 to 8% of DM. Below that level could lead to insufficient nitrogen for normal rumen microbial activity and hence for maintenance and production requirement of the animal.

Therefore, the CP content of forages was insufficient to meet the nutritional requirement of dairy cows for both maintenance and production if fed alone especially during the dry season. The observed CP content (13.97% DM) of the farmers' concentrate supplement was slightly higher than that reported by Mtengeti *et al*. (2008) in the same area. It is possible that the differences might be attributed to different ingredients used to compound the concentrate that will affect its composition. The CP content of the formulated test concentrate mixture of 16.3% DM observed in the current study was higher than in the farmers' concentrate (14% DM). The differences in CP values between the concentrate mixtures were possibly due to different ingredients used in formulation. The observed higher CP content in the test concentrate was attributed to higher inclusion level of different ingredients, such as sunflower seedcake than in the farmers' concentrate. This was intended because more CP was required to correct for the deficiency in the diet offered by the smallholder dairy farmers obtained in Investigation 1. This implies that the farmers prepared concentrates which do not meet the nutrients required by lactating cows. The observed NDF and ADF contents (63.16 and 36.27% DM, respectively) in mixed forages indicated that low quality forages were fed to lactating dairy cows in the study area. Normally, forage containing NDF value of 40% DM is of higher quality than the one with 60% of DM. Earlier findings by Bwire and Wiktorson (2003) showed that in grass based diet, the critical value of NDF is 75% of DM above which intake and animal productivity are interfered. This implies that the grass is of low quality and when used as a major component of the animals' ration will result into low animal production due to its high fibre content which limits its intake and digestibility, eventually low nutrient intake. However, in the study area *P. maximum* ranked second after *P. purpureum* on the farmers' feed preferences for feeding their animals which were largely based on the abundance and easiness to cut. The high NDF (74.69% DM) and ADF (41.83% DM) content observed for the grasses could probably be due to the stage of maturity. Therefore, dairy farmers when prefer using *P. maximum* as main component in the feed for their cows they have to make sure that the grass (*P. maximum*) is harvested during the early stage of growth for high performance of the animals.

The observed value (7.24 MJ/kg DM) of the metabolizable energy (ME) content of the mixed forages was lower than the recommended value of 12 MJ ME/kg DM for good quality forage (McDonald *et al*., 2010). The probable reason for this low ME content in the forages could be the stage of harvest whereby most of the forages were cut and collected for feeding the animals in advanced maturity. It is well known that plants at their early growth stage contains high nutrient content such as energy, protein, minerals and low cell wall contents and that nutrients decrease with advancing maturity due to decreased proportion of leaves and increase in stem contents. This implies that forages at their late stage of growth particularly during the dry season in Turiani are of poor quality. The observed ME content (10.85MJ/kg DM) of maize bran was more less equal to the ME content (10.48MJ/kg DM) of the farmer's concentrate mixtures (Table 8). This implies that maize bran provides energy fairly equivalent to the farmers' concentrate mixtures. The observation could be attributed to the poor mixing ratios of the concentrate ingredients by the farmers. On the other hand, the observed ME content (10.48MJ/kg DM) of the farmers' concentrate was lower than the ME content (11.69MJ/kg DM) of the test concentrate. This indicated that the test concentrate was formulated to meet the energy required by the lactating cows that was deficient in the feeds offered by smallholder farmers in the study area and that the ME content in the test concentrate was higher than 10MJ ME/kg DM, a recommended energy value for dairy cattle (NRC, 2001). The differences in ME contents between the farmer's concentrate and test concentrate may be associated to the type of milling machine and different inclusion levels of different concentrate ingredients used to compound the concentrates. This was in agreement with the earlier findings by Mlay *et al*. (2005).

In the current study, the observed digestibility (IVDMD and IVOMD) values of mixed forages (41.75 and 41.43% DM, respectively) were within the range of tropical grasses (30 to 75% DM). However, the observed digestibility values of mixed forages in this study are low. These low values could be possibly due to high fibre contents brought by the stage of growth of forage and variations of forage type experienced in many smallholder systems. Also, it has been argued that good forage that can support moderate and high production must have IVDMD of 50 to 60% DM and IVOMD of equal or more than 70% DM (Temu, 1997).

Since the fibre contents of forages increases with advancing age and that during the dry season forages are more mature, smallholder dairy farmers are encouraged to harvest forages at their early stage of growth and store for use during period of scarcity. On the other hand, alkaline or urea treatment of these poor quality forages could be another alternative to improve their digestibility. The observed values of IVDMD (69.83% DM) and IVOMD (68.97% DM) of the farmers' concentrate were lower than 78.34% DM and 77.93% DM, respectively of the test concentrate. The variation between the farmers' concentrate and the test concentrate was due to differences in fibre contents (NDF) of the ingredients used. Farmers' concentrate contained leaf meals of dried *Moringa* and sunflower seedcakes, which both had relatively high NDF content. This implies that nutrients in the test concentrate were more digestible and available for utilization by the animal body for maintenance and production than those in the farmers' concentrate.

Basing on the observed feeding values of the common feedstuffs used to feed cows in the study area, it is evident that the estimated nutrients deficiencies (Appendix 28) in the cows are attributed to poor feed quality and inadequate supply of digestible dry matter. This observation could be the main limiting factor to milk production in smallholder farms during the dry season. It is therefore necessary to supplement the cows with adequate well balanced concentrate during the dry season in order to meet the deficient nutrients.

5.2 Assessment of the feeding practices and performance of lactating cows

The observation that feeding practices by smallholder dairy farmers in the study area were mainly based on sole natural pastures, *P. purpureum* (Napier grass) and crop residues (22.22%), was in consistence with earlier findings (Gimbi, 2006; Njarui *et al*., 2011; Urassa, 2012 and Lukuyu *et al*., 2012). In the existing feeding practices it was revealed that there was low performance of the dairy cows. This indicates that the lactating dairy cows under these feeding practices do not receive enough nutrients to support maintenance and high milk production. This effect could be attributed to underfeeding the animals in both basal diet and concentrates (Table 10). This trend could probably be due to limited feed resources available to the smallholder dairy farmers for feeding their cows especially during the dry season.

The observed available feed resources namely; natural pastures, Napier grass, crop residues and supplements are generally low in nutrients that cannot support high production of the lactating crossbred dairy cows. In order to support high production of dairy cows, the forage has to contain CP value of more than 7.5 and energy value of at least 10 MJ ME/kg DM (Doto *et al*., 2004). Therefore, to attain high milk production from the cows in Turiani division, protein and energy supplementation is of paramount important.

Despite the fact that 66.67% of the farmers offered forages to their dairy cattle twice a day, the quantity given at a time was too low. The observed total amount given approximately 21-30 kg/cow/d of fresh weight (as fed) was lower than the expected (50-60 kg/cow/d) reported by Lukuyu *et al*. (2012). The quality of these feeds was also poor and consequently the animals did not receive adequate nutrients required for production. Normally a dry matter consumed by a dairy cow in a day should be 2.5 to 3% of her body weight (McDonald *et al*., 2010). In the study area, the mean body weight of lactating cow was slightly lower than 400kg with genetic potential of producing 20 litres of milk per cow per day, which was supposed to be fed a total dry matter of 12 kg (Laswai *et al*., 2013). This is expected to provide a daily supply of 135 MJ ME, 1978 g CP, 68 g Ca and 44 g P. However, only 7.78 kg DM was given, which led to nutrient deficit of 85.98 MJ ME, 1306.1 g CP, 57.98 g Ca and 38.47 g P per day. The intakes of CP and ME were therefore unlikely to be sufficient to sustain satisfactory animal production levels by the crossbred cows found in the area. Even though dairy farmers admitted increase in milk yield when forage legumes were fed to the lactating dairy cow, the present study revealed that legumes were less fed to the animals. This implies that farmers are aware of the importance of the leguminous species to increase milk production but their limited availability made farmers not consider them as feed for dairy cattle. According to Kakengi *et al*. (2001), lactating dairy cows fed on grass-legume mixture normally at 70:30 resulted into higher intake of ME due to the increase in provision of nitrogen in the rumen for microbial activity. In dairy production systems where animals are stall fed, without a proper constructed feeding trough, usually forages are presented to animals without chopping. In the study area, this caused trampling and inefficient utilisation of feeds which in turn affected animal performance.

The observed higher intakes of DM, CP and ME by cows supplemented with well mixed concentrate compared to those supplemented with sole maize bran and the none supplemented ones suggest the need for developing a proper feeding practice in improving milk production in the area. The appropriate practice should consider proportions of each ingredient in the concentrate mixture in relation to the requirements of the cows for both maintenance and production. The observed amount of concentrate (2-3 kg/cow/d) offered to the lactating cows normally during milking time in the study area was generally low and fixed throughout the lactation period without being adjusted to specific nutrient required based on milk production. This could be the cause of low milk production by the cows in the area. The observation that maize bran was the principle supplement offered to dairy cows in most farms (50%) and few (27.78%) farms, they also used other milling by-products such as hominy meal and sunflower seedcake. However, most farmers perceived that they are costly, hence, they were offered in low quantities. Mineral supplements in form of powder or blocks were not a common practice in the area. These could be the reason why smallholder dairy farmers in Turiani did not realize the full genetic potential in milk production from their cows.

The observed mean milk yield by crossbred lactating dairy cows in Investigation 1 (6.13 litres) with a range of 4.6-7.4 litres per cow per day was consistent with the earlier findings by Mtengeti *et al*. (2008) in the same area who reported a range of 4-6 l/cow/d. The low milk yield in the study area was probably caused by the poor feeding practices. The quantity and quality of feeds (both forages and concentrates) offered to the lactating cows was not sufficient to provide adequate nutrients required by the animals for maintenance and high milk production especially during the dry season where feeds are scarce. The observed large range between the lowest and the highest values for milk production in the present study indicates that under improved feeding practices there is an opportunity for enhancement in milk production from crossbred dairy cattle in Turiani. Another problem facing dairy production in Turiani could be the frequency in which drinking water is supplied to the animals. In the study area, animals had no access to drinking water throughout the day since it was provided mainly in the afternoon and this was attributed to lack of built in water troughs in most of the animal houses. Water availability and quality are extremely important for animal health and productivity.

Results from Investigation 1 give a useful insight into the existing feeding practices, quantities and qualities of feeds supplied to animals in the study area during the dry season. The quality and quantity of feeds offered was variable but generally poor. Therefore, both the low levels of concentrates used and poor quality of forages suggest the need for development of an appropriate dry season feeding practice, which provides all the necessary nutrients required by the animals for improved milk yield by the cows in Turiani.

5.3 Effect of feeding practice on nutrients intake and performance of the cows

The observed higher total daily DMI by cows on practice P3 than those on P2 and P1 was probably due to the fact that lactating cows on P3 were supplied with forages *ad libitum* and sufficient amount of concentrates over those on P2 and P1. This implies that low quality forages when fed sufficiently and supplemented with adequate amount of quality concentrate feeds improve feed intake considerably. However, the level of fibre (NDF) content in the forages offered may limit the amount of forage intake since fibrous foods may have to spend a long time in the digestive tract for their digestible components to be extracted (McDonald *et al*., 2010). Roughage containing high fibre has lower palatability, reduced protein levels and is less digestible than high quality roughage. Less digestible feed materials stay for a long time in the rumen leading into low DMI as the cow cannot consume more feed until the feed in the rumen is digested (McDonald *et al*., 2010). Furthermore, roughage intakes by lactating cows depend on forage quality, cow size and concentrate levels. Insufficient supply of forages, concentrate or absence of concentrate supplementation by farmers could be the cause of low DMI by the cows on P1 (Table 13). Therefore, supplying adequate amount of forages and supplement with appropriate quantity of concentrate mixture could increase DMI and eventually animal performance.

The observed lower DMI from forages by the supplemented cows on P2 compared to those on P1 indicates substitution of forages by the extra concentrate supplied to the cows on P2. This implies that the supplemented cows on P2 preferred concentrates first and little from poor forages. It is well known that when the protein (CP) and energy (ME) concentration supplied from forages is low, increased concentrate supplementation lead to increased DMI as was the case in those on P3. This was in agreement with earlier findings by Urassa (2012) who reported that supplementation brought about increased DMI when the CP and ME concentration supplied from forages is low. Similar trend was followed in total CP and ME intake where by the animals on P3 had significantly higher intake than those on P2 and P1 (Table 13). However, the CP and ME intakes from forages by cows on P1 was higher than the supplemented cows on P2. This observation could be due to the fact that animals on P1 were mainly fed on forages with little or without supplementation and hence consumed more forages than their counterparts on P2. Furthermore, the CP and ME intake from concentrate source was higher in supplemented cows (P3 and P2) than in those on P1, this could be attributed to higher dry matter intake by the supplemented animals.

In the current study, it was observed that calcium (Ca) and phosphorus (P) intakes were significantly higher for animals on P3 than those on P2 and P1. This could be attributed to high total DMI as well as the high Ca and P contained in both forages and concentrate offered to cows on P3 than those on P2 and P1. In addition, the observation that animals received more Ca from forage source and more P from concentrate source (Table 13) implies that during the dry season forages were more deficient in P than Ca. Therefore, since most of the smallholder dairy farmers depend on natural pastures, supplementation with minerals in dry season is of importance to sustain optimum productivity of their animals. The observed higher milk yield from animals on P3 than those on P2 and P1 could be attributed to adequate supply of forages. This implies that supplementation and *ad libitum* provision of forages resulted into increased DMI as reflected on a significantly higher milk yield by cows on P3 than those on P2 and P1. The trend that milk yield by cows on P2 being not significantly different from those on P1 but significantly different from cows on P3 could probably be that farmers were somehow influenced by the research process. This made them to offer better than normal feeds when observed by an outsider, since the research took a short period of time. On the other hand, during Investigation 1 it was observed that there was a gain in milk yield of 2.5 l/cow/day. This also suggests that during Investigation 2 dairy farmers improved on the feeding practice, quality and quantity of feeds offered to the lactating cows. Moreover, high milk yield by supplemented animals could probably be due to the fact that animals were supplied with concentrates and minerals more often than cows on P1. Likewise, the low milk yield from the cows on P1 was attributed to low DMI by the animals. Therefore, increasing DMI by the animals could increase performance. The observed lower daily average milk gain for the cows on P1 compared to their counterpart implies that animals that were not supplemented had lower nutrient intake from basal feed. The higher milk yield gain by supplemented cows on P3 than those on P2 was attributed to the increased nutrients intake that was contributed by both well formulated concentrate and extra forages fed to the lactating cows.

The higher response to concentrate supplementation by supplemented cows could mean that the crossbred cows in Turiani had higher potential for milk production. This was supported by the observed increase in milk yield gain of 1.11 and 1.81 l/kg DM concentrate intake per day by the supplemented cows on P2 and P3, respectively. These results are in agreement with earlier findings by Nkya *et al*. (2002) in Morogoro who reported an increase in milk yield of 1.26 l/kg DM concentrate intake. The lower milk yield (13 l/cow/d) than the expected yield of 20 l/cow/d by the lactating crossbred cows could be attributed by low genetic potential for milk production by cows in the study area (Urassa, 2012). Moreover, the genetic constituents of dairy cattle in Turiani are not known (Mtui, 2004). The use of artificial insemination of which their dairy traits are known could improve the genetic quality of the animals in the area. On the other hand, milk production can be affected by the environmental conditions. The observed increase in ambient temperature in the study area during the study period together with the level of genetic constituents of the cows could be attributed with the observed lower milk yield.

The observed higher weight gain (g/d) by supplemented animals on P3 was probably due to the influence of extra concentrate and forages supplied to the cows. It is well known that when lactating cows are in their 1st and 2nd parity and on forages and are supplemented with different levels of protein and energy, increases their daily weight gain (Chaussa, 2013) indicating that the animals are still growing and therefore the nutrients are partitioned for growth, ultimately more weight gain and less increase in milk yield (McDonald *et al*., 2010). In the current study most of the animals maintained their body condition implying that the supplements supplied additional protein, energy and minerals that were deficient in the poor quality forages. This was also reflected in increased milk yield by the supplemented lactating cows. Therefore, establishment of an appropriate feeding practice for the crossbred lactating dairy cows could improve the nutrients intake and subsequently milk yield by the animals in the study area.

It has been revealed that lactating dairy cows in the study area are producing below their genetic potential mainly due to underfeeding in both basal and concentrate diets resulting into low CP, ME and mineral intakes. The calculated daily nutrients intake (Appendix 28) offered to a lactating cow weighing 400 kg live body weight in the study area did not meet the higher production levels of these cows to produce 20 litres of milk per day. According to NRC (2001) a cow weighing 400kg, in order to produce 20 litres of milk will require daily supply of 135MJ ME, 1 978 g CP, 68 g Ca and 44 g P. Therefore, supplementary ration supplying 49.02MJ, 671.9 g CP, 10.02 g Ca and 5.53 g P per day will be required to cover the deficit of 14 litres of milk per day. This can be obtained when a cow is fed supplementary ration that consists of 2.74 kg DM of hominy meal (2.96 kg as fed), 1.09 kg DM of sunflower seedcake (1.18 kg as fed), 0.02 kg of farmers superlick, 0.02 kg of limestone, 0.01 kg of dicalcium phosphate and 0.01 kg of table salt. Since the animals were observed to be underfed on both forages and concentrates, in addition to the concentrate, lactating cows should be supplied with extra forage of *P. purpureum* at a rate of 5.01 kg DM (22 kg as fed) per cow per day.

The tested feeding practice (P3) to be used by dairy farmers during the dry season was based on the availability of feed resources (concentrate ingredients and forages) in the study area and the current feeding management of those cows. The formulated ration and extra forage of *P. purpureum* was assumed to increase milk yield from 6 to 20 l/cow/d in the study area during the dry season. The tested feeding practice was observed to result into milk production of 13 l/cow/d.

High ambient temperature cause heat stress to animals as a result lower feed intake by the cows which in turn lower animal performance (McDonald *et al*., 2010). The observed lower milk yield of 13 l/cow/d than the expected 20 l/cow/d may be attributed to various factors including high ambient temperature experienced in the study area during the experiment, low genetic potential for high milk production by the cows and parity of the animals. Lactating cows at their 1st and 2nd parity are still growing. These animals if happened to be involved in the experiment during the study period probably could be the reason of why the expected milk yield of 20 l/cow/day was not attained because it could be that the animals partitioned some of the nutrients supplied for growth instead of milk production (Migose *et al*., 2006).

In addition, this also may suggest that the crossbred dairy animals found in the area have lower genetic potential for high milk production than the expected level. Similar findings on the genetic potential of crossbred dairy cows producing 12-15 l/cow/d have been reported in the urban and peri-urban areas of Morogoro and Kibaha district by Mlay *et al*. (2005) and Nkenwa (2009), respectively. However, it is well known that underfeeding cows during the gestation period and in the first day of lactation negatively affects milk yield by the animals (Lukuyu *et al*., 2012). Earlier findings by Migose *et al*. (2006) and McDonald *et al*. (2010) indicated that increased nutrition during the last two weeks of gestation has positive effects on the early lactation curve. Increasing nutrition level in the first or second week of lactation as the case in the current study, the cow will first compensate for the body condition before increasing the milk yield. This together with the short period (45 days) used for intervention on nutrition could be one of the reasons for why the expected milk yield by the cows was not attained.

The involvement of farmers in the formulation of the concentrate and extra forage collection for tested feeding practice to increase milk production by the lactating cows was the approach aimed to empower smallholder farmers to carry on their own analysis of what can be done to improve profitability from the dairy enterprise. In addition, this approach was expected to encourage farmers to adopt the practice. This was in consistence with earlier findings by Peters (2001) who reported that involvement of farmers in decision making build up confidence and develop sense of ownership among farmers.

In the current study, it was observed that the additional production costs of the formulated concentrate and forages were relatively higher than that of farmers' commonly fed rations. This was because of high amount of concentrate and forage proposed to be offered and that family labour was not used to collect forages during the dry season since forages were sourced far away from homestead by hired labour. Higher profit was obtained using the tested feeding practice (10 417.27 Tsh per cow per day) compared to what obtained before (4 668.33 Tsh per cow per day) due to relatively higher milk yield obtained from the use of the tested appropriate feeding practice. This implies that feeding lactating cows adequate amount of basal diet with proper supplementation according to the animal requirements is more economical for optimum milk production.

The use of *P. purpureum* as additional extra forage to lactating cows was based on its local availability throughout the year and its outstanding nutritive value. It has been also reported that when *P. purpureum* was used as a source of basal diet resulted into high milk yield (Machibula, 2000). The tested feeding practice also resulted into increased body weight gain for the cows. This is advantageous to the dairy enterprise because it ensures that the animals calved frequently and hence increases overall milk production.

Therefore, smallholder dairy farmers in Turiani division could use the tested appropriate feeding practice (P3) to enhance productivity from their lactating crossbred dairy cows.

5.4 Limitations of live bodyweight measurement

Live bodyweight of the lactating animals were measured by using a weighing band. The ability of smallholder farmers and researcher to estimate live bodyweight using weighing band can affect the likelihood of under- or over-estimation of the animals' true body weight.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results of the current study it can be concluded that;

i. The feedstuffs commonly used by smallholder dairy farmers in Turiani division for feeding lactating animals in dry season are low in digestible nutrients, hence unable to supply sufficient nutrients to meet the requirements of the animals.

ii. The existing feeding practices of lactating cows under smallholder zero grazing system in Turiani division have inadequate nutritional supply, making the animals producing milk below their genetic potential.

iii. The tested feeding practice (P3) where additional 3.9 and 5 kg DM per day of concentrate diet and *P. purpureum* respectively is supplied on top of what the farmer is feeding could meet the nutritional demand of the animals and improve milk production during the dry season.

6.2 Recommendations

In order to improve performance of the lactating dairy cows particularly in the dry season the following could be recommended;

i. Supply lactating dairy cows with adequate good quality forages and well balanced concentrates according to their nutritional demands.

ii. Smallholder dairy farmers in Turiani could adopt the tested feeding practice (P3) in feeding their lactating cows.

iii. Further research on the genetic constituents of dairy animals kept by smallholder farmers in Turiani should be carried out to identify their genetic quality and more feeding experiments which covers calf rearing, heifer and pregnant cow feeding are of important to be carried out.

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APPENDICES

Appendix 1: Individual animal values for the amount of feeds offered (kg/d), body weight (kg), milk yield (l/d), CP (g/d) and ME (MJ/d) intakes by the animals

Feeding practices	Parameters														
	Amntfg	DMfg	AmntConc	DMConc	Fgdmint	Codmint	Tdmint	Bwt	Mlkyld	Cpfrg	Cpconc	Tcp	Mefrg	Meconc	Tme
NP	26.77	24.55	.	.	9.23	.	9.23	367	2.4	1036.036	.	1036.036	67.19551	.	67.19551
NP	24.67	18.92	.	.	8.33	.	8.33	350	3.7	917.1447	.	917.1447	60.19049	.	60.19049
NP	24.8	28.92	.	.	7.38	.	7.38	367	6.3	1173.375	.	1173.375	75.65992	.	75.65992
NP	25.4	31.91	.	.	9.81	.	9.81	357	3.8	1136.827	.	1136.827	74.82876	.	74.82876
NP	30.47	19.92	.	.	6.88	.	6.88	347	6.8	1006.107	.	1006.107	66.63186	.	66.63186
NP+MB	24.3	28.92	3	92.73	6.57	1.96	8.53	366	4.6	749.8407	383.0676	1132.908	45.60886	35.05194	80.6608
NP+MB	31.2	21.71	4	88.9	6.13	1.26	7.39	243	4.9	722.7346	467.9696	1190.704	43.96014	44.8056	88.76574
NP+MB	34.66	24	2.5	89.9	6.87	1.4	8.27	296	8.3	887.5733	295.771	1183.344	53.98642	22.475	76.46142
NP+MB	29.12	23.7	3	90.6	7.4	2.39	9.79	427	6.2	736.3836	419.1156	1155.499	44.79035	29.898	74.68835
NP+MB	25.58	28.92	3	92.73	7.89	2.68	10.57	374	6.3	789.3384	383.0676	1172.406	48.01131	35.05194	83.06325
NP+MB	30.33	28.92	3	90.81	8.77	2.72	11.49	480	7.6	935.9122	358.5179	1294.43	56.92662	34.32618	91.2528
NP+MB	24.73	31.91	3	88.2	8.11	1.79	9.87	403	6.9	842.0063	408.0132	1250.02	51.21482	33.3396	84.55442
NP+MB	24.07	23.48	4.7	88.22	8.32	2.22	10.54	427	8.4	603.0296	639.3656	1242.395	36.67912	45.60974	82.28886
NP+MB	34.9	29.05	3	88.9	5.65	4.17	9.82	363	5.1	1081.773	350.9772	1432.75	65.79854	26.67	92.46854
NP+MB	43	19.92	3	92.26	6.07	2.72	8.79	397	2.9	913.9495	426.7948	1340.744	55.59074	30.4458	86.03654
NP+MB	36.5	29.05	2	88.2	10.6	1.77	12.37	409	7.5	1131.367	272.0088	1403.376	68.81509	19.404	88.21909
NP+MB	25.96	27.77	4	88.22	10.01	2.65	12.66	371	8.5	769.2101	544.141	1313.351	46.78701	38.8168	85.60381
NP+MDC	25.5	39.74	3	88.2	14.02	2.7	16.72	247	8.4	1081.266	408.0132	1489.279	65.76771	29.106	94.87371
NP+MDC	39.57	25.3	3	88.22	12.76	2.7	15.46	349	10.7	1068.196	348.2926	1416.489	64.97275	26.466	91.43875
NP+MDC	15.6	89.86	3	89.9	10.69	2.64	13.34	345	6.4	1495.738	354.9252	1850.663	90.97786	26.97	117.9479
NP+MDC	14.2	89.86	3	89.9	11.02	2.21	13.23	421	8	1361.505	354.9252	1716.43	82.81318	26.97	109.7832
NP+MDC	26.92	39.74	3	88.21	10.68	2.2	12.88	365	7.2	1141.477	408.0595	1549.537	69.43007	29.1093	98.53937
NP+MDC	27.73	39.74	2.5	88.2	10.13	2.65	12.78	387	7.5	1175.824	313.7715	1489.596	71.51916	25.7985	97.31766
NP+MDC	26.87	39.74	2.5	88.2	10.14	2.67	12.81	541	8.2	1139.357	313.7715	1453.129	69.30112	25.7985	95.09962

NP: Natural pasture; MB: Maize bran; MDC: Mixed concentrate; Amntfg: Amount of forage; DMfg: Forage dry matter; AmntConc: Amount of concentrate; DMConc: Concentrate dry matter; Fgdmint: Forage dry matter intake; Codmint: Concentrate dry matter intake; Tdmint: Total dry matter intake; Bwt: Body weight; Mlkyld: Milk yield; Cpfrg: Crude protein of forage; Cpconc: Crude protein of concentrate; Tcp: Total crude protein; Mefrg: Metabolizable energy of forage; Meconc: Metabolizable energy of concentrate; Tme: Total metabolizable energy

Appendix 2: GLM procedure for the effect of feeding practices on the average dry matter intake from forages during investigation 2

Dependent Variable: Fdmint

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	80398901.2	40199450.6	5.17	0.0149
Error	21	163241672.4	7773413.0		
Corrected Total	23	243640573.5			

R-Square	Coeff Var	Root MSE	Fdmint Mean
0.329990	30.34072	2788.084	9189.248

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	80398901.16	40199450.58	5.17	0.0149

Appendix 3: GLM procedure for the effect of feeding practices on the average dry matter intake from concentrates

Dependent Variable: Cdmint

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	70793735.94	35396867.97	60.22	<.0001
Error	21	12343660.54	587793.36		
Corrected Total	23	83137396.48			

R-Square	Coeff Var	Root MSE	Cdmint Mean
0.851527	12.45657	766.6768	6154.800

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	70793735.94	35396867.97	60.22	<.0001

Appendix 4: GLM procedure for the effect of feeding practices on the average total dry matter intake

Dependent Variable: Tdmint

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	204957374.3	102478687.1	12.02	0.0003
Error	21	179078700.4	8527557.2		
Corrected Total	23	384036074.7			

R-Square	Coeff Var	Root MSE	Tdmint Mean
0.533693	19.03148	2920.198	15344.04

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	204957374.3	102478687.1	12.02	0.0003

Appendix 5: GLM procedure for the effect of feeding practices on the average crude protein intake from forages

Dependent Variable: Cpforg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	870060.566	435030.283	11.49	0.0004
Error	21	795062.531	37860.121		
Corrected Total	23	1665123.097			

R-Square	Coeff Var	Root MSE	Cpforg Mean
0.522520	25.84389	194.5768	752.8928

Source	DF	Type III SS	Mean Square	F Value	Pr >
Trtmnt	2	870060.5660	435030.2830	11.49	0.0004

Appendix 6: GLM procedure for the effect of feeding practices on the average crude protein intake from concentrates

Dependent Variable: Cpconc

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2188993.967	1094496.983	104.28	<.0001
Error	21	220418.596	10496.124		
Corrected Total	23	2409412.563			

R-Square	Coeff Var	Root MSE	Cpconc Mean
0.908518	11.82579	102.4506	866.3323

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	2188993.967	1094496.983	104.28	<.0001

Appendix 7: GLM procedure for the effect of feeding practices on the average metabolizable energy intake from forages

Dependent Variable: Fomeint

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2530.36608	1265.18304	3.44	0.0512
Error	21	7732.99947	368.23807		
Corrected Total	23	10263.36555			

R-Square	Coeff Var	Root MSE	Fomeint Mean
0.246544	34.04100	19.18953	56.37182

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	2530.366081	1265.183041	3.44	0.0512

Appendix 8: GLM procedure for the effect of feeding practices on the metabolizable energy intake from concentrates

Dependent Variable: Comeint

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	13830.01836	6915.00918	45.79	<.0001
Error	21	3171.50420	151.02401		
Corrected Total	23	17001.52256			

R-Square	Coeff Var	Root MSE	Comeint Mean
0.813458	16.83421	12.28918	73.00125

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	13830.01836	6915.00918	45.79	<.0001

Appendix 9: GLM procedure for the effect of feeding practices on the total crude protein intake

Dependent Variable: Tcp

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	4258331.494	2129165.747	42.21	<.0001
Error	21	1059244.375	50440.208		
Corrected Total	23	5317575.869			

R-Square	Coeff Var	Root MSE	Tcp Mean
0.800803	13.87015	224.5890	1619.225

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	4258331.494	2129165.747	42.21	<.0001

Appendix 10: GLM procedure for the effect of feeding practices on the total metabolizable energy intake

Dependent Variable: Tmeint

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	23070.67813	11535.33907	24.38	<.0001
Error	21	9935.87259	473.13679		
Corrected Total	23	33006.55072			

R-Square	Coeff Var	Root MSE	Tmeint Mean
0.698973	16.81316	21.75171	129.3731

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	23070.67813	11535.33907	24.38	<.0001

Appendix 11: GLM procedure for the effect of feeding practices on calcium intake from forage

Dependent Variable: Cafrg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	86.9594371	43.4797186	5.17	0.0149
Error	21	176.5621460	8.4077212		
Corrected Total	23	263.5215832			

R-Square	Coeff Var	Root MSE	Cafrg Mean
0.329990	30.34072	2.899607	9.556817

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	86.95943712	43.47971856	5.17	0.0149

Appendix 12: GLM procedure for the effect of feeding practices on calcium intake from concentrate

Dependent Variable: Caconc

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	31.58314469	15.79157235	142.43	<.0001
Error	21	2.32834273	0.11087346		

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Corrected Total	23	33.91148742			

R-Square	Coeff Var	Root MSE	Caconc Mean
0.931341	12.02475	0.332977	2.769093

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	31.58314469	15.79157235	142.43	<.0001

Appendix 13: GLM procedure for the effect of feeding practices on the total calcium intake

Dependent Variable: Tca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	152.6084132	76.3042066	8.91	0.0016
Error	21	179.8490075	8.5642385		
Corrected Total	23	332.4574207			

R-Square	Coeff Var	Root MSE	Tca Mean
0.459031	23.74244	2.926472	12.32591

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	152.6084132	76.3042066	8.91	0.0016

Appendix 14: GLM procedure for the effect of feeding practices on phosphorus intake from forages

Dependent Variable: Pfrg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	9.29412079	4.64706039	5.17	0.0149
Error	21	18.87074670	0.89860699		
Corrected Total	23	28.16486749			

R-Square	Coeff Var	Root MSE	Pfrg Mean
0.329990	30.34073	0.947949	3.124344

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	9.29412079	4.64706039	5.17	0.0149

Appendix 15: GLM procedure for the effect of feeding practices on phosphorus intake from concentrate

Dependent Variable: Pconc

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	68.54941639	34.27470819	92.78	<.0001
Error	21	7.75744910	0.36940234		
Corrected Total	23	76.30686549			

R-Square	Coeff Var	Root MSE	Pconc Mean
0.898339	12.20632	0.607785	4.979263

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	68.54941639	34.27470819	92.78	<.0001

Appendix 16: GLM procedure for the effect of feeding practices on the total phosphorus intake

Dependent Variable: Tp

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	94.9721797	47.4860899	36.38	<.0001
Error	21	27.4114807	1.3053086		
Corrected Total	23	122.3836604			

R-Square	Coeff Var	Root MSE	Tp Mean
0.776020	14.09866	1.142501	8.103613

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	94.97217974	47.48608987	36.38	<.0001

Appendix 17: GLM procedure Least Square Means for Investigation 2

GLM procedure Least Square Means for dry matter intake from forages

Trtmnt	**Fdmint** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	8567.7434	985.7366	<.0001	1
2	7323.9414	985.7366	<.0001	2
3	11676.0584	985.7366	<.0001	3

Pr > |t| for H0: LS Mean(i)=LS Mean(j)

Dependent Variable: Fdmint

i/j	1	2	3
1		0.3824	0.0368
2	0.3824		0.0052
3	0.0368	0.0052	

GLM procedure Least Square Means for dry matter intake from concentrates

Trtmnt	**Cdmint** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	3743.92500	271.06119	<.0001	1
2	7104.55875	271.06119	<.0001	2
3	7615.91500	271.06119	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Cdmint

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.1965
3	<.0001	0.1965	

GLM procedure Least Square Means for total dry matter intake

Trtmnt	**Tdmint** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	12311.6500	1032.4460	<.0001	1
2	14428.5125	1032.4460	<.0001	2
3	19291.9625	1032.4460	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Tdmint

i/j	1	2	3
1		0.1619	0.0001
2	0.1619		0.0032
3	0.0001	0.0032	

GLM procedure Least Square Means for crude protein intake from forages

Trtmnt	Cpforg LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	671.56021	68.79328	<.0001	1
2	571.25844	68.79328	<.0001	2
3	1015.85961	68.79328	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Cpforg

i/j	1	2	3
1		0.3143	0.0019
2	0.3143		0.0002
3	0.0019	0.0002	

GLM procedure Least Square Means for crude protein intake from concentrates

Trtmnt	Cpconc LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	443.56795	36.22175	<.0001	1
2	1025.13229	36.22175	<.0001	2
3	1130.29652	36.22175	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Cpconc

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.0527
3	<.0001	0.0527	

GLM procedure Least Square Means for total crude protein intake

Trtmnt	Tcp LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	1115.12818	79.40419	<.0001	1
2	1596.39073	79.40419	<.0001	2
3	2146.15614	79.40419	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Tcp

i/j	1	2	3
1		0.0003	<.0001
2	0.0003		<.0001
3	<.0001	<.0001	

GLM procedure Least Square Means for metabolizable energy intake from forages

Trtmnt	Meforg LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	51.6916761	6.7845235	<.0001	1
2	46.8072742	6.7845235	<.0001	2
3	70.6165200	6.7845235	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Meforg

i/j	1	2	3
1		0.6160	0.0619
2	0.6160		0.0216
3	0.0619	0.0216	

GLM procedure Least Square Means for metabolizable energy intake from concentrates

Trtmnt	Meconc LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	40.3274385	4.3448807	<.0001	1
2	81.3573750	4.3448807	<.0001	2
3	97.3188875	4.3448807	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Meconc

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.0168
3	<.0001	0.0168	

GLM procedure Least Square Means for total metabolizable energy intake

Trtmnt	**Tmeint** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	92.019115	7.690390	<.0001	1
2	128.164669	7.690390	<.0001	2
3	167.935442	7.690390	<.0001	3

Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Tmeint

i/j	1	2	3
1		0.0032	<.0001
2	0.0032		0.0015
3	<.0001	0.0015	

GLM procedure Least Square Means for calcium intake from forages

Trtmnt	Cafrg LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	8.9104525	1.0251659	<.0001	1
2	7.6168988	1.0251659	<.0001	2
3	12.1431000	1.0251659	<.0001	3

Dependent Variable: Cafrg

i/j	1	2	3
1		0.3824	0.0368
2	0.3824		0.0052
3	0.0368	0.0052	

GLM procedure Least Square Means for calcium intake from concentrate

Trtmnt	Caconc LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	1.15312875	0.11772503	<.0001	1
2	3.45281625	0.11772503	<.0001	2
3	3.70133500	0.11772503	<.0001	3

Dependent Variable: Caconc

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.1504
3	<.0001	0.1504	

GLM procedure Least Square Means for total calcium intake

Trtmnt	Tca LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	10.0635875	1.0346641	<.0001	1
2	11.0697250	1.0346641	<.0001	2
3	15.8444250	1.0346641	<.0001	3

Dependent Variable: Tca

i/j	1	2	3
1		0.4992	0.0007
2	0.4992		0.0037
3	0.0007	0.0037	

GLM procedure Least Square Means for phosphorus intake from forages

Trtmnt	Pfrg LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	2.91303125	0.33515052	<.0001	1
2	2.49014000	0.33515052	<.0001	2

3	3.96986000	0.33515052	<.0001	3

Dependent Variable: Pfrg

i/j	1	2	3
1		0.3824	0.0368
2	0.3824		0.0052
3	0.0368	0.0052	

GLM procedure Least Square Means for phosphorus intake from concentrate

Trtmnt	Pconc LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	2.60202875	0.21488437	<.0001	1
2	5.95362125	0.21488437	<.0001	2
3	6.38213875	0.21488437	<.0001	3

Dependent Variable: Pconc

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.1732
3	<.0001	0.1732	

GLM procedure Least Square Means for total phosphorus intake

Trtmnt	Tp LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	5.5150750	0.4039351	<.0001	1
2	8.4437500	0.4039351	<.0001	2
3	10.3520125	0.4039351	<.0001	3

Dependent Variable: Tp

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.0031
3	<.0001	0.0031	

Appendix 18: GLM procedure Duncan's multiple range tests for the dependent variables for investigation 2

Duncan's Multiple Range Test for Fdmint

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Trtmnt
A	11676	8	3
B	8568	8	1
B			
B	7324	8	2

Duncan's Multiple Range Test for Cdmint

Duncan Grouping	Mean	N	Trtmnt
A	7615.9	8	3
A			
A	7104.6	8	2
B	3743.9	8	1

Duncan's Multiple Range Test for Tdmint

Duncan Grouping	Mean	N	Trtmnt
A	19292	8	3
B	14429	8	2
B			
B	12312	8	1

Duncan's Multiple Range Test for Cpforg

Duncan Grouping	Mean	N	Trtmnt
A	1015.86	8	3
B	671.56	8	1
B			
B	571.26	8	2

Duncan's Multiple Range Test for Cpconc

Duncan Grouping	Mean	N	Trtmnt
A	1130.30	8	3
A			
A	1025.13	8	2
B	443.57	8	1

Duncan's Multiple Range Test for Tcp

Duncan Grouping	Mean	N	Trtmnt
A	2146.2	8	3
B	1596.4	8	2
C	1115.1	8	1

Duncan's Multiple Range Test for Fomeint

Duncan Grouping		Mean	N	Trtmnt
	A	70.617	8	3
B	A	51.692	8	1
B		46.807	8	2

Duncan's Multiple Range Test for Comeint

Duncan Grouping	Mean	N	Trtmnt
A	97.319	8	3
B	81.357	8	2
C	40.327	8	1

Duncan's Multiple Range Test for Tmeint

Duncan Grouping	Mean	N	Trtmnt
A	167.94	8	3
B	128.16	8	2
C	92.02	8	1

Duncan's Multiple Range Test for Cafrg

Duncan Grouping	Mean	N	Trtmnt
A	12.143	8	3
B	8.910	8	1
B			
B	7.617	8	2

Duncan's Multiple Range Test for Caconc

Duncan Grouping	Mean	N	Trtmnt
A	3.7013	8	3
A			
A	3.4528	8	2
B	1.1531	8	1

Duncan's Multiple Range Test for Tca

Duncan Grouping	Mean	N	Trtmnt
A	15.844	8	3
B	11.070	8	2
B			
B	10.064	8	1

Duncan's Multiple Range Test for Pfrg

Duncan Grouping	Mean	N	Trtmnt
A	3.9699	8	3
B	2.9130	8	1
B			
B	2.4901	8	2

Duncan's Multiple Range Test for Pconc

Duncan Grouping	Mean	N	Trtmnt
A	6.3821	8	3
A			
A	5.9536	8	2
B	2.6020	8	1

Duncan's Multiple Range Test for Tp

Duncan Grouping	Mean	N	Trtmnt
A	10.3520	8	3
B	8.4438	8	2
C	5.5151	8	1

Appendix 19: GLM procedure for the effect of feeding practices on the average initial body weight

Dependent Variable: Inbwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	928.08333	464.04167	0.36	0.7032
Error	21	27209.25000	1295.67857		
Corrected Total	23	28137.33333			

R-Square	Coeff Var	Root MSE	Inbwt Mean
0.032984	9.607349	35.99554	374.6667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	928.0833333	464.0416667	0.36	0.7032

Appendix 20: GLM procedure for the effect of feeding practices on the average final body weight

Dependent Variable: Fnbwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	8911.00000	4455.50000	2.91	0.0416
Error	21	32126.62500	1529.83929		
Corrected Total	23	41037.62500			

R-Square	Coeff Var	Root MSE	Fnbwt Mean
0.217142	9.993781	39.11316	391.3750

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	8911.000000	4455.500000	2.91	0.0416

Appendix 21: GLM procedure for the effect of feeding practices on the average body weight gain

Dependent Variable: Bwtgn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2.57570904	1.28785452	30.95	<.0001
Error	21	0.87380180	0.04160961		
Corrected Total	23	3.44951084			

R-Square	Coeff Var	Root MSE	Bwtgn Mean
0.746688	54.93911	0.203984	0.371292

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	2.57570904	1.28785452	30.95	<.0001

Appendix 22: GLM procedure for the effect of feeding practices on the average initial milk yield

Dependent Variable: Inmlkyld

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1.90375833	0.95187917	0.23	0.7932
Error	21	85.34583750	4.06408750		
Corrected Total	23	87.24959583			

R-Square	Coeff Var	Root MSE	Inmlkyld Mean
0.021820	31.52192	2.015958	6.395417

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	1.90375833	0.95187917	0.23	0.7932

Appendix 23: GLM procedure for the effect of feeding practices on the average final milk yield

Dependent Variable: Fnmlkyld

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	107.3630083	53.6815042	5.08	0.0158
Error	21	221.8257875	10.5631327		
Corrected Total	23	329.1887958			

R-Square	Coeff Var	Root MSE	Fnmlkyld Mean

	0.326144	29.47823	3.250097	11.02542	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	107.3630083	53.6815042	5.08	0.0158

Appendix 24: GLM procedure for the effect of feeding practices on the average milk gain

Dependent Variable: Mlkgn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	83.8366750	41.9183375	8.44	0.0020
Error	21	104.2433250	4.9639679		
Corrected Total	23	188.0800000			

R-Square	Coeff Var	Root MSE	Mlkgn Mean
0.445750	48.12087	2.227996	4.630000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trtmnt	2	83.83667500	41.91833750	8.44	0.0020

Appendix 25: GLM procedure least square means for investigation 2

GLM procedure least square means for initial body weight

Trtmnt	**Inbwt** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	365.875000	12.726344	<.0001	1
2	378.875000	12.726344	<.0001	2
3	379.250000	12.726344	<.0001	3

Dependent Variable: Inbwt

i/j	1	2	3
1		0.4781	0.4656
2	0.4781		0.9836
3	0.4656	0.9836	

GLM procedure Least Square Means for final body weight

Trtmnt	**Fnbwt** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	369.875000	13.828590	<.0001	1
2	387.625000	13.828590	<.0001	2
3	416.625000	13.828590	<.0001	3

Dependent Variable: Fnbwt

i/j	1	2	3
1		0.3744	0.0263
2	0.3744		0.1530
3	0.0263	0.1530	

GLM procedure Least Square Means for body weight gain

Trtmnt	**Bwtgn** LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	0.08888750	0.07211935	0.2314	1
2	0.19442500	0.07211935	0.0135	2
3	0.83056250	0.07211935	<.0001	3

Dependent Variable: Bwtgn

i/j	1	2	3
1		0.3126	<.0001
2	0.3126		<.0001
3	<.0001	<.0001	

GLM procedure Least Square Means for initial milk yield

Trtmnt	Inmlkyld LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	5.99875000	0.71274886	<.0001	1
2	6.56250000	0.71274886	<.0001	2
3	6.62500000	0.71274886	<.0001	3

Least Squares Means for effect Trtmnt
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Inmlkyld

i/j	1	2	3
1		0.5819	0.5411
2	0.5819		0.9511
3	0.5411	0.9511	

GLM procedure Least Square Means for final milk yield

Least Squares Means

Trtmnt	Fnmlkyld LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	8.5000000	1.1490829	<.0001	1
2	10.9000000	1.1490829	<.0001	2
3	13.6762500	1.1490829	<.0001	3

Least Squares Means for effect Trtmnt
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Fnmlkyld

i/j	1	2	3
1		0.1545	0.0045
2	0.1545		0.1023
3	0.0045	0.1023	

GLM procedure Least Square Means for milk gain

Trtmnt	Mlkgn LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	2.50125000	0.78771567	0.0046	1
2	4.33750000	0.78771567	<.0001	2
3	7.05125000	0.78771567	<.0001	3

Least Squares Means for effect Trtmnt
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Mlkgn

i/j	1	2	3
1		0.1142	0.0005
2	0.1142		0.0238
3	0.0005	0.0238	

Appendix 26: GLM procedure Duncan's multiple range tests for the dependent variables for investigation 2

Duncan's Multiple Range Test for Inbwt

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Trtmnt
A	379.25	8	3
A	378.88	8	2
A	365.88	8	1

Duncan's Multiple Range Test for Fnbwt

Duncan Grouping	Mean	N	Trtmnt
A	416.63	8	3

Duncan Grouping		Mean	N	Trtmnt
B	A	387.63	8	2
B		369.88	8	1

Duncan's Multiple Range Test for Bwtgn

Duncan Grouping	Mean	N	Trtmnt
A	0.8306	8	3
B	0.1944	8	2
B	0.0889	8	1

Duncan's Multiple Range Test for Inmlkyld

Duncan Grouping	Mean	N	Trtmnt
A	6.625	8	3
A			
A	6.563	8	2
A			
A	5.999	8	1

Duncan's Multiple Range Test for Fnmlkyld

Duncan Grouping		Mean	N	Trtmnt
	A	13.676	8	3
B	A	10.900	8	2
B				
B		8.500	8	1

Duncan's Multiple Range Test for Mlkgn

Duncan Grouping	Mean	N	Trtmnt
A	7.051	8	3
B	4.338	8	2
B			
B	2.501	8	1

Appendix 27: Daily feeding costs and gross income per cow under farmers' feeding practices

Feeding practices	Parameters							
	Feed type	Amount fed (kg/d)	Feed cost (Tsh/kg)	Total feed cost (Tsh/d)	Milk yield (l/cow/d)	Price of milk (Tsh/l)	Income from milk sale (Tsh/d)	Gross profit (Tsh/d)
NP alone	Forages	40	40	1 600	5.1	1 000	5 100	3 500
	Forages	28	40	1 120				
NP+MB	Concentrate	3	280	840	6.36	1 000	6 360	4 400
	Forages	28	40	1 120				
NP+MDC	Concentrate	3	295	885	8.11	1 000	8 110	6 105
	Forages	50	40	2 000				
Proposed feeding practice	Test concentrate	4.2	300.65	1 262.7	13.68	1 000	13 680	10 417.27

NP: Natural pasture; MB: Maize bran; MDC: Mixed concentrate

Appendix 28: Daily nutrient requirements of a dairy cow weighing 400 kg live weight and producing 20l of milk per day

Parameters	CP (g)	ME (MJ)	Ca (g)	P (g)
Requirements	1 978	135	68	44
Nutrient available	1 306.1	85.98	57.98	38.47
Deficit	- 671.9	- 49.02	-10.02	- 5.53

Appendix 29: Cost of individual ingredients, extra forage and overall cost of preparing 100kg (as fed) of test concentrate

Ingredient and forage	**Amount (kg)**	**Price(Tshs /kg)**	**Feed costs (Tshs)**
Hominy meal	70.5	280	19 740
Sunflower seedcake	28.0	300	8 400
Farmers superlick	0.5	1 750	875
Limestone	0.5	200	100
Dicalcium phosphate (DCP)	0.25	3 000	750
Salt	0.25	800	200
Total	**100**		**30 065**
Concentrate cost per kg		300.65	300.65
Extra forage (bundle)	75	40	3 000