NUTRITIONAL INTERVENTIONS ON DAIRY PERFORMANCE AND PROFITABILITY IN KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this or any other University for the award of a degree.

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DEDICATION

This work is dedicated to my beloved family and friends for their support and prayers.

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God bless you all.

ABSTRACT

Use of conserved forages and proper ration formulation have great potential to bridge the gap in dairy nutrition and reduce seasonal variations in feed availability and milk yield. This study aimed at determining effects of various fodder conservation and ration formulation interventions on dairy performance in North rift, Central and Eastern regions of Kenya. Twelve farms from each intervention i.e. use of maize train and baled silage, production of silage with support from Service Provider Enterprises (SPEs), and ration formulation using *Rumen8* software were compared with twelve control farms for each intervention, making a total of 72 purposively sampled farms. Objective one involved chemical analysis and *in-vitro* degradability of feed ingredients used in different intervention, while objective two and three involved the use of questionnaire to collect data on dairy performance and income over feed costs. The data was analysed using multi-linear regression model to assess the relationship between independent variables (interventions) and dependent variables (dairy performance). The data was subjected to analysis of variance using the General linear model of statistical Analysis system (2002). The Significant means was separated using least significant difference at 5%. Results from chemical analysis of feed ingredients showed that dry matter content of maize silage varied between the maize train and service provider enterprises silage (34.9% vs 32.33% respectively) $P<0.05$. *In-vitro* degradability potential at 48 hours showed baled maize silage being highly degraded 40.5% while SPEs silage had the least degradability (34.7%). Both proximate analysis and *in-vitro* degradability results showed no significant differences among concentrate ingredients within the same group from different interventions. Farms using *Rumen8* software had better performance with average daily milk yield of 24.3kg/cow in North rift region compared to those using maize train/baled and SPEs silage (17.2kg/cow and 14.3kg/cow). The interactions between different interventions and regions, grazing systems, and farm sizes did not have an effect on milk yield at $P>0.05$. Average cost of feed production was high in farms using *Rumen8* software (KES 28.85/litre) and lowest in SPEs farms (KES 18.46/litre). Income over feed cost was higher in farms using Rumen8 software formulated diets (KES 24.59/litre) and lowest in farms using SPEs feeds (KES 16.47/litre). It is concluded that use of maize train and baled silage and *Rumen8* software developed diets are ideal for sustaining feed availability in dairy farms to reduce seasonal milk fluctuation and for increased farm income.

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LIST OF ABBREVIATIONS

ADF	Acid detergent fibre
ADG	Average daily gain
ADL	Acid detergent lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BCS	Body Condition Score
BF	Butter fat
BW	Body weight
CFPs	Commercial fodder producers
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
FA	Fatty acids
FAO	Food and agricultural organization of United Nations
FCE	Feed conversion efficiency
GDP	Gross domestic product
GM	Gross Margin
IOFC	Income over feed costs
KMDP	Kenya Market-led Dairy Program
LSFs	Large Scale Farms
MoALF	Ministry of Agriculture, Livestock and fisheries
MSDF	Medium Scale Dairy Farm
NDF	Neutral detergent fibre
ROF	Return over feed costs
SNV	Netherlands development organization
SPEs	Service provider enterprises
SCFA	Short chain fatty acids
TMR	Total mixed ration

DEFINITION OF TERMS

Maize train and baled silage	This is a concept of silage making that involves a lot of mechanization and commercialization. The concept involves land preparation, quality seed selection, planting, weeding, harvesting which involves maize fodder chopping and crushing of maize kernels, ensiling and proper compaction using heavy machines and the feed-out process to minimize losses, silage heating-up and molding. Also, the concept of baling the silage to facilitate transportation to other farms, or proper storage practices.
Service provider enterprises maize silage	This is maize silage made by groups of entrepreneurial youth trained by the Netherlands development organization (SNV) under the KMDP project. They make silage in dairy farms when called upon and they charge according the acreage or tonnage of maize silage to be prepared. Apart from silage making, these group of youth also provide other dairy advisory services like ration formulation, record keeping, dairy structures, and general dairy management.
***Rumen8* software**	This is a feed balancing software that is equipped with local feed library and their nutritional values. Using the knowledge of an animal nutritionist, one can formulation a balanced feed ration that is of high quality based on the production potential of the animals. The software also calculates feed cost per cow/litre of milk, Income from milk sales and the margins i.e. income over feed cost. The software is more suited for ruminant dairy cows only, hence the term '*Rumen8'* meaning '*Rumen-aiding tool'.*
Control farms	These are farms purposively selected from regions where the interventions are being practiced. However, these farms did not adopt the interventions either ration formulation or maize silage making using maize train, silage baling or using SPEs services.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The dairy sector is the largest agricultural sub-sector in Kenya, and its share in GDP is approximately 4% and 3.5% of total GDP (Muriuki *et al.,* 2003). Dairy farming in Kenya is concentrated in the high altitude agro-ecological zones of the Eastern, Central highlands and Rift Valley regions with a high and bimodal rainfall and relatively low temperatures between 15^{o}C and 24^{o}C. More than three-quarters of the households in the regions engage in agriculture with 73% practicing integrated crop/dairy production. Dairy cattle are kept under intensive and semi-intensive production systems, with the distinction made between the two based on size, level of management and use of inputs (Wanyoike *et al.,* 2005; Wambugu *et al.,* 2011).

The available on-farm feed is estimated at less than 5 kg of the dry matter per head per day (Kashongwe *et al*., 2017), which is an amount that cannot even support maintenance requirements of a cow producing 10 litres of milk a day. This reflects feed scarcity which worsens during the dry season when the feed available in abundance is crop residues, but farmers underutilize this feed resource because they face challenges in improving its nutritive value. The feed fed is characterized by high degree of lignification high cell-wall content, low organic matter digestibility (<55%), low crude protein (<8%), and negligible available protein (3 to 4%) and low content of soluble sugars, deficiency in calcium and phosphorus minerals and vitamins, and low metabolizable energy (5 to 8MJ/kg DM) (Kashongwe *et al*., 2017). These nutritional attributes limit animal dry matter intake to levels that are inadequate to meet the production requirements. The organic matter digestibility (OMD) of feeds is a measure of energy available to ruminants and is used in protein evaluation systems (Gosselink *et al*., 2004) to calculate rumen fermentable OM, which in turn is used to estimate rumen microbial protein synthesis.

Kenya market-led dairy programme (KMDP) feed and fodder interventions in North Rift, Eastern and Central regions of Kenya aimed at increasing year-round access to good quality fodder both on-farm and from commercial fodder producers (CFPs). This includes support to dairy farmers and CFPs on fodder management skills in production, mechanization and preservation (Ettema, 2015). As regards improved production and utilization of fodder crops in medium and large scale dairy farms (M/LSFs), the KMDP had numerous interventions, namely; silage conservation and storage, feedstuff composition, ration formulation, dry matter intake of different groups of animals, on-farm training on practical aspects of feeding, body condition scores, calf rearing, health and reproduction, housing and cow welfare, judging quality of maize and grass silage, record keeping and farm planning (Otieno *et al*., 2015). All these interventions aimed at improving M/LSFs performance and optimization of the production cost. Use of SPE silage-making services was most frequent among farmers in Eastern and Central regions, where the majority (75%) of farmers used the services.

According to the focus group discussions (FGDs), it took the formation of the SPEs for silage to become a common practice in their regions of operation. Most farmers relied on traditional feeding practices, such as open grazing, tethering and feeding on maize Stover. Service provider enterprises (SPEs) were formed mainly to support farmers increase silage production and use. Silage making services include harvesting, chopping, compacting and tubing and, sometimes, provision of the materials required for ensiling. According to the representatives from the eight SPEs, the groups made about 11,269 tons of silage in 2016 (Kilelu *et al.,* 2017).

Feed cost is the main component of dairy production accounting to between 50% and 60% of the total cost of production (FAO, 2014). The performance of dairy enterprises is still low and the cost of production high. Scarcity and low quality of feed resources constitutes one of the major constraints to improved dairy productivity. Therefore, improving the efficiency of feed conversion to milk can have a significant impact on the profitability of dairy production. At low dry matter intake (DMI), associated with low feed quality, cows lose weight, produce less milk which is often low in solids, have a poor fertility and are susceptible to metabolic diseases. Consequently, profitability of the dairy business is affected.

Cost of milk production especially the estimation of cash and economic costs is the key indicator for sustainable dairy farming, as well as the means of measuring overall economic competitiveness (Ndambi *et al.,* 2017). The choice of production and marketing strategies by farmers therefore, contribute to high/low cost of production. As a result, there has been continued interest from the public and from policy makers in the profitability and competitiveness of Kenya dairy production (Hemme *et al.,* 2014).

1.2 Statement of the Problem

Fodder conservation and dairy ration formulation are some of the intervention options by the Netherlands development organization (SNV), Kenya market-led dairy programme (KMDP) adopted by medium and large-scale dairy farms in Kenya. However, Dairy performance (milk yield, milk butter fat and protein, and nitrogen use efficiency) is still low due to low quality, scarcity and high cost of feed resources. The nutritional value of the fodder and feed ration ingredients used in the *Rumen8* software has not been analysed to ascertain the actual nutritional content. This leads to feeding practices that are based on low quality feeds and feed rations which results to low quality and quantity milk production and cases of metabolic disorders. The cost and benefits of the interventions have not been assessed to ascertain their effectiveness on dairy performance and profitability in different regions of Kenya. Therefore, there is need to determine the actual nutritional quality of dairy rations and fodder crops used in interventions adopted by the medium and large-scale dairy farms in different regions of Kenya.

1.3 Objectives of the Study

1.3.1 General Objective

To contribute to sustainable dairy performance and profitability in medium and large-scale dairy farms in Kenya through utilization of fodder related interventions.

1.3.2 Specific Objectives

i. To determine the nutritive value of feeds and feed ration ingredients from different interventions adopted by medium and large-scale dairy farms in Kenya.

ii. To determine the effects of fodder conservation and ration formulation options on dairy cow performance in Kenyan dairy farms.

iii. To assess the income over feed cost of fodder conservation and ration formulation options in Kenyan dairy farms.

1.4 Hypotheses

i. There is no significant difference in nutritive value of feed and feed ration ingredients from different interventions used by dairy farms in Kenya.

ii. There is no significant difference among different fodder conservation and ration formulation options on dairy farms performance in Kenya.

iii. There is no significant difference in the income over feed cost of fodder conservation and ration formulation options in Kenyan dairy farms.

1.5 Justification of the Study

Feed cost is the main component of dairy enterprise accounting to between 50% and 60% of the total cost of production (FAO, 2014). The fodder related interventions by the Dutch funded Kenya market-led dairy programme (KMDP) focused on improving fodder conservation and ration formulation options and quality to medium scale dairy farmers in Kenya. In order to identify and prioritize the best fodder conservation and ration formulation interventions under various circumstances, it would be required to assess the impact of these interventions on the dairy cow performance and general farm profitability.

The use of feed balancing (*Rumen8*) software was adopted and is being used by farmers based on the current feed library. The nutritional content of the feed library has been sourced from different feed analysis sources like FeedPlus, BLGG Research AgroXpertus (Wageningen, the Netherlands), AKEFEMA, and MoALF. The actual nutritional content of the feed ingredients being used in the *Rumen8* tool has not been determined. This study therefore, carried out the feed analysis to determine the actual nutritional value of the feeds used in the *Rumen8* feed library.

Cost of milk production especially the estimation of cash and the economic costs is the key indicator for sustainable dairy farming as well as the means of measuring overall economic competitiveness (Hemme *et al.*, 2014). Strategies to improve dairy farm profitability should therefore focus on improving feed efficiency and reducing feed costs per unit of output. Scarcity and low quality of feed resources constitutes one of the major constraints to improved dairy productivity. These existing practices result in enormous losses during ensiling and feed-out and greatly reduce nutritional value (ME MJ/kg DM) of the silage and dry matter (DM) intake of the cows. Therefore, improving the efficiency of feed conversion to milk can have a significant impact on the productivity and profitability of dairy farms. The potential of dairy cows' production depends on the nutrient composition of the ration presented to the animal as well as on the quality of feed ingredients.

CHAPTER TWO
LITERATURE REVIEW

2.1 Dairy Farming in Kenya

Kenya has a vibrant dairy industry with an estimated value of 4% of gross domestic product (GDP). This vibrancy is anchored on the increasing domestic milk production (averaging 5.3% per year), processing capacity (averaging 7% per year), annual per capita milk consumption (averaging 5.8% per year, currently at 110 litres) and export potential (MoALF, 2010; KDB, 2015). The sector is in a transition phase from smallholder subsistence farming with on average 3-4 crossbreed cows for home consumption and sales of small quantities of excess milk (5-10 litres per day), to dairy entrepreneurs with dairy as core business (Leenstra, 2014). The latter invest in amongst others exotic breeds, improved dairy barns and fodder production and preservation. This segment of dairy farms/farmers is of a varied composition in terms of farming systems (zero grazing and semi-zero grazing with pastures), size of landholdings/herd and owner-ship/ management. However, they have one thing in common which is that they all are in dairy farming as a business.

This commercializing segment of farmers consists of smallholders who invest in dairy as a core business and have been able to grow their dairy business to “the next level”. These farmers are fully commercial however limited in their growth by lack of capital, land and the inability to grow and preserve fodder in sufficient quantities. Often the household has various sources of income from on-farm and off-farm activities/employment, and part of this is invested in the dairy enterprise. These farms have 5 up to 15 lactating cows and produce over a 100 litres of milk per day on landholdings ranging from 1-5 acres in the densely populated Mount Kenya milk sheds (zero- grazing) to 5-10 acres in other parts of Central Province (Kinangop, Nyandarua) and North Rift (semi-zero grazing). Often land is leased for fodder production (Ettema, 2015).

Medium and large-scale farmers who have “(re-) discovered” dairy farming as a profitable business. Some are farm owner-manager. But many of these are well-off Kenyans with ample land and resources and a passion for farming, and usually in formal employment or on retirement. The level of mechanization is much higher as compared to the former segment of farmers, especially fodder production and preservation is fully mechanized. Farm sizes and herds may go up from 20 to 500 acres and 20-100 cows respectively. A good number of the

MSFs are landowners with formal jobs outside agriculture, also referred to as "telephone farmers". Medium scale famers invest often quite heavily in dairy usually lack sufficient skills to make the dairy farm profitable (Ettema, 2015).

Generally, farmers in Kenya are very focused in improving the quality of their herd, milk production and move towards efficient operations on their farms, amongst many other areas. This is mainly due to the revival of the dairy sector, high milk prices, increased business acumen and levels of education of owners and managers.

2.2 Characteristics of Dairy Production Systems

Dairy farming in Kenya is concentrated in the high altitude agro-ecological zones of the central highlands and Rift Valley regions with a high and bimodal rainfall and relatively low temperatures between 15^{o}C and 24^{o}C. More than three-quarters of the households in the two regions engage in agriculture with 73% practicing integrated crop/dairy production. Slightly over half (54%) of smallholder faming households holding up to one acre of land keep cattle. In 2015, the Kenyan dairy cattle population was estimated at 4.3 million and produced over 3.43 billion litres of milk. Smallholder dairy farmers accounted for over 80% of the total national milk output (Wambugu *et al.,* 2011).

The ministry of Livestock Development estimated that the national dairy cattle herd was made up of 50% cows, 10% heifers of over one year, (Behnke and Muthami, 2011). Dairy cattle are kept under intensive and semi-intensive production systems, with the distinction made between the two based on size, level of management and use of inputs. In places with higher population density, many keep their animals confined on farm and stall-feed them crop residues and planted fodder. Smallholders using more intensive systems for dairy production typically produce on a few acres only usually less than three with a herd size of one to five pure or crossbred cows or a mixture of both. Less intensive systems combine stall-feeding and some grazing (Muia *et al.,* 2011).

2.3 Relevance of Medium Scale Farmers in the Dairy Sector

Kenya market-led dairy programme's analysis on MSFs shows that for long-term sustainable growth, the dairy sector needs to transition from smallholder semi-subsistence farming, to an industry that relies for the supply of raw milk on fully commercial dairy farming systems (Ettema, 2015). The relevance of MSFs for the Kenya dairy sector can be summarized as follows:

Innovation. This group of farmers are engaged in dairy farming as a core business (rather than as a livelihood strategy). They are willing and able to invest in expansion of the herd, cow housing, training of farm managers, on-farm (mechanized) fodder production and preservation, and in innovations.

Dairy support-infrastructure. These farmers have the ability to attract more credible input suppliers and service providers. Where applicable they can forge business linkages with the Dutch private sector or other international players. In doing so, they can fast-track the development of a professional dairy support infrastructure that once in place is expected to also benefit the smallholder supply chain (Ettema, 2015).

Lobbying. Through their political and business networks they also have the ability to push for policy reforms that will benefit the dairy sector as a whole.

Demonstration and training. A number of the more successful commercial dairy farms have gone into training (of peers and also of smallholders) as a side-business; some position themselves as Practical Dairy Training Farms or Centres (PDTF). To some extent this fills the gap in practical dairy training and extension that was created after withdrawal by the government extension services.

Business linkages with smallholder dairy farmers. Medium scale farms have the potential to supply smallholders with inputs and services. For example, the supply of fodder and heifers or leasing of farm machinery for fodder production and preservation. Some MSFs have started bulking milk from smallholder dairy farmers around them offering enhanced market access for their milk (Ettema, 2015).

2.4 Kenya Market-led Dairy Programme (KMDP) Fodder Interventions

As regards to improved production of fodder crops in MSF farms, the KMDP program had numerous interventions. Hay and maize (and to some extent Napier grass and fodder sorghum), are the main fodder products preserved by dairy farmers. Both hay and maize production and handling (i.e. preservation, storage) have room for significant improvements and optimization, if management and mechanization are enhanced (Ettema, 2015).

During KMDP's inception phase on feed and fodder implementation, the study confirmed that one of the most important bottlenecks for enhanced competitiveness and growth is access/ availability of quality fodder (Rademaker *et al*., 2015). This applies both to smallholders and MSFs. The sector is in agreement that the fodder issue is more important than breed. Without proper feed and feed rations/regimes the genetic potential of the breed remains unlocked, and good fertility management relies heavily on the animal's health and feeding. The limited access to/availability of quality fodder is partly due to land size and competition with others crops. But also, it is directly related to low skills and knowledge as regards to fodder management and preservation, mechanization and unavailability of high energy and protein fodder seed varieties. The fodder gap has severe impact on cost price of milk, profitability of the farm enterprise and seasonality in milk supply.

Kenya market-led dairy programme's fodder interventions aimed at increasing year-round access to good quality fodder both on-farm (smallholders and MSFs) and from Commercial Fodder Producers (CFPs). This includes support to dairy farmers and CFPs on fodder management skills in production, mechanization and preservation, introducing new fodder seed varieties and piloting innovative technologies and business concepts for marketing of preserved fodders (Ettema, 2015). In summary, focus in North Rift, Central and Eastern in KMDP's MSF agenda has been on the following interventions:

i. Maize silage making and conservation
ii. Ration calculation and compounding
iii. Dry matter feed intake of different groups of animals
iv. On-farm training on practical aspects of feeding
v. Improving BCS, calf rearing, health and reproduction, housing and cow welfare
vi. Grazing practice and paddocking
vii. Record keeping and farm planning

2.5 Effects of Feeds and Feeding on Dairy Performance

Studies addressing the optimization of dietary protein have shown that concentrations beyond 160 g/kg crude protein do not positively impact milk yield (Groff and Wu, 2005; Colmenero and Broderick, 2006). Overfeeding crude protein reduces profit margins due to the relatively high cost of protein supplements and low efficiency of nitrogen use by dairy cows fed high protein diets. Dairy cows excrete about 2-4 times more N in manure than in milk, which increases both costs of milk production plus environmental N pollution (Broderick, 2006; Corea *et al*., 2017).

Dietary protein content is the most important factor determining milk nitrogen efficiency, urinary nitrogen losses, and consequently, ammonia emissions from dairy cow manure (Powell *et al.,* 2011; Hristov and Giallongo, 2014). The results showed that reducing dietary crude protein from 170 to 155 g/kg does not impair milk or component yield but decreased N excretion as well as feed costs. Several recent studies show that the protein efficiency (ratio of milk protein to feed protein) increases as dietary protein concentration decreases (Kälber *et al.,* 2012; Cantalapiedra-Hijar *et al.,* 2014). Further, Spek *et al.* (2013) noted that decreasing dietary crude protein should result in lower nitrogen losses via urinary and milk urea. Therefore, it might be expected that the nitrogen-conversion efficiency from feed to milk would rise if protein concentrates are restricted or omitted and roughage quality remains good.

When diets are formulated to contain an equal amount of forage DM, neutral detergent fibre (NDF) concentrations of diets generally will be higher for diets containing grasses compared with legumes. Increasing dietary NDF concentration often has a negative impact on the amount of DM consumed by lactating dairy cows (Allen, 2000). It is common for dairy producers to supplement forage with concentrates based on the average requirement of the herd, which is described as flat rate feeding by Gill and Kaushal, (2000). Where flat rate feeding is practiced, all cows are offered the same amount of concentrate DM irrespective of individual cow's potential milk production, BW, or stage of lactation.

Table 2.1 below shows nutrient requirements of dairy cows at different body weight and milk production. This gives a guide when formulating feed rations to achieve maximum production potential of the animals. The nutrient composition in the feed rations determine the amount of milk a dairy cow produces (Fuentes-Pila *et al.,* 2003).

Table 2.1. Daily nutrient requirements for a dairy cow based on live weight and milk yield

Cow LWT (kg)	Milk yield (kg)	DMI (kg)	ME (MJ)	CP (g)	Ca (g)	P (g)
350	5	10	72	806	27	27
	10	11	97	1093	42	36
	15	13	123	1393	57	45
400	5	11	78	874	29	29
	10	12	103	1161	44	39
	15	14	129	1448	58	48
450	5	11	84	946	31	32
	10	13	110	1234	45	41
	15	15	135	1521	60	50
	20	17	161	1826	75	59
500	10	14	113	1275	46	43
	15	16	138	1560	59	51
	20	18	162	1823	74	59
550	10	15	121	1359	48	46
	15	17	145	1635	61	53
	20	19	168	1892	75	62
	25	21	194	2179	90	71
600	10	16	129	1431	50	49
	15	18	152	1710	63	55
	20	20	174	1984	77	65
	25	22	201	2262	91	75
	30	23	227	2545	106	85

LWT= Live weight, **DMI**= Dry matter intake, **CP**= Crude protein, **ME**= Metabolizable energy, **Ca**= Calcium, **P**= Phosphorus

Source**:** Fuentes-Pila *et al.* (2003)

According to Lukuyu *et al.* (2011), and Goopy and Gakige, (2016), the optimal dairy cattle feeding regime should consist of 75% energy sources, 24% protein sources and 1% mineral sources. Energy is necessary for body maintenance, milk production, growth, weight gain and reproduction. Protein is necessary to break down the roughage into usable nutrients. Younger plants, particularly legumes (pasture and fodder), have a rich protein and vitamin content. Examples of protein sources are bean straw, sweet potato vines, Desmodium, Lucerne, fishmeal, sunflower and white clover as well as fodder trees such as Calliandra, Leucaena, mulberry and Sesbania. The higher dietary starch in the corn grains treatment would likely cause an increase in insulin concentrations, and insulin seems to play either a direct or indirect role in milk protein synthesis (Apelo *et al.*, 2014).

2.6 Effects of Feeds and Feeding on Milk Yield

Utilization of diets by dairy cows is largely influenced by the nutrient composition and physical characteristics of the forage in the ration. Grasses generally contain higher total neutral detergent fibre (NDF) and potentially digestible NDF concentrations, which have a slower rate of digestion but greater extent of digestion than legumes affecting milk yield (Buxton and Redfearn, 1997). In general, lactating dairy cows fed grass-based diets have lower DMI and milk production compared with cows fed legume-based diets (Steinshamn, 2010; Wambugu *et al.*, 2011). The variation in maturity at ensiling during the grain filling period results in major changes in the content and composition of the carbohydrates (starch/NDF ratio) in maize silages, affecting silage DMI, milk yield and milk composition of dairy cows.

Increased protein content of pasture milk over total mixed ration (TMR) milk has been shown by Couvreur *et al.* (2006) who reported a linear increase in milk protein content with increasing pasture content of the cows' diet. They attributed the increase in protein content to a modification of energy provided to the udder by an increase in propionic acid supplied to the rumen from grass diets (O'Callaghan *et al.*, 2016). An animal's feed intake, and how well that feed is digested, determine the feed's production performance. The nutritive value, or energy content, of an animal feed is determined predominately by its digestibility, which affects intake, or how much the animal will eat. Digestibility and intake, in turn, determine the feed's productive performance, such as to support milk synthesis or muscle growth (Getachew *et al.*, 2004). The performance of animals maintained in resource-poor surroundings is usually poor due to seasonal fluctuations in the quality and supply of animal feeds. When accessible even in limited quantities, the fibrous feeds such as cereal crop residues and poor-quality mature grasses cannot maintain animals during much of the year (Osuga *et al.*, 2008).

In-vitro gas methods primarily measure digestion of soluble and insoluble carbohydrates (Menke and Steingass, 1988), and the amount of gas produced from a feed on incubation reflects production of volatile fatty acids (VFA), which are a major source of energy for ruminants. Gas arises directly from microbial degradation of feeds, and indirectly from buffering of acids generated as a result of fermentation. In the gas technique gases were produced directly as a result of fermentation containing CO_2 and CH_4 and the indirect gas produced from the buffering of SCFA (Blummel and Ørskov, 1993). Rumen fermentation by anaerobic microbes results in production of short chain fatty acids (SCFA), gases (carbon dioxide (CO_2) and methane (CH_4)) and microbial mass. The amount of gas produced is proportional to acid production, thereby serving as an indicator of acids produced by fermentation. The amount of gas produced during incubation is measured to predict the extent and rate of feed digestion.

The pattern of feed fermentation (kinetics of fermentation) is one of several factors that influence voluntary feed intake by ruminants. The rate at which different chemical constituents are fermented is a reflection of microbial growth and accessibility of the feed to microbial enzymes. Service provider enterprises (SPEs) were formed mainly to support farmers increase silage production and use. Silage making services include harvesting, chopping, compacting and tubing and, sometimes, provision of the materials required for ensiling.

Use of SPE silage-making services was most frequent among farmers in Central and Eastern regions, where the majority (75%) of farmers used the services at least four times in 2016 (Kilelu *et al.,* 2018). Maize silage was the most common silage made by all SPEs, with an estimated 9,415 tons made in 2016 (about 83% of the total silage made) (Kilelu *et al.*, 2018). Scarcity and low quality of feed resources constitutes one of the major constraints to improved dairy productivity. Therefore, improving the efficiency of feed conversion to milk can have a significant impact on the productivity and profitability of dairy farms. This experiment aimed to determine the actual nutritional quality of dairy ration ingredients and fodder crops used in interventions adopted by dairy farms in Kenya.

2.7 Effects of Feeds and Feeding on Milk Butter Fat

Milk quality may be significantly affected by feeding strategies. Forage-concentrate proportions and the origin of roughages affect the concentration of value-giving n-3 fatty acids (FA) and conjugated linoleic acids in milk fat (Khiaosa-ard *et al.,* 2010; Shingfield *et al.,* 2013). Corn grain is typically substituted for forage in dairy cattle diets to increase the energy density of the ration providing glucose precursors for milk production and substrates for microbial protein production. Identifying alternative feedstuffs that provide energy and maintain milk component yields will decrease dependence on high-starch ingredients such as corn. Non-forage fiber sources (NFFS) have been researched as alternatives to starch for lactating dairy cattle (Boerman *et al.,* 2015).

Similar studies by Couvreur *et al.* (2006) found that the use of a total mixed rations (TMR) feeding system can produce milk with higher fat contents. Feeding of TMR diets high in unsaturated fatty acids (UFA) has been linked with a reduction in milk fat content as UFA are toxic to many rumen bacteria, particularly those responsible for fibre degradation, resulting in reduced activity of acetyl CoA carboxylase enzyme and de novo synthesis (O’Callaghan *et al.,* 2016).

2.8 Effects of Feeds and Feeding on Body Condition Scores

In dairy management systems, body condition scores (BCS) is used as an indicator of body fat content and cow nutritional status. Cows should be managed to achieve appropriate BCS both pre- and postpartum to reduce threats to welfare, since BCS at calving may affect early lactation dry matter feed intake (DMFI), post calving body condition scores’ loss, milk yield, cow immunity, and fertility. At calving, DMFI and BCS are negatively correlated (Hayirli *et al.,* 2002; Matthews *et al.,* 2012), so that “fat” cows undergo a more pronounced and prolonged depression in DMI, leading to a deeper negative energy balance.

The benefit of body condition score (BCS) as a dairy herd management tool is dependent on accurate quantification of marginal differences in BCS at critical periods of the inter-calving interval on overall profitability. Furthermore, the greater energy costs associated with heavier cows must be assessed with consideration of any additional benefits, economic or otherwise, accruing from heavier cows such as higher milk production or increased carcass weight (Berry *et al.,* 2007). The association between BCS at calving and milk production may be influenced by the quality of diet post-calving (Roche *et al.*, 2007), with high milk production associated with greater BCS loss in early lactation.

2.9 Feed Efficiency in Dairy Cows

Feed efficiency represents a key driver in high yielding dairy cows. In general, feed efficiency in dairy cows is determined by the kg of milk produced per kg of dry matter consumed. It therefore determines the ability of cows to turn feed nutrients into milk components. As the energy amount of milk varies due to fat and protein content, the simple measure produced kg of milk per kg of consumed dry matter (DM), optimal ranging from 1.4 to 1.9 is energy-corrected (Ojango *et al.,* 2011).

Feed efficiency (FE) varies within one animal species, as younger animals have the highest FE due to their growing and the fact, that they turn most of their energy intake into their growth. Ruminants however, show a rather low FE which is related to their digestive system. Unlike mono-gastric, which focus on enzymatic digestion, ruminants show big microbial fermentation processes in their rumen before nutrients are absorbed. In the rumen, a complete microbial ecosystem has evolved and is specialized on the fermentation of roughage, especially fibre. The huge 'fermentation chamber' is able to digest fibre, to turn non-protein nitrogen (NPN) into highly valuable amino acids, to produce B vitamins and to detoxify the organism. However, the maintenance of this sophisticated ecosystem is rather expensive, as the first nutrients being available from ruminal fermentation are required to supply the located microbials. More than 50% of the feed is used for maintenance, explaining the difficulties of feed selection in regard to feed efficiency, compared to pigs, poultry or fish (Ojango *et al.,* 2011).

2.10 Cost-benefits of Feeding Strategies in Dairy Farms

Feed costs contribute to up to 60% of dairy production costs, improving the efficiency of feed conversion to milk can have a significant impact on the profitability of dairy production. Improving production efficiency has always been a goal of animal agriculture to ensure sufficient food and fibre supply, and to maintain producer profitability (Connor, 2015). Income over feed cost (IOFC) is a term used to assess and define feed efficiency of dairy herds and examines efficiency directly from a profitability stand-point also called return over feed (ROF). It is calculated as the difference between the total revenue obtained from the sale of milk during a selected time interval and the feed costs associated with its production (Hemme *et al.,* 2014).

Cost of milk production especially the estimation of cash and economic costs is the key indicator for sustainable dairy farming as well as the means of measuring overall economic competitiveness both factor and product market, locally and internationally (Ndambi *et al.,* 2017, 2018). Therefore, to remain competitive, dairy organizations and farmers must strive to reduce costs at farm level (Koonawootrittriron *et al.,* 2012). Cost-benefit analysis not only bases decisions on costs and benefits; it also looks for the value of net benefits after deducting costs from benefits. While benefits can be of different kinds and are put together to the extent that they can be through a selection of weights (or ranges of weights), costs are seen as foregone benefits.

2.11 Estimation of Production Costs

Analysis of gross margins using the USAID-KAVES baseline data showed that the dairy farming is profitable, with average gross margins of KES 32 per litre, ranging from a high of KES 38 reported in Kisumu to a low of KES 21 in Uasin-Gishu. These are significantly higher than margins of KES 2 per litre for zero-grazing systems and KES 4 for non-zero-grazing systems in Kiambu. The unit cost of production ranges from a low of KES 8.46 in Meru to a high of KES 14.73 in Uasin Gishu, with a median of KES 12.43 (Wambugu *et al.,* 2011).

A study by Staal *et al. (*2003), showed average costs of production per litre of milk to be KES 17.20, 11.90 and KES 13.30 in Kiambu, Nyandarua and Nakuru respectively. Ojango *et al.* (2011) reported average production costs ranging from KES 10.3 to KES 21.0 per litre for extensive systems and from KES 8.1 to KES 14.9 for semi-extensive dairy systems in Kenya. Baltenweck *et al.* (2012) further indicated that these differences were driven by the geographical location and the production intensity.

In Kenya, forage production and forage markets are largely determined by seasonality and volume based. Quality of forages (nutritive value) is as yet of secondary concern. Prices of forages traded in the market (mainly hay and Napier grass) shoot up during the dry season to as high as KES 300-350 for a bale of poor-quality hay which on average is 13 kilos per bale. Therefore, approximately KES 31-36/kg dry matter (at 80% DM content). The scope to improve hay quality is significant if well managed, fertilized, harvested at the right cutting stage, and especially if improved grass seed varieties become available in the market (Leeuward *et al*., 2019).

Reducing milk losses is critical to increasing farmer returns. As an income-generating activity, the average dairy enterprise in this sample easily meets the minimum annual consumption expenditure requirements of individual rural households. Any factor that could lower or increase expenses is a source of risk to the economic performance of the dairy business (Bailey, 2001). Some of these risks are: milk prices, purchased feed prices, hired labour, crop /forage production among others. Dairy production in Kenya is faced by a multitude of perceived and often experienced risks, which contribute to high costs of production and low average productivity.

Measuring the cost of production is important if a farmer wants to know whether or not he is making profit. While one can tell the milk price right away, it is often difficult to measure milk production costs and profits (Bailey, 2001). The cost of milk production and its profitability is also affected by factors that determine farm-gate milk prices across the rural areas of Kenya (Muriuki *et al.*, 2003). The choice of production and marketing strategies by farmers therefore, contribute to high costs of production and low average productivity. As a result, there has been continued interest from the public and from policy makers in the profitability and competitiveness of Kenya dairy production. Therefore, an understanding of the costs and benefits of smallholder dairy farmers is an important pre-requisite for policy formulations aimed at improving productivity.

2.12 Dairy Farm Profits

Revenue in a dairy enterprise accrues from sale of milk, manure and animals (calves, heifers and bulls), and milk consumed by households and calves. The survey by Mburu *et al.* (2007) showed significant differences between returns in lower highlands and upper midlands. The returns were lowest in lower highlands at KES 2.3 per kg and highest in upper midlands at KES 6.3 per kg. In the lower midlands the returns were KES 3.45. The high returns in upper midlands can be attributed to low cost of production, high milk prices offered by informal milk marketing channels and low labour and water expenses. However, the low returns in lower highlands was due to low milk prices of KES 17.5 per kg offered by dairy cooperatives and high costs of production of KES 19.1 per kg.

A study by Staal *et al.* (2003) reported returns of KES 3.4 per kg. The same study simulated estimates of cost of production and revenues in Kiambu, Nakuru and Nyandarua districts showed negative overall profit. The value of manure used on crops and planted forages represents additional revenue to the farm. Studies in Kenya highlands have estimated that the value of manure may be 30% of the value of milk sold.

The survey carried out in the Kenya highlands by Mburu *et al.* (2007) showed that dairy enterprise is the most important income generating farming activity in 96% of households in Kenya highlands and probably the most single important farming activity in the region. Farmers in upper midlands are making much more profit from milk than those in lower highlands due to higher milk prices. These showed that cooperatives are not competitive in milk pricing and lower highlands farmers should utilize the other available milk marketing channels. The survey showed that in Kiambu district, the cooperatives experience shortage and surplus of milk in the dry (January- April) and wet (rest of the year) seasons respectively.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Sites

The study was carried out in North Rift region (Trans-Nzoia and Uasin-Gishu Counties), Eastern region (Meru and Machakos Counties), and Central region (Kiambu, Nyeri, Muranga, and Kirinyaga Counties) of Kenya. The rainfall (mm/year) in these regions ranges from 900-1300mm, 1000-2020mm, and 700-1400mm respectively. While the altitude ranges (meters above sea level) from 1800- 2500m, 1000-2000m, and 1800-2500m respectively (Jaetzold *et al*., 2010).

3.2 Sampling Procedure

Medium and large-scale dairy farms were sampled based on the fodder interventions adopted with support from Pro-dairy and Kenya market-led dairy program (KMDP) staff using a purposive sampling technique. A typology of the farms which had access to these interventions was done and the farms classified based on the interventions they adopted. A structured questionnaire was used to obtain farm characteristics. Two groups of farms were identified, i.e. farms producing silage and farms practicing feed rationing. These two groups were further sub-divided as follows:

Two groups on silage: Farms with support from service provider enterprises (SPEs) including farm advice and farms using maize train or silage balers including farm advice. Then one group on feed rationing, i.e. Farms using *Rumen8* software to formulate dairy rations. A control group for each intervention was established comprising of farmers not implementing the above fodder interventions without farm advisory.

Diagrammatic representation of the interventions is shown in figure 1 below.

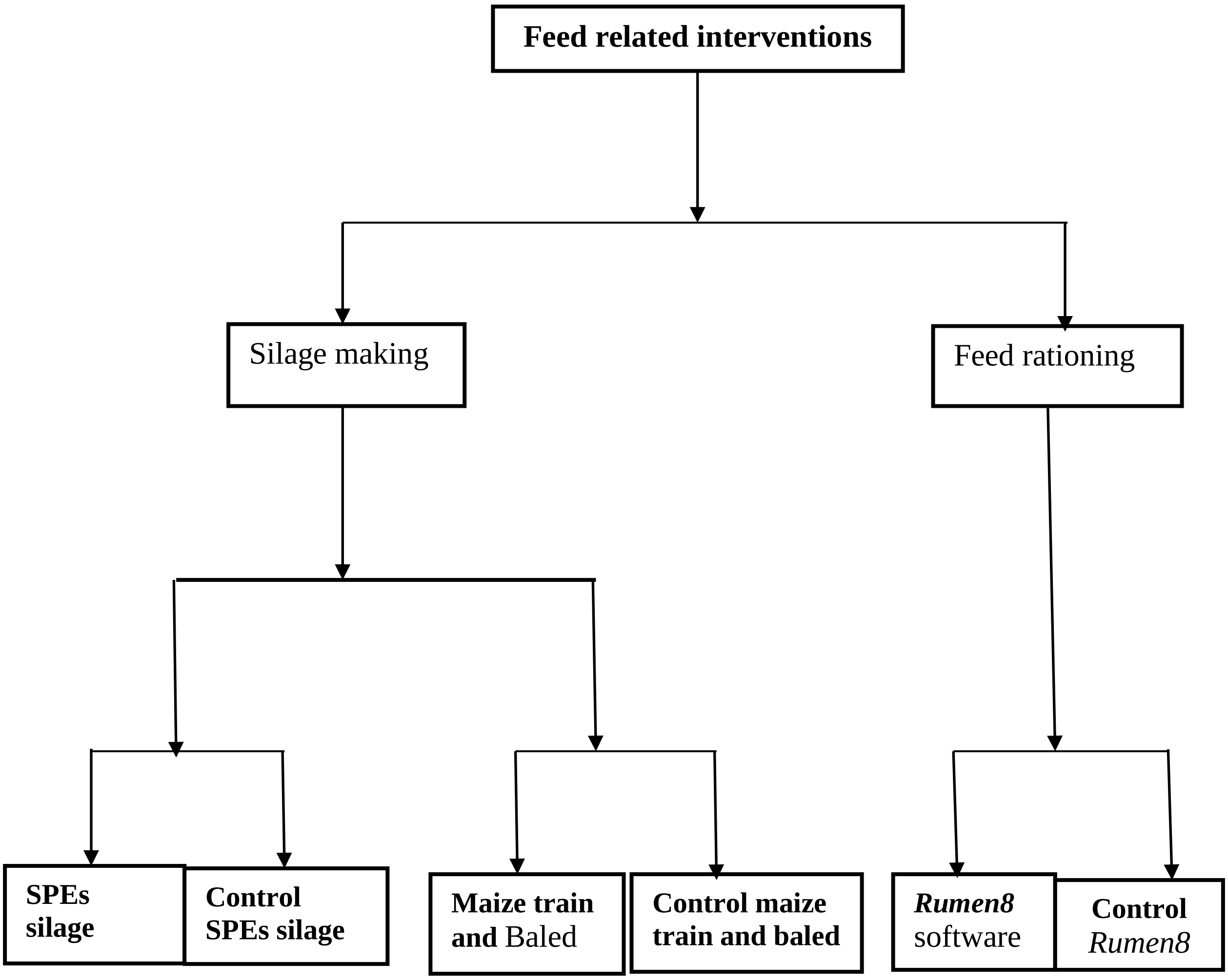

Figure 1. Interventions by Kenya Market-led Dairy Program
SPEs = Service provider enterprises

The diets in the interventions were;

3.2.1 Maize Train and Baled Silage

This silage was prepared in the sampled farms by the aid of the KMDP staff in North Rift region. The process involved land preparation, seed selection (selection of forage maize variety or hybrid suitable for forage production i.e. with low neutral detergent fibre (NDF), cob to stem ratio of 50:50 (dry matter basis) and high in starch, planting (the correct seed rate to get the desired plant population avoid plant competition and ensure maximum yield per acre or hectare), weed and pest control, harvesting (done at the right stage aimed at a DM level of the whole crop of 30-35% and a starch level of at least 30%, chopping and kernel which reduced losses, enables easier compaction, increased voluntary feed intake per cow and avoids selective feeding. Transportation, ensiling and compaction (using the heaviest machine available within 12 hours), covering, and proper feeding-out of silage where quick removal of silage prevented heating up, molding and rotting of silage at the face of the silo.

Forage Innovation Team Limited (FIT Ltd), offered professional forage baling services to dairy farmers whereby fresh maize from the field was chopped and baled directly or ensiled maize that is being scooped from a bunker for baling. Silage bales were wrapped with 6 to 8 layers of stretch foil that made them less vulnerable to damage during handling, transport and storage.

3.2.2 Service Provider Enterprises (SPEs) Silage

This silage was made by groups of youth in Central, Eastern and some parts of North Rift (Baringo) regions who had received practical training, facilitated by the Netherlands development organization (SNV), on silage making. They offered “next door” services in fodder establishment, silage making and some advisory services. Most farmers were harvesting their maize at milky stage which made it easier for the use of chaff cutters which lack kernel crusher. The chopped maize forages were later transported for ensiling in pit silos. Compared to maize train and baled silages, SPEs silage was made using molasses to enhance fermentation process which compensate poor crop production or silage management.

3.2.3 Feed Balancing (*Rumen8*) Software

Farms using a dairy ration calculation software that was introduced and equipped with a Kenyan Feed Library with support from KMDP to formulate rations. A dairy ration formulation software was introduced and equipped with a Kenyan Feed Library with support from KMDP. The software balanced rations using the available feed resources (maize silage, hay, maize germ, wheat bran, wheat pollard, cotton seed meal, sunflower meal, soybean meal) on the farms to formulate a total mixed ration that allowed the dairy cows to increase DM intake and thus increase milk production and productivity.

3.2.4 Control Farms

The diets included maize silage made on-farm without any advisory services, concentrates (maize germ, wheat bran, cotton seed meal, sunflower meal, soybean meal) from local feed millers) that were used to formulate rations without the use of feed balancing (*Rumen8*) software. The farms which were using the control diets were selected based on the regions where the interventions were being applied.

Table 3.1. Description of the Farms used in the Study

Region	Intervention	Number of Cows	Lactating Cows	Land size (acres)	Breed of Cows	Production System	Dairying (Years)	Dominant Market Outlets
North Rift	***Rumen8***	25	18	40.0	Friesian	Zero-grazing	10	Own milk bars/ATM
	***Rumen8* control**	19	15	20.5	Friesian	Zero-grazing	7	Co-operative society, ATMs
	Maize train silage	26	21	37.0	Friesian, Ayrshire	Semi-Zero-grazing	15	Co-operative society, Schools, Hotels
	Baled maize silage	18	14	23.0	Friesian	Zero grazing	5	Co-operative society, Schools, Hotels
Central	***Rumen8***	27	19	10.5	Friesian	Zero-grazing	10	Milk bars/ATM, Hotels
	***Rumen8* control**	19	14	11.0	Friesian	Zero-grazing	8	Milk bars/ATM, Hotels, Hawkers at farm gate
	SPEs silage	17	12	8.0	Friesian	Zero-grazing	6	Schools, Hotels, Hawkers
	SPEs control	18	13	5.5	Friesian	Zero-grazing	7	Hotels, Hawkers at farm gate
Eastern	***Rumen8***	25	17	15.0	Friesian	Zero-grazing	8	Milk bars/ATM, Hotels
	***Rumen8* control**	17	12	8.5	Friesian	Zero-grazing	10	Schools, Hotels, Hawkers
	SPEs silage	15	12	10.0	Friesian	Zero-grazing	7	Hotels, Hawkers, ATM
	SPEs control	20	14	6.5	Friesian	Zero-grazing	10	Hotels, Hawkers, ATM

SPEs = Service provider enterprises; *Rumen8* = Software for dairy ration formulation; ATM = Automated teller machine for dispensing milk.

3.3 Objective One: Determination of Nutritive Value of Feeds and Feed Ration Ingredients from Different Interventions used by Dairy Farms in Kenya

This experiment involved laboratory analysis to determine the nutritive value of feed samples from maize train/baler silage commonly in North Rift region, Service Provider Enterprises (SPEs) silage common in Central and Eastern regions, and feed ingredients used in farms with feed balancing (*Rumen8*) software across the three regions, and lastly feed samples from control farms (farms in the same geographical location not having access to the KMDP fodder advisory services) for each intervention. The experiment involved both proximate analysis and *in-vitro* degradability as described below.

3.3.1 Proximate Analysis

Proximate composition (dry matter (DM), crude protein (CP), Crude fat (CF) and Ash) of the feed samples was analysed in duplicate as per the standard procedures (AOAC, 2012). The cell wall constituents namely; neutral detergent fibre (NDF) and acid detergent fibre (ADF) was determined (Van Soest, 1991).

Dry matter was measured by drying samples of feed ingredients at 90°C for 15 hours. Feed ingredients, total mixed ration (TMR) and faecal samples was weighed and dried at 60°C for 48 hours for DM determination. Dried samples were ground to pass a 1-mm screen and analysed for total N, NDF with the method of Van Soest *et al.* (1991), and for ash by combustion in a muffle furnace at 600°C for 8 hours. Acid insoluble ash in feed and faeces was determined to estimate apparent digestibility of DM.

3.3.2 *In-vitro* Degradability of Feed Ingredients used in Different Interventions

Rumen liquor was collected in the morning (6 am) from fistulated animal before feeding and watering into a pre-warmed thermos-flask and taken to the laboratory. One litre of rumen fluid from the cows was kept in a warm flask after being filtered through two layers of cheese-cloth to obtain strained rumen fluid which was then be flushed with carbon dioxide (CO_2) and combined with buffers to simulate the action of saliva. A weight of 200mg of feed samples (1mm screen) in duplicate was prepared and placed into 100ml glass syringes in duplicate.

The rumen fluid and buffer medium were mixed in the ratio of 1:2 (v/v). Buffer -rumen fluid mixture of 30ml was passed into syringes holding samples, shaken gently and any air bubbles released. Finally, the syringes were incubated in a thermostatically controlled water bath at 39^{o}C for 0-96 hours. Both the samples and blank (rumen fluid +buffer) was run in duplicates. The fermentative activity of the mixed microbial population was determined using the gas production technique described by Menke and Steingass (1988).

The volume of gas produced was determined at 3, 6, 9, 12, 18, 36, 48, 72, and 96 hours by reading the calibration of the piston. Two blank syringes containing only 30 ml of buffered rumen fluid was incubated to estimate gas production due to endogenous substrates for the blank corrections. The gas produced is the total increase in volume minus the mean blank value. The calculated values of gas production were fitted into the model developed by Ørskov and McDonald, (1979) to determine the degradability of the feed ingredients.

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

where;

Y=the volume of gas produced with time (t)

a=initial gas production by the soluble fraction

b=gas produced during incubation by the insoluble but slowly fermenting fraction

c= gas production rate constant (fraction /hour)

't' is time of fermentation.

Then (a+b) represents the potential extent of the gas production.

In-vitro OM digestibility was estimated using methods suggested by Van Soest *et al.* (1991). Metabolizable energy (ME) content was calculated using the equation of Menke *et al.* (1989) as follows;

3.3.3 Calculations and Data Analysis

Organic matter digestibility (OMD%), Metabolizable energy ME (MJ/kg DM) content of feeds and short chain fatty acids (SCFA mmol/200mg DM) was calculated using equations of McDonald *et al.* (1995), Menke and Steingass (1988), and Menke *et al.* (1979) as:

SCFA (mmol/200mg DM) =0.0222 GP-0.00425.

ME (MJ/kg DM) = 1.06 + 0.1570 × Gas produced (ml/200 mg DM) + 0.0084 × CP (g/kg DM) + 0.022 × EE (g/kg DM) – 0.0081 × Ash (g/kg DM), Menke and Steingass (1989).

OMD (%) 48HR =18.53+0.9239*(gas production at 48hrs) +0.0540*CP (Menke and Steingass, 1988).

Data from the two experiments was subjected to the analysis of variance using the General linear model of statistical analysis system (2002). Significant means was separated using LSD at 5% significance.

3.4 Objective two: Evaluating the Effects of Fodder and Ration Formulation Interventions on Dairy Performance in Kenya

This experiment involved a longitudinal study that was carried out in 72 dairy farms over a six months period located in North Rift, Eastern and Central regions of Kenya. The full list of active farms benefitting from the Kenya Market Led Dairy Program (KMDP) interventions was used as the initial sampling frame that was limited to 72 farms using simple random sampling. Dairy performance (milk yield, milk butter fat, milk protein content, total dry matter intake, feed efficiency) as a result of the interventions (maize train/baled silage and silage from service provider enterprises (SPEs) and feed rationing using *Rumen8* software) was determined. The following variables were measured; daily feed intake, average milk yield, butter fat content, milk protein content, and feed conversion efficiency. The variables in the study were determined as the average of the entire six-month period without considering the effect of time, this was due to the fact that the interventions had been adopted and were being used since the last two years.

To determine average daily milk yield (kg/cow) for each fodder/ration formulation intervention, milk data from each farm was recorded daily. Butter fat content in the milk sample from farms practicing different feeding interventions was determined based on Babcock test method whereby 18 grams of milk or 17.6 millilitres was measured into graduated test tubes then 17.6 millilitres of 90-92% sulfuric acid added and centrifuged at 50°C, fat which was floating on top of liquid in the test tubes was measured. Protein content of the sampled milk was determined by Kjeldahl method (AOAC, 2012). Average feed intake (kg) per cow per day was determined by weighing feeds offered in the morning and subtracting feed remaining the following morning before feeding. Feed conversion efficiency was determined by comparing average daily milk yields to the amount of feed intake during the experimental phase.

3.4.1 Data Analysis

A multiple-linear regression model was used to assess the relationship between the independent variables (interventions, region, Farm size, and grazing system) and dependent variables (milk yield, milk protein, milk butter fat, dry matter feed intake, and feed efficiency).

$Y = \beta_0 + \beta_1 X_1 + \beta_2(X_2{}^*X_3) + \beta_3(X_2*X_4) + \beta_4(X_2*X_5) + \beta_5(X_1*X_2*X_3) + \beta_6(X_1{}^*X_2{}^*X_4) + \beta_7 (X_1{}^*X_2{}^*X_5) + \mathcal{E}$

where;

Y = is the predicted value of a dependent variable (milk yield, milk butter fat, milk protein, dry matter feed intake, and feed efficiency).

β_0=the intercept

B_1, β_2, β_3, β_4, β_5, β_6 and β_7 = regression coefficients

X_1, X_2, X_3, X_4 and X_5 = independent variables (Feed intervention, Levels, region, farm size and grazing system)

$\mathcal{E}$= random error term

Data was subjected to the analysis of variance (ANOVA) using the General linear model (GLM) of statistical Analysis system (2002). The Significant means was separated using least significance difference (LSD) at 5% significance.

3.5 Objective Three: Assessing the Income Over Feed Cost of Fodder Conservation and Ration Formulation Interventions in Dairy Farms in Kenya

This experiment aimed at determining the cost-benefits of fodder related interventions (silage by service provider enterprises (SPEs), maize train/ baled silage) and ration formulation using *Rumen8* software used by dairy farmers then comparing with the control (farms which did not adopt the interventions) for each intervention. Purposive sampling technique was carried out to permit an in-depth analysis of the costs and benefits of the selected farms. Data was collected using interviews and questionnaires. A cost benefit analysis was done to assess the economic feasibility of fodder related interventions being used by market-oriented dairy farms in Kenya.

3.5.1 Data Collection

A purposive descriptive survey technique using structured questionnaires was used in data collection, with respondents sampled from farmers' lists provided by SNV. The study combined both primary and secondary data. The data included the quantities and prices of all inputs (feeds) and outputs of milk production. The study involved the use of *Rumen8* Software to calculate: -Feed costs (KES/L, Cow/d), Income from milk sales (KES/L, Cow/d), and Margin (income over feed costs) (KES/L, Cow/d).

IOFC (KES/L/d) = (*P*milk*DAMP) - (DFC (KES/L/d))

where;

IOFC = income over feed cost

KES/L/d = Kenya shillings per litre per day

*P*milk*DAMP = price of milk multiplied by daily average milk production

DFC = daily feed cost

3.5.2 Data Analysis

Analysis of data collected was done using descriptive statistics including mean and standard deviation and then hypothesis testing done using the t-test.

CHAPTER FOUR
RESULTS

3.4 Objective One: Nutritive Value of Feed Ingredients used in Different Interventions

This objective involved proximate analysis, fibre analysis, and *in-vitro* degradability of feed samples. The samples were collected from farms with the interventions and those without the intervention.

4.1.1 Chemical Composition

The results here show dry matter content (DM), crude protein (CP), crude fat (CF), neutral detergent fibre (NDF)C acid detergent fibre (ADF), and Ash (representing the mineral content of the ingredients) of the feed samples from different interventions. The nutrient composition differed significantly among the silage from different interventions but there was less variations among concentrates as shown below (Table 4.1).

Table 4.1. Chemical Composition of Ingredients used in Different Interventions

Feed Ingredients	Group	DM %	CP %	CF %	NDF %	ADF %	Ash %
Maize train silage	1	34.4±0.4^{a}	8.1±0.2^{a}	3.4±0.1^{a}	45.8±0.4^{a}	25.7±0.3^{a}	4.1±0.3^{a}
Baled maize silage		34.9±0.4^{a}	7.9±0.2^{a}	3.4±0.1^{a}	44.6±0.4^{a}	25.7±0.3^{a}	3.9±0.3^{a}
SPEs Silage		32.3±0.4^{b}	7.2±0.2^{a}	3.1±0.1^{a}	46.6±0.4^{b}	28.1±0.3^{b}	5.2±0.3^{b}
Maize germ (*Rumen8)*	2	89.8±0.3^{a}	11.5±0.5^{a}	12.3±0.5^{a}	35.7±0.3^{a}	9.3±0.3^{a}	3.0±0.2^{a}
Maize germ (Control)		89.5±0.3^{a}	11.5±0.5^{a}	12.4±0.5^{a}	35.7±0.3^{a}	9.1±0.3^{a}	3.2±0.2^{a}
Wheat bran (*Rumen8)*	3	87.3±0.5^{a}	16.7±0.6^{a}	3.8±0.2^{a}	34.5±0.7^{a}	13.3±0.3^{a}	5.9±0.2^{a}
Wheat bran (Control)		87.2±0.5^{a}	16.3±0.6^{a}	3.9±0.2^{a}	34.8±0.7^{a}	13.2±0.3^{a}	5.8±0.2^{a}
Cotton seed meal (*Rumen8)*	4	90.7±0.2^{a}	34.9±0.2^{a}	7.1±0.1^{a}	35.9±1.3^{a}	30.7±0.3^{a}	5.4±0.3^{a}
Cotton seed meal (Control)		90.5±0.2^{a}	35.0±0.2^{a}	7.1±0.1^{a}	36.1±1.3^{a}	31.0±0.3^{a}	5.3±0.3^{a}
Sunflower meal (*Rumen8)*	5	92.5±0.6^{a}	34.1±0.4^{a}	9.2±0.2^{a}	37.3±0.4^{a}	35.9±0.8^{a}	6.3±0.2^{a}
Sunflower meal (Control)		90.4±0.6^{a}	33.6±0.4^{a}	9.3±0.2^{a}	37.4±0.4^{a}	35.6±0.8^{a}	6.4±0.2^{a}
Soybean meal (*Rumen8)*	6	90.0±0.3^{a}	42.7±0.1^{a}	3.6±0.1^{a}	13.9±0.2^{a}	9.5±0.2^{a}	7.0±0.3^{a}
Soybean meal (Control)		89.6±0.3^{a}	42.8±0.1^{a}	3.4±0.1^{a}	14.1±0.2^{a}	9.7±0.2^{a}	6.9±0.3^{a}
P		<.0001	<.0001	<.0001	<.0001	<.0001	<.0002

^{ab} Means within the same group with different superscripts differ (P<0.05), DM=dry matter; CP=crude protein; CF=crude fat; ADF=acid detergent fibre; NDF=neutral detergent fibre; SEM-standard error of the mean; SPEs=service provider enterprises.

The dry matter (DM) content in maize silage ranged from 34.9% in baled maize silage to 32.3% in SPEs silage which differed (*P*<0.05). There was no significant different in DM content between maize train and baled maize silage. However, dry matter content of concentrate feeds used in different interventions did not differ significantly. Maize train silage had 45.8% NDF lower than 46.6% in SPEs silage (*P*>0.05). but NDF did not differ significantly between maize train and baled maize silage (Table 4.1). The ash contents were high in SPEs silage (5.2%) and lowest in baled maize silage (3.9%) (*P*<0.05). The DM, CP, CF, NDF, ADF, and Ash within the same feed ingredients from different interventions did not differ (*P*>0.05) as shown in table 4.1 above.

4.1.2 *In-vitro* Degradability of Feed Samples

Dry matter degradability of feed ingredients was determined *in-vitro* where by the higher the degradability the better the feeds in terms of its efficiency in dairy performance. Fermentative characteristics a, b, a+b, c, and RSD are constants in the equation (Ørskov and McDonld, 1989) that explains the degradability potential of the feed ingredients as shown in table 4.2. The constant ‘a’ which represents the potential gas production from readily soluble fractions of organic matter, was recorded high in baled maize silage (13.8) compared to maize train and SPEs silage (12.6 and 10.9) respectively. Among the concentrate ingredients from different interventions, the potential gas production from soluble fractions of organic matter was not different (*P*>0.05) within the groups (Table 4.2).

Table 4.2. In-vitro gas production and characteristic parameters of ingredients used in different interventions

Feed ingredients	Group	Total degradation (%)		Fermentation characteristics				
		24	**48**	**A**	**b**	**a+b**	**c**	**RSD**
Maize train Silage	**1**	42.5±0.04^{a}	33.4±0.03^{a}	10.9±0.03^{a}	9.8±0.01^{a}	20.8±0.03^{a}	0.2±0.03^{a}	16.7±0.04^{a}
Baled maize Silage		56.7±0.04^{b}	40.5±0.03^{b}	13.8±0.03^{b}	15.3±0.01^{b}	29.1±0.03^{b}	0.2±0.03^{a}	21.2±0.04^{b}
SPEs Silage		45.4±0.04^{c}	34.7±0.03^{c}	12.6±0.03^{c}	11.9±0.01^{c}	24.6±0.03^{c}	0.2±0.03^{a}	17.5±0.04^{c}
Maize germ (*R8*)	**2**	12.1±0.04^{a}	9.1±0.01^{a}	8.0±0.02^{a}	13.8±0.02^{a}	15.7±0.05^{a}	12.0±0.2^{a}	3.9±0.01^{a}
Maize germ (Ctrl)		12.6±0.04^{b}	11.6±0.01^{b}	4.4±0.02^{b}	2.5±0.02^{b}	6.9±0.05^{b}	0.1±0.2^{b}	4.8±0.01^{b}
Wheat bran (*R8*)	**3**	14.2±0.05^{a}	13.1±0.02^{a}	6.0±0.01^{a}	5.2±0.14^{a}	11.2±0.05^{a}	32.2±0.13^{a}	7.4±0.20^{a}
Wheat bran (Ctrl)		15.3±0.05^{b}	13.2±0.02^{a}	7.1±0.01^{b}	4.3±0.14^{b}	11.4±0.05^{b}	22.3±0.13^{b}	7.5±0.20^{b}
Cotton meal (*R8*)	**4**	12.1±0.21^{a}	10.1±0.03^{a}	8.7±0.03^{a}	3.0±0.03^{a}	8.8±0.01^{a}	22.1±0.02^{a}	4.2±0.01^{a}
Cotton meal (Ctrl)		12.5±0.21^{a}	10.4±0.03^{b}	5.7±0.03^{b}	2.7±0.03^{b}	8.5±0.01^{b}	7.1±0.02^{b}	4.2±0.01^{a}
Sunflower (*R8*)	**5**	7.9±0.15^{a}	5.9±0.02^{a}	4.4±0.02^{a}	1.3±0.02^{a}	5.7±0.01^{a}	7.5±0.03^{a}	4.7±0.20^{a}
Sunflower (Ctrl)		7.1±0.15^{b}	6.1±0.02^{b}	4.6±0.02^{b}	1.4±0.02^{a}	5.9±0.01^{b}	7.2±0.03^{b}	4.7±0.20^{a}
Soybean meal (*R8*)	**6**	13.9±0.17^{a}	7.4±0.03^{a}	5.8±0.03^{a}	2.4±0.02^{a}	8.2±0.01^{a}	12.6±2.36^{a}	7.8±0.01^{a}
Soybean meal (Ctrl)		14.4±0.17^{b}	7.7±0.03^{b}	4.9±0.03^{b}	4.4±0.02^{b}	9.3±0.01^{b}	12.5±2.36^{a}	9.1±0.01^{b}

SPEs = Service provider enterprises; R8 = *Rumen8*; Ctrl = control; a, b, c are constants in the equation (Ørskov and McDonld, 1989); c = gas production rate; a = gas production (ml) from readily soluble fraction; b = gas production (ml) from insoluble fraction; (a+b) = potential gas production; ^{ab} Means in the same group with different superscripts differ (P<0.05).

The results presented in table 4.2 above show higher degradability in baled maize silage (40.5%) and lower (33.4%) in SPE silage ($P<0.05$) at 48 hours. The potential gas production rate (a+b) was also high (29.1) in baled silage but low (20.8) in maize train silage. The degradability rate of concentrate ingredients within same group from different interventions showed some variations at different hours as shown in table 4.2.

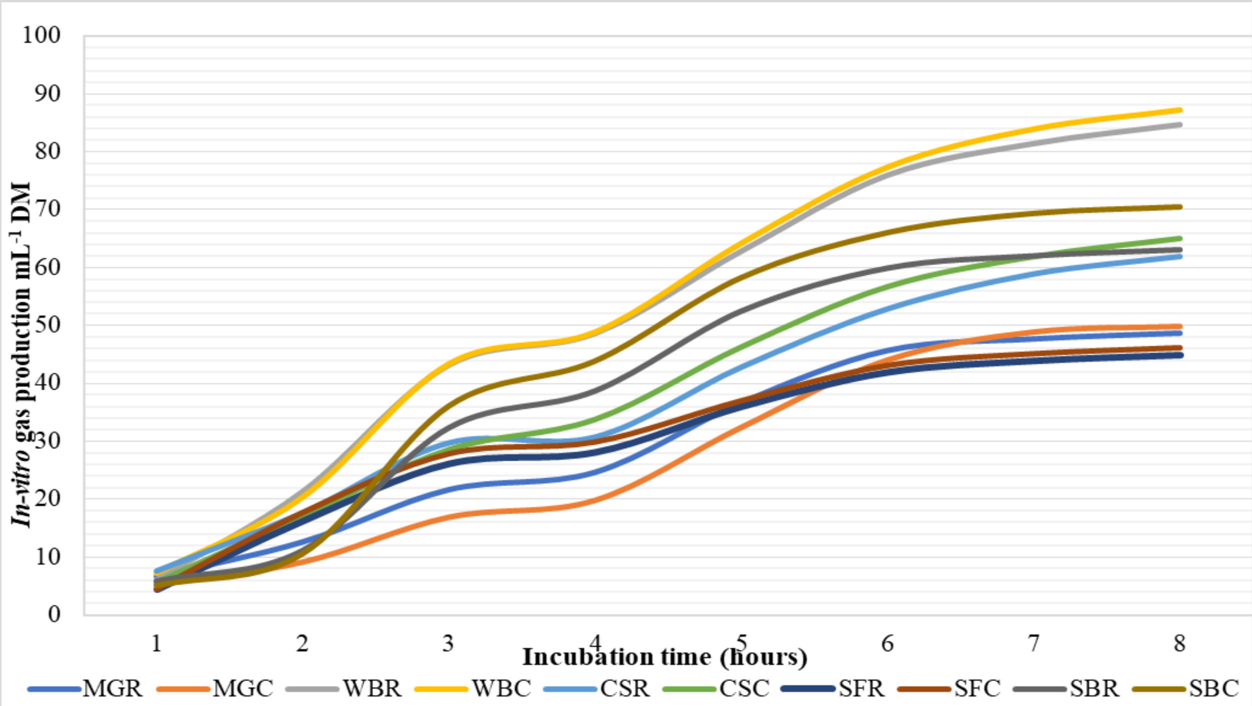

Figure 2. *In-vitro* dry matter degradability of feed ingredients from different interventions

WBR=wheat bran (*Rumen8 farms*); WBC=wheat bran (control farms); CSR=cotton seed meal (*Rumen8* farms); CSC= cotton seed meal (control farms); SFR=sunflower meal (*Rumen8* farms); SFC=sunflower meal (control farms); SBR=soybean meal (*Rumen8* farms); SBC=soybean meal (control farms).

Similarly, gas production (mL^{-1} DM) of concentrate ingredients within same group but from different interventions showed some variations as shown in in figure 2.

Among the silage ingredients from fodder interventions, baled silage had high gas production (>180mL^{-1} DM) at 48 hours compared to SPE silage (160mL^{-1} DM) and maize train (140Ml^{-1} DM) as shown in figure 3.

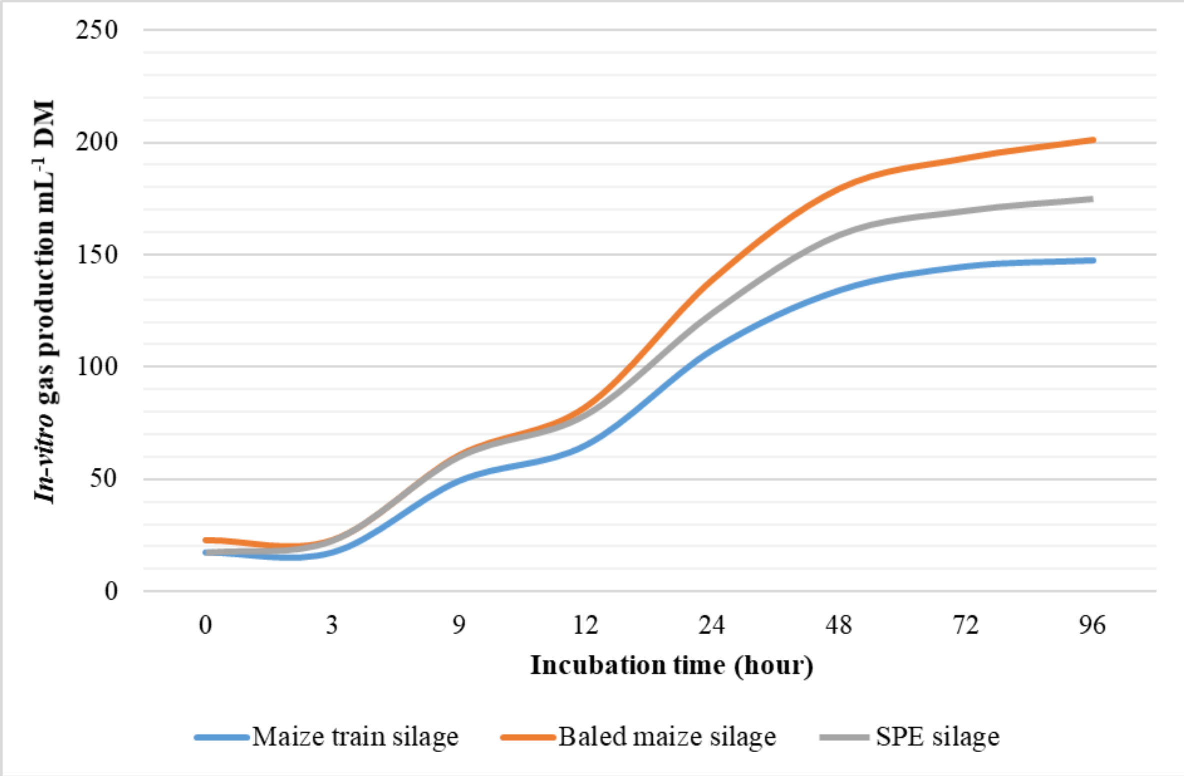

Figure 3. ***In-vitro*** **dry matter degradability of silage from different interventions**
SPE=service provider enterprises

4.1.3 Metabolizable Energy, Short Chain Fatty Acid, and Organic Matter Digestibility by *In-vitro* Gas Production

The levels of short chain fatty acids (SCFA) among silage in fodder interventions was higher in baled maize silage (1.3mmol/200mg DM) and lowest in maize train and SPE silage (0.9 and 1.0mmol/200mg DM), respectively (Table 4.3). The SCFA did not differ ($P>0.05$) among the concentrate ingredients within the same group from different interventions (Table 4.3). Organic matter digestibility (OMD%) among the silage in fodder conservation interventions was highest in baled maize silage (56.4%) and lowest in SPE silage (43.5%) ($P<0.05$). While among the concentrates, organic matter digestibility did not differ significantly within ingredients in the same group from different interventions (Table 4.3). Metabolizable energy (ME MJ/kg DM) differed significantly among silage samples from different fodder conservation interventions. Baled maize silage had the highest metabolizable energy (11.9MJ/Kg DM) compared to maize train and SPE silage (10.7 and 9.2MJ/Kg DM), respectively. Similarly, metabolizable energy among concentrate ingredients within the same group from different interventions did not vary significantly (Table 4.3).

Table 4.3. Evaluated Short chain fatty acids, metabolizable energy, and organic matter digestibility of feed ingredients by in-vitro degradability

Feed Ingredients	Group	SCFA (mmol/200mg DM)	ME MJ/Kg DM	OMD% 48HR
Maize train silage	1	0.9±0.10^{a}	10.7±0.59^{ab}	50.9±0.65^{b}
Baled maize silage		1.3±0.10^{a}	11.9±0.59^{a}	56.4±0.65^{a}
SPEs Silage		1.0±0.10^{a}	9.2±0.59^{b}	43.5±0.65^{c}
Maize germ (*Rumen8*)	2	0.6±0.08^{a}	14.7±0.36^{a}	27.5±0.21^{b}
Maize germ (Control)		0.3±0.08^{b}	13.4±0.36^{b}	30.0±0.21^{a}
Wheat bran (*Rumen8*)	3	0.3±0.06^{a}	12.3±0.39^{a}	31.5±0.69^{a}
Wheat bran (Control)		0.3±0.06^{a}	11.7±0.39^{a}	31.6±0.69^{a}
Cotton meal (*Rumen8*)	4	0.3±0.07^{a}	10.1±0.38^{a}	29.7±0.58^{a}
Cotton meal (Control)		0.2±0.07^{a}	11.1±0.38^{a}	30.0±0.58^{a}
Sunflower meal (*Rumen8*)	5	0.2±0.05^{a}	10.0±0.05^{a}	25.8±0.42^{a}
Sunflower meal (Control)		0.1±0.05^{a}	8.7±0.05^{b}	26.0±0.42^{a}
Soybean meal (*Rumen8*)	6	0.3±0.05^{a}	13.1±0.46^{a}	28.0±0.61^{a}
Soybean meal (Control)		0.3±0.05^{a}	12.3±0.46^{a}	28.4±0.61^{a}
P value		<.0001	<.0001	<.0001

SPEs = Service provider enterprises; OMD = Organic matter digestibility; ME= Metabolizable energy; SCFA = Short chain fatty acids; ^{ab} Means in the same group with different superscripts differ (P<0.05).

4.1.4. Nutrient Composition of the Diets from Different Interventions

Using the *Rumen8* software, the dietary compositions of different rations used in in different interventions was calculated. The results are shown in table 4.4 below. The crude protein (CP) varied across the interventions with Rumen8 rations having the highest (16.1%) while rations used in SPEs had the lowest CP (9.1%). Similarly, dry matter, metabolizable energy and neutral detergent fibre varied among the diets.

Table 4.4. Nutritional composition of diets used in different interventions

Diet/Intervention	DM (%)	CP (%DM)	ME (MJ/Kg DM)	CF (%DM)	NDF (%DM)	Ash (%DM)
1. Maize train silage	59.3	14.3	10.7	3.4	42.5	5.7
2. Baled maize silage	69.7	14.4	10.1	3.6	41.5	5.9
3. *Rumen8* ration	71.6	16.1	11.4	3.2	39.7	6.3
4. Control *Rumen8*	62.8	15.3	10.5	3.2	42.3	7.2
5. SPEs silage	56.7	10.7	10.1	3.7	45.5	6.4
6. Control SPEs silage	57.4	9.1	8.6	3.8	46.7	6.7

SPEs = Service provider enterprises; DM = Dry matter; CP = Crude protein; ME = Metabolizable energy; CF = Crude fat; NDF = Neutral detergent fibre.

4.2 Objective Two: Effects of Interventions on Dairy Performance in Kenya

This objective determined average milk yield per farm and per cow, milk butter fat content, milk protein content, and feed efficiency as a result of different interventions among the dairy farms in Kenya.

4.2.1 Milk Yield

Daily milk yield (kg/cow) differed across the interventions in different regions (*P*=0.003, R^2=0.80). Farms using feed balancing (*Rumen8*) software recorded high daily milk yield of 24.3kg/cow in North Rift region compared 22.1 and 19.2kg/cow in Eastern and Central regions respectively (*P*<0.05). The results also showed that control farms under feed balancing intervention performed better than the farms with the intervention in Central region (20.2kg versus 19.2kg/cow) but the difference did not differ (*P*>0.05) (Table 4.5).

Daily milk yield from farms using service provider enterprises (SPEs) silage and their control farms did not differ (*P*>0.05) both in Central and Eastern region. However, SPEs farms in Eastern region performed better (14.3kg/cow) compared to SPEs farms in Central regions (13.3kg/cow) (Table 4.5). Farms using maize train silage in North Rift region had high daily milk yield of 17.2kg/cow compared to farms using SPEs silage intervention (13.3 and 14.3kg/cow) in Central and Eastern regions respectively (*P*<0.05). Farms using SPEs silage intervention had high daily milk yield (13.3 and 14.3kg/cow) compared to their counterpart control farms not using the intervention (10.9 and 12.5kg/cow) in Central and Eastern regions respectively ($P<0.05$). The interactions among the independent variables (interventions, regions, farm size, and grazing systems) did not have an effect on daily milk yield (kg/cow) (Appendix 2).

Table 4.5. Dairy Performance under Different Interventions in Different Regions

Regions	Intervention	Milk yield/cow (kg)	Feed intake/cow (kg DM)	MBF (%)	MP (%)	FE
Central	*Rumen8* rations	19.2 ± 0.4[c]	19.3 ± 0.4[b]	3.7 ± 0.1[a]	2.7 ± 0.1[a]	0.9 ± 0.1[a]
	Rumen8 Control	20.2 ± 4.7[c]	17.9 ± 4.8[c]	3.7 ± 0.1[a]	2.8 ± 0.1[a]	1.1 ± 0.1[a]
	SPEs silage	13.3 ± 0.2[e]	12.3 ± 0.6[e]	3.8 ± 0.1[a]	2.6 ± 0.1[b]	1.0 ± 0.1[a]
	SPEs Control	10.9 ± 3.3[f]	12.5 ± 0.7[e]	3.8± 0.1[a]	2.6 ± 0.1[b]	0.8 ± 0.1[a]
Eastern	*Rumen8* rations	22.1 ± 2.3[b]	17.6 ± 2.9[b]	3.7 ± 0.1[a]	2.7 ± 0.1[a]	1.0 ± 0.1[a]
	Rumen8 Control	21.2 ± 2.3[c]	21.9 ± 2.8[a]	3.7 ± 0.1[a]	2.7 ± 0.1[a]	1.0 ± 0.1[a]
	SPEs silage	14.3 ± 0.4[e]	12.3 ± 0.5[e]	3.8 ± 0.1[a]	2.6 ± 0.1[b]	0.9 ± 0.1[a]
	SPEs Control	12.5 ±0.2[ef]	14.6 ±0.1[de]	3.7 ± 0.1[a]	2.5 ± 0.1[b]	1.1 ± 0.1[a]
North Rift	*Rumen8* rations	24.3 ± 4.1[a]	19.0 ± 1.9[b]	3.6 ± 0.1[a]	2.7 ± 0.1[a]	1.1 ± 0.1[a]
	Rumen8 Control	16.0 ± 2.5[d]	15.9 ± 1.0[d]	3.8 ± 0.1[a]	2.8 ± 0.1[a]	0.9 ± 0.2[a]
	Maize train	17.2 ± 2.8[d]	15.4 ± 2.8[d]	3.7 ± 0.1[a]	2.7 ± 0.1[a]	1.0 ± 0.1[a]
	Maize train	14.6 ± 1.0[e]	13.4 ± 1.0[e]	3.7 ± 0.1[a]	2.6 ± 0.1[b]	1.0 ± 0.2[a]
	P value	*0.003*	*0.004*	*0.047*	*0.003*	*0.898*
	R^2	0.80	0.81	0.66	0.80	0.23

[abcdef] Means within columns with different superscripts differ at $P<0.05$, MBF= Milk butter fat, MP= Milk protein, SPEs= Service provider enterprises, Maize train and SPEs silage.

4.2.2 Milk Quality

There was significant difference in milk butter fat among the interventions across the regions (Table 4.5). However, farms using silage aided by service provider enterprises (SPEs), had the highest MBF (3.8%) compared to farms using feed balancing (*Rume8*) software (3.6%). Milk protein contents did not differ across the interventions in different regions (P>0.05). Although farms using feed balancing software showed a high milk protein content (2.8%) compared to farms using SPEs silage (2.5%) (Table 4.5).

4.2.3 Daily Feed Intake (Kg DM/cow)

There was variation in daily feed intake kg/cow (P=0.004, R^2=0.81) in different interventions across the three regions, (Table 4.5). High feed intake was recorded high in farms using feed balancing (*Rumen8*) software 19.6 kg/cow in Eastern region compared to 19.3 kg/cow in Central region, 19.0 kg/cow in North Rift regions, and lowest 12.3 and 13.4 kg/cow in farms using SPEs silage and control farms under maize train silage, respectively, (P>0.05) (Table 4.5). Daily feed intake kg/cow differed significantly among farms using maize train silage and their controls in North Rift regions. Similarly, farms using feed balancing software had high daily feed intake (kg/cow) compared to their controls across the regions except Eastern region. Effects of interactions among the independent variables (interventions. grazing system, region and farm sizes) did not influence daily feed intake per cow kg DM (P>0.05) (Appendix 2).

4.2.4 Feed Efficiency

The efficiency of the dairy cows to turn feed nutrients into milk i.e. kg of milk produced per kg of dry matter consumed was observed highest (1.1) in farms using the feed balancing (*Rumen8*) software, maize train silage and SPEs silage (P>0.05) and lowest (0.8) in SPEs control farms in Central region (Table 4.5). There was no difference in feed efficiency across the three regions, farm sizes and grazing systems (P>0.05).

4.2 Objective Three: Income Over Feed Cost of the Interventions in Dairy Farms in Kenya

The results presented here shows the cost of feeds, income from milk sales, and the income above feed cost. This was calculated using the *Rumen8* software. The software factors in variable cost of feeds as used under different interventions. The software also uses the income from milk sales per litre and per cow to calculate the margins i.e. income over feed cost (KES/litre/day) (Table 4.6).

Table 4.6. Income Over Feed Cost of the Interventions in Dairy Farms in Kenya

Regions	Interventions	Feed cost (KES/Litre)	Milk income (KES/Litre)	IOFC (KES/Litre)
North rift	*Rumen8* rationing	24.64±0.91[a]	49.23±1.13[a]	24.59±1.12[a]
	Rumen8 control	27.12±0.91[a]	46.14±1.13[a]	19.02±1.12[a]
	Maize train	24.87±0.91[a]	43.10±1.13[b]	18.23±1.12[b]
	Maize train control	21.69±0.91[b]	39.00±1.13[c]	17.19±1.12[b]
	P value	*0.0194*	*0.0012*	*0.0065*
	R^2	*0.69*	*0.85*	*0.77*
Eastern	*Rumen8*	28.85±0.71[a]	47.23±0.53[a]	18.38±0.41[b]
	Rumen8 control	19.47±0.71[b]	41.50±0.53[b]	22.03±0.41[a]
	SPE	18.46±0.71[b]	40.80±0.53[b]	22.34±0.41[a]
	SPE control	14.35±0.71[c]	35.00±0.53[c]	20.65±0.41[a]
	P value	*0.0001*	*0.0001*	*0.0005*
	R^2	*0.97*	*0.97*	*0.88*
Central	*Rumen8*	23.77±1.71[a]	49.37±2.13[a]	25.40±2.00[a]
	Rumen8 control	23.26±1.71[b]	45.12±2.13[ab]	21.86±2.00[a]
	SPE	23.11±1.71[ab]	39.58±2.13[b]	16.47±2.00[a]
	SPE control	16.84±1.71[b]	35.54±02.13[c]	18.72±2.00[a]
	P value	*0.0623*	*0.0082*	*0.0596*
	R^2	*0.58*	*0.75*	*0.58*

SPEs=service provider enterprises, IOFC=Income over feed cost

This study determined the margins obtained from milk sales when feed costs are considered excluding other production costs which account for less than 40%. The results from the study showed that income over feed cost ranged from KES 25.40 per liter in farms with feed balancing (*Rumen8*) software to KES 16.47 per liter in farms with SPEs services (Table 4.6). The study also showed that farms using the interventions experienced high cost of milk production as compared to their control farms but income from high milk produced was high hence able to get reasonable margins (Table 4.6)

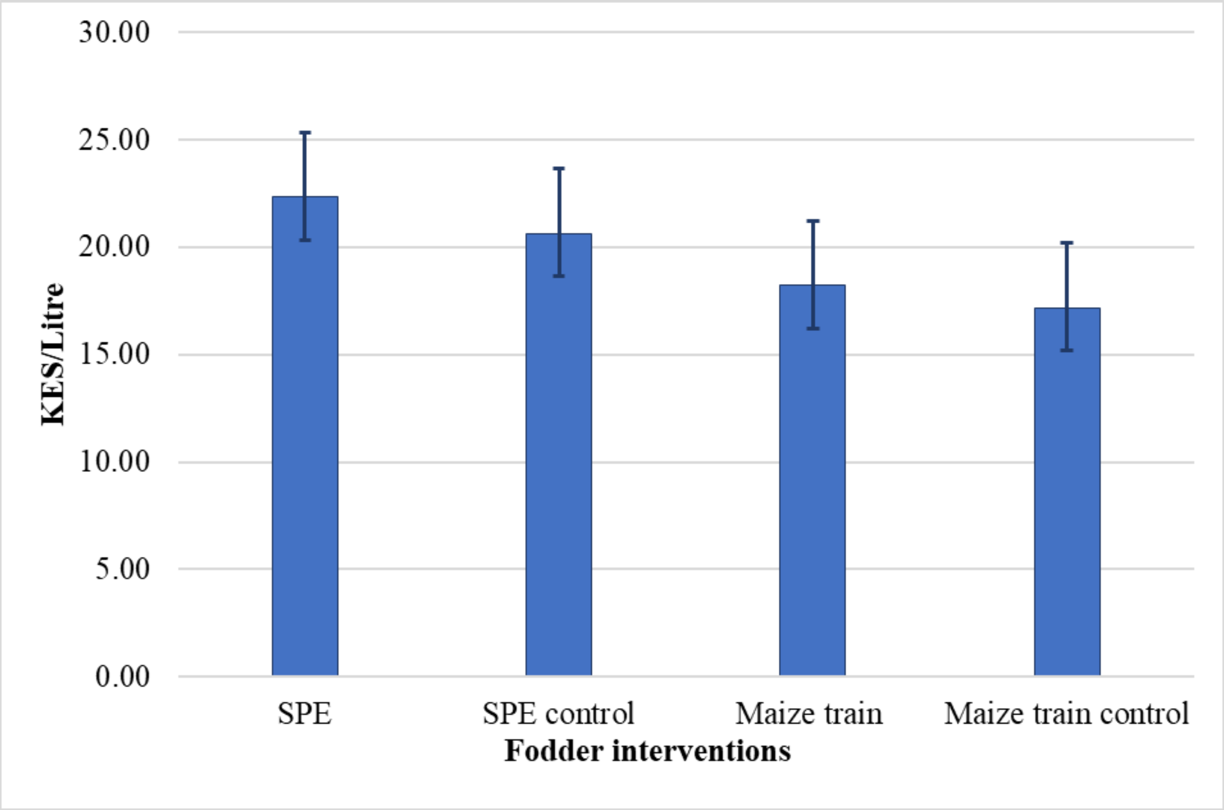

Figure 4. Comparison of Income Over Feed Cost among Fodder Conservation Interventions

SPE=service provider enterprises

Farms using service provider enterprises (SPE) silage interventions recorded high income over feed cost compared to those farms using maize train and baled silage interventions (Figure 5). Income over feed cost and feed cost per litre differed (P<0.05) among the fodder conservation interventions (Table 4.6).

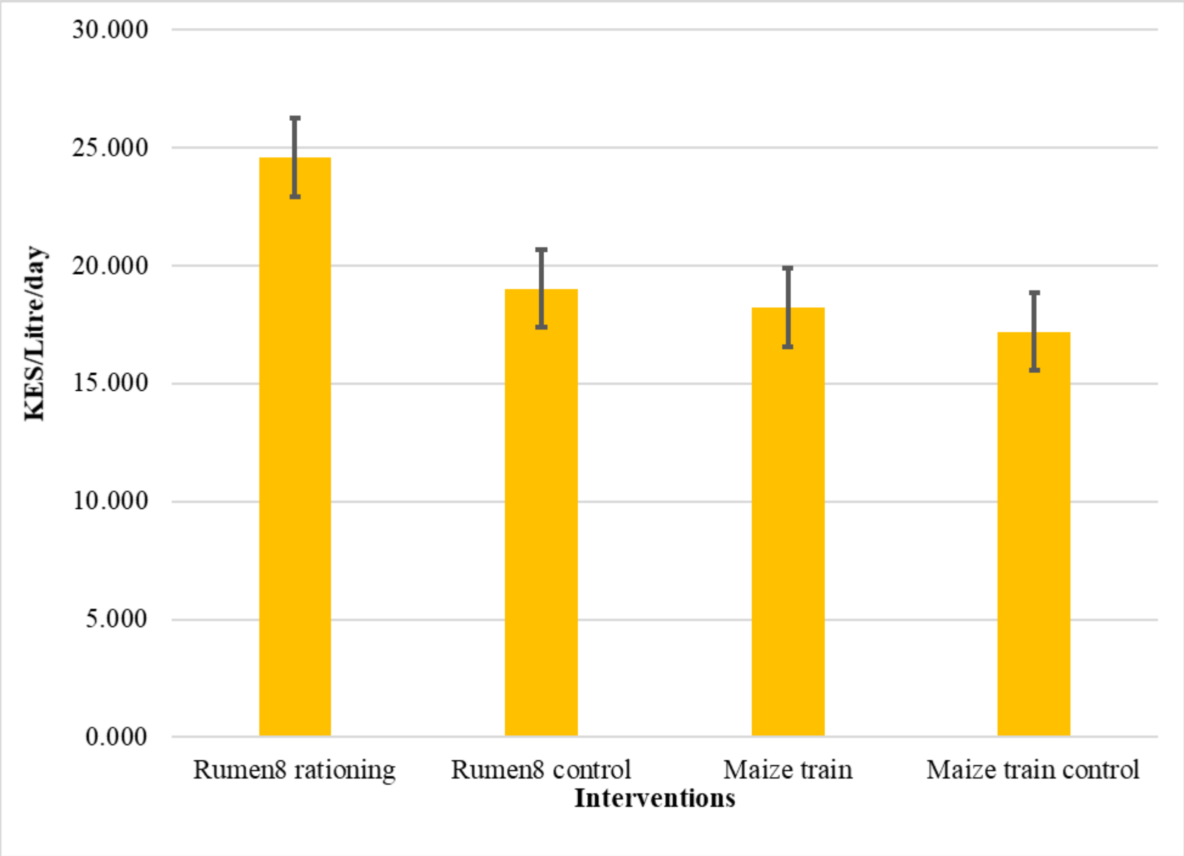

Figure 5. Comparison of income over feed cost among fodder conservation and feed rationing interventions
SPE=service provider enterprises

Income over feed cost (IOFC) differed significantly among the feed rationing and fodder conservation interventions (Figure 6). Farms using *Rumen8* software recorded high IOFC (KES. 24.59) compared to those using maize train (KES. 18.23) (Table 4.6).

The results from the study showed a high milk income from farms with feed balancing in Central region (KES 49.37) while the lowest income was observed in farms with SPEs silage from Eastern region (KES. 35.00) (Table 4.6). Farms with maize train silage had an average milk income of KES 43.10 which was higher compared to income from SPEs farms in Central (KES. 39.58) and Eastern regions (KES. 40.80).

CHAPTER FIVE
DISCUSSIONS

5.1 Chemical Composition of Feed Ingredients

The results for NDF in maize train and baled silage ranging between 44.6 - 45.8% were slightly higher than those reported by Leeuwarden (2019) (37.0 – 42.0%). The high NDF observed in service provider enterprises (SPEs) silage compared to maize train and baled silages was attributed to the stage and quality of maize forage harvested for ensiling. Right harvesting stage, crushing of maize kernels, and proper compaction guarantees good quality silage. The lowest detergent insoluble cell walls (NDF and ADF) obtained was attributed to good characteristic of the feed, (Lamba *et al.,* 2014). High neutral detergent fibre (NDF) and acid detergent fibre (ADF) resulted to longer eating time, low feed intake, low digestibility as well as animal's poor performance as reported by McDonald *et al.* (2002). Higher NDF-ADF results to a lower ME/kg DM as observed in silage from SPEs farms. Due to limited land and feed availability in both Central and Eastern regions, dairy farmers were relying on poor quality maize for silage making. Chemical composition did not vary (P<0.05) in the concentrates across the interventions because farmers sourced the feed ingredients from common places.

5.2 *In-vitro* Digestibility of Feed Ingredients

Differences in gas production among the feed ingredients could be due to the amount of substrate fermented *in vitro*. The *in-vitro* gas production and fermentation parameters indicate the presence of potential degradable nutrient in the feed ingredients. The high extent of gas production of maize train silage maybe attributed to high organic matter (OM) availability which was fermented to form volatile fatty acids and, therefore, high gas volumes produced (Getachew *et al*., 2000).

The highest rate of gas production observed in maize train silage was probably due to presence of fermentable carbohydrate availability, on the other hand, it is a reflection of microbial growth and accessibility of feed to microbial enzymes (Getachew *et al*., 2004; Fievez *et al*., 2005). Akinfemi *et al.* (2009) suggested that gas production from protein fermentation is relatively small as compared to carbohydrate fermentation while the contribution of fat to gas production is negligible. The variations observed between the feeds in the lag time may be explained by the neutral detergent fibre and lignin content of the diet consumed by grazing cattle, which delay the onset of degradation of nutrients in the rumen (Fievez *et al.,* 2005).

5.3 Metabolizable Energy and Short Chain Fatty Acids by *In-vitro* Digestibility

The level of SCFA (Acetate, Propionate, and Butyrate) is an indicator of the energy value of diets. Although they are waste products, fermentative gases (mainly CO_2 and CH_4) represent parts of the feeds which have been degraded. Conceptually, the use of *in-vitro* gas tests is then only justified by a close linkage between the waste products and useful fermentation products, i.e. short chain fatty acids (SCFA) and/or microbial biomass (Blümmel *et al.*, 1997).

It is likely that additional N and amino acid and peptide supply in the protein feed sources increases overall substrate incorporation into microbial cells, with less substrate being converted to SCFA (Acetate, propionate, and butyrate) and gases. In this case the depressing effect of protein on gas production would be caused by a change in the partitioning of fermented substrate between microbial cells and SCFA and gases and not by a distortion of the stoichiometrical relationship between SCFA and gas production. Similar findings were reported by Blümmel *et al.* (1997). This explains the high mmol/kg^{-1} DM of SCFA produced by silage from the interventions, while among the protein concentrates, the amount of SCFA was as low as 0.1mmol/kg^{-1} DM.

The ME values of the feeds were within the ranges reported by Menke and Steingass (1988), where the ME values of various European feeds ranged from 4.5 to 15MJkg^{-1} DM. although the extent of the negative effect of NDF on gas production and digestibility was much higher in maize train silage versus wheat bran. This demonstrates that the effect of NDF on fermentation becomes less important as the level of NDF declines. In addition to carbohydrate fermentation, protein degradation also leads to a proportionally smaller amount of SCFA as observed among the protein concentrates. Although gas production reflects the amount of substrate used for VFA production, it has also been shown that gas production is positively related to feed intake (Blümmel and Ørskov, 1993) and microbial protein synthesis (Krishnamoorthy *et al*., 1991).

5.4 Daily milk Yield per Cow

The variations in milk yield within the intervention levels in different regions may be explained by variations in feed quality, quantity, and the type of intervention being used.

When all the animal factors (breed, stage of lactation) were kept constant, the animals on rations formulated using feed balancing software (*Rumen8*) had better performance compared to the other interventions and the control. The *Rumen8* software enabled dairy ration formulation by considering the animal's nutrient requirements for production i.e. crude protein and energy requirements. An increase in energy and CP intake leads to an increase in milk yield (Johnson *et al.,* 2016).

Farms which were not using any of the interventions (control farms) had lower milk yield which was attributed to the feeding rations that were low in metabolizable energy and crude proteins, which did not meet the dairy cow's nutrient requirement for milk production. The rations were of diverse feed resources, predominantly Napier grass, pastures, and crop residues which are low in metabolizable energy and crude proteins. Kashongwe *et al*. (2017) reported that Napier grass and other pastures are low in dry matter content (20-35%), crude protein (8-10%) and high crude fibre of over 37% which makes them insufficient to support high milk production.

The lowest production observed in SPE farms was due to a predominance of Napier grass and green maize stover used as forage. The farms were often fed concentrates, either dairy meal or other industrial by-products (maize germ, wheat bran, wheat pollard) most often in low amounts (<2kg/day DM). The feeding in these farms was not adjusted based on how much milk the cows were producing. This resulted to low milk yields as observed in North Rift region, same observations were reported by Richard *et al.* (2016). The low rates of energy and protein supplied resulted to under-nutrition in the early part of the lactating cycle and affected milk production throughout the lactation, a similar observation was reported by Lukuyu *et al.* (2011).

Farmers using maize train silage had better daily milk yield/cow compared to SPE silage farms. This can be attributed to the quality of silage in terms of metabolizable energy, dry matter and crude proteins content. Most of the SPEs farmers in Central and Eastern regions lack sufficient land for forage production, majority own between 0.5 to 5 acres out of which 80% is committed to food crop production (Lanyasunya *et al.,* 2006). This contributed to high milk yield in North Rift region under the interventions and low yield in Central and Eastern regions. Similar findings were reported by Kilelu *et al.* (2018). Farms under maize train silage in North Rift performed better than their controls which was attributed to feeding systems with low input grazing strategy adopted compared to high input feeding strategies supplemented with purchased concentrate feeds, same observations were reported by Lukuyu *et al*. (2011).

Farmers in Central and Eastern regions invested more in commercial concentrates to supplement their dairy cows with the required metabolizable energy and protein for milk production, However, the quantity of concentrates given was low (<2kg/cow/day) which was not commensurate with amount of milk produced due to unavailability of quality feeds throughout the year. Lukuyu *et al.* (2011), Omore *et al*. (1996) and Staal *et al.* (1998) attributed low milk yield to poor nutrition and lack of supplementation with high proteins. The results from farms using SPEs silage concurs with reports by Kilelu *et al*. (2018) who noted that farms using SPEs intervention performed better than the controls in both Eastern and Central regions. However, comparing with farms using maize train silage in North Rift region, SPEs had low performances. Which is attributed to in adequate and low-quality feed resources.

The low milk yield of 10.5 kg/cow/day observed in the control farms were comparable to the results by Muia *et al.* (2011) who reported milk production of 8.4 kg/cow/day in the Central regions while Mungube *et al.* (2014) reported a daily milk yield of 6 kg/cow in the semi-arid region of Eastern Kenya. This shows that dairy interventions had a significant improvement on dairy cows' performance. Feeding higher amounts of concentrate in early lactation has been shown to increase milk yield by 20% (Romney *et al.*, 2000). This finding was observed in farms using the feed balancing (*Rumen8)* software where large amounts of concentrates was being used to supply enough nutrients for milk synthesis. However, there were reported cases of ruminal acidosis and diarrhea among the farms under *Rumen8* software due to high concentrate to roughage ratio above the recommended 60 to 40%.

Average milk production was highest in the high potential maize zone (24.3 kg/cow) in North rift, followed by Central highlands (23.5 kg/cow), while Eastern region had the lowest milk production at 20.3kg/cow. The relatively higher production level as compared to other regions can also be attributed to the choice and intensity of the grazing system as well as the favourable climate for rearing dairy animals. Both Central highlands and the high potential maize zone have an annual rainfall of about 750mm. High feed intake was attributed to better feed formulation in *Rumen8* software feed formulation assisted farms as compared to the other interventions. Maize train silage intervention farms had better feed intake compared to farms using silage from SPEs which was attributed to the quality of silage. However, there was no difference ($P<0.05$) in feed intake within the *Rumen8* feed formulation assisted farms across the regions.

Several factors in feed management can affect feed efficiency, like acidosis (e.g. due to short particle size of forage), high levels of feed intake, or a lack of ruminal degradable protein (RDP) that may lead to a poorer digestibility. As in ruminants the digestion of fibre is of great importance, it goes without saying that high quality forage will raise the availability of energy from the ration. Protein efficiency of a diet is very closely linked to feed efficiency. Low milk butter fat recorded in farms with feed balancing (*Rumen8*) software was attributed to the type of rations used which was high in concentrate to forage ratio compared. Farms using SPEs silage intervention had high milk butter fat content attributed to the high forages used compared to concentrates. Roughages are associated with higher acetate production, hence higher milk butter fat contents (Kashongwe *et al.*, 2014).

5.5 Income Over Feed Cost of the Interventions

Feed cost in control farms was cheaper and the cows received less feed compared to the cows of the farms with interventions, leading to a huge difference in feed cost between the two groups. The high share of feed cost was in agreement with the study done by Hemme *et al.* (2014), who found that feed cost was more than 50% of the total cost. On the other hand, feed cost is also directly linked to the price of concentrates, especially Soybean meal and Maize by-products. This explains the high feed costs observed in farms with feed balancing (*Rumen8*) software and silage interventions, as compared to their controls. The recent increase of the grain price, as a general tendency of other food commodities, as well as a greater use of grain for biofuel or ethanol and biogas production, is a matter of concern for dairy farmers. Increasing feed efficiency is one of the promising ways to reduce cost and increase profitability. The level of feed cost is also influenced by the level of milk production, feeding systems, land availability and prices (Hutjens, 2005, Hemme *et al.*, 2014).

This study provided key insights on specific input and factor costs. The feed costs had the greatest impact on the total cost. The main reason for this was that they are located in regions with unreliable rainfall patterns therefore it is not possible to produce and conserve any feeds. Feed was mainly imported from Uganda and Tanzania thus increasing their feed cost. A study conducted to evaluate profitability of dairy enterprise in Kenya by Staal *et al.* (2005)

estimated cost of production per litre in Kiambu, Nyandarua and Nakuru at KES17.20, KES 11.90 and KES 13.30 per litre respectively.

Farmers interviewed mentioned increased milk production as a primary benefit of silage-making services. Considering the average daily milk productivity of 5 kg/cow in Kenya, and with access to feed and feeding management being key limiting factors to productivity (MoALF, 2010), the productivity increases in the silage intervention farms in Central and Eastern regions can be linked to the work of the SPEs, especially to the silage making.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

Conclusions

i. Nutritional values of silage from maize train and bales and SPEs differed significantly but those of feed ration ingredients did not differ significantly across the interventions.

ii. Fodder conservation and feed ration interventions had significant effect on dairy farm performances. Maize train and baled silage and ration formulation using *Rumen8* software can support sustainable fodder management and feed rationing measures in dairy farms that can reduce seasonal milk fluctuation.

iii. The interventions had significant effect on income over feed cost in dairy farms in Kenya

Recommendations

i. To ensure quality silage, medium and large-scale dairy farms should adopt the concept of farm machinery, processes and logistics of ensuring proper fodder conservation.

ii. Dairy farmers should adopt the use of maize train and bale silage and ration formulation (*Rumen8*) software to achieve high milk yield.

iii. Dairy farms can adopt the use of the ration formulation software to enable them adjust the ration programs to accommodate the variations in cost of feeds and milk prices so as to achieve optimum income.

Further Research

Further studies on the effectiveness of forage and fodder as well as feeding regimes on smallholder dairy farms in Kenya is recommended.

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APPENDICES

Appendix 1: Analysis of variance (ANOVA)

Dependent Variable: Dry matter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	21689.91590	1807.49299	3192.58	<.0001
Error	26	14.72000	0.56615		
Corrected Total	38	21704.63590			

R-Square	Coeff Var	Root MSE	DM Mean
0.999322	0.979010	0.752432	76.85641

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	12	21689.91590	1807.49299	3192.58	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	12	21689.91590	1807.49299	3192.58	<.0001

Dependent Variable: Crude fibre

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	8653.341026	721.111752	1398.48	<.0001
Error	26	13.406667	0.515641		
Corrected Total	38	8666.747692			

R-Square	Coeff Var	Root MSE	CP Mean
0.998453	2.966336	0.718081	24.20769

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	12	8653.341026	721.111752	1398.48	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	12	8653.341026	721.111752	1398.48	<.0001

Dependent Variable: Ether extracts

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	438.5789744	36.5482479	181.35	<.0001
Error	26	5.2400000	0.2015385		
Corrected Total	38	443.8189744			

R-Square Coeff Var Root MSE EE Mean

0.988193	7.120083	0.448930	6.305128

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	12	438.5789744	36.5482479	181.35	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	12	438.5789744	36.5482479	181.35	<.0001

Dependent Variable: Neutral detergent fibre

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	3137.327692	261.443974	213.98	<.0001
Error	26	31.766667	1.221795		
Corrected Total	38	3169.094359			

R-Square	Coeff Var	Root MSE	NDF Mean
0.989976	3.217058	1.105348	34.35897

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	12	3137.327692	261.443974	213.98	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	12	3137.327692	261.443974	213.98	<.0001

Dependent Variable: Acid detergent fibre

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	4143.172308	345.264359	664.63	<.0001
Error	26	13.506667	0.519487		
Corrected Total	38	4156.678974			

R-Square	Coeff Var	Root MSE	ADF Mean
0.996751	3.383010	0.720755	21.30513

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	12	4143.172308	345.264359	664.63	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	12	4143.172308	345.264359	664.63	<.0001

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	63.25897436	5.27158120	26.16	<.0001
Error	26	5.24000000	0.20153846		

Corrected Total	38	68.49897436			
R-Square	Coeff Var	Root MSE	Ash Mean		
0.923503	8.515702	0.448930	5.271795		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	12	63.25897436	5.27158120	26.16	<.0001
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	12	63.25897436	5.27158120	26.16	<.0001

Dependent Variable: Milk yield per cow

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	7	169.9203198	24.2743314	4.80	0.0166
Error	9	45.5502685	5.0611409		
Corrected Total	16	215.4705882			
R-Square	Coeff Var	Root MSE	Milk Mean		
0.788601	12.48201	2.249698	18.02353		
Source	DF	Type I SS	Mean Square	F Value	Pr > F
Region	2	9.3324216	4.6662108	0.92	0.4323
Intervention	3	128.2402209	42.7467403	8.45	0.0055
Farmsize	1	0.2802089	0.2802089	0.06	0.8192
GrazingSystem	1	32.0674684	32.0674684	6.34	0.0329

		Standard		LSMEAN
Region	Milk LSMEAN	Error	Pr > |t|	Number
North rift	17.0068792	0.8766483	<.0001	1
Central	17.6065436	1.7211157	<.0001	2
Eastern	14.2122483	1.4854174	<.0001	3

		Standard		LSMEAN
Intervention	Milk LSMEAN	Error	Pr > |t|	Number
Rumen8	20.2359620	1.1333101	<.0001	1
Maize train	16.6409955	1.8055918	<.0001	2
SPEs silage	13.2837808	1.7971457	<.0001	3
Control	14.9401566	1.1860928	<.0001	4

				H0:LSMean1=
		Standard	H0:LSMEAN=0	LSMean2
Farmsize	Milk LSMEAN	Error	Pr > |t|	Pr > |t|
Lage scale	16.4391499	1.3629349	<.0001	0.8081
Medium scale	16.1112975	0.9095314	<.0001	

Grazing System	Milk LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
Semi-zero	14.4292506	1.5034117	<.0001	0.0329
Zero grazing	18.1211969	0.8007087	<.0001	

Dependent Variable: Milk yield per cow

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	179.3179607	19.9242179	3.86	0.0444
Error	7	36.1526276	5.1646611		
Corrected Total	16	215.4705882			

R-Square	Coeff Var	Root MSE	Milk Mean
0.832215	12.60901	2.272589	18.02353

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Region	2	9.3324216	4.6662108	0.90	0.4477
Intervention	3	128.2402209	42.7467403	8.28	0.0106
Farmsize	1	0.2802089	0.2802089	0.05	0.8225
GrazingSystem	1	32.0674684	32.0674684	6.21	0.0415
Intervent*GrazingSys	2	9.3976409	4.6988205	0.91	0.4454

Dependent Variable: Milk yield per Farm

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1321938.036	188848.291	12.12	0.0006
Error	9	140250.589	15583.399		
Corrected Total	16	1462188.625			

R-Square	Coeff Var	Root MSE	Milk Mean
0.904082	25.35629	124.8335	492.3176

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Region	2	174256.8987	87128.4494	5.59	0.0264
Intervention	3	466992.2693	155664.0898	9.99	0.0032
Farmsize	1	599615.0726	599615.0726	38.48	0.0002
GrazingSystem	1	81073.7951	81073.7951	5.20	0.0485

Dependent Variable: Milk protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.03668369	0.00524053	1.15	0.4120
Error	9	0.04096337	0.00455149		
Corrected Total	16	0.07764706			

R-Square	Coeff Var	Root MSE	MP Mean
0.472441	2.487852	0.067465	2.711765

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Region	2	0.00748039	0.00374020	0.82	0.4701
Intervention	3	0.00199806	0.00066602	0.15	0.9295
Farmsize	1	0.01310939	0.01310939	2.88	0.1239
GrazingSystem	1	0.01409584	0.01409584	3.10	0.1123

Dependent Variable: Feed efficiency

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.11396631	0.01628090	1.52	0.2745
Error	9	0.09662192	0.01073577		
Corrected Total	16	0.21058824			

R-Square	Coeff Var	Root MSE	FE Mean
0.541181	10.61103	0.103614	0.976471

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Region	2	0.03542157	0.01771078	1.65	0.2453
Intervention	3	0.04663953	0.01554651	1.45	0.2925
Farmsize	1	0.00589555	0.00589555	0.55	0.4776
GrazingSystem	1	0.02600966	0.02600966	2.42	0.1540

Dependent Variable: Milk butter fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.15370411	0.02195773	1.90	0.1819
Error	9	0.10394295	0.01154922		
Corrected Total	16	0.25764706			

R-Square	Coeff Var	Root MSE	MBF Mean
0.596568	2.913786	0.107467	3.688235

Source	DF	Type I SS	Mean Square	F Value	Pr > F

Region	2	0.04514706	0.02257353	1.95	0.1973
Intervention	3	0.10784884	0.03594961	3.11	0.0812
Farmsize	1	0.00004590	0.00004590	0.00	0.9511
GrazingSystem	1	0.00066231	0.00066231	0.06	0.8161

Dependent Variable: Milk yield per Cow ANOVA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	131.03185	32.75796	7.02	0.0038
Error	12	56.00815	4.66735		
Corrected Total	16	187.04000			

Root MSE 2.16040 R-Square 0.7006

Dependent Mean 17.60000 Adj R-Sq 0.6007

Coeff Var 12.27502

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	25.97515	2.97866	8.72	<.0001
Region	1	-0.63287	0.79316	-0.80	0.4404
Intervention	1	-1.77239	0.42092	-4.21	0.0012
Farmsize	1	0.69161	1.25505	0.55	0.5917
GrazingSystem	1	-2.95255	1.26603	-2.33	0.0379

C(p) Selection Method

Number in Model	C(p)	R-Square	AIC	BIC	SSE	Variables in Model
2	1.7225	0.6825	27.2627	31.0539	59.38019	Intervention GrazingSystem
3	3.3037	0.6930	28.6937	33.4559	57.42546	Region Intervention GrazingSystem
3	3.6367	0.6847	29.1477	33.6715	58.97974	Intervention Farmsize GrazingSystem

Dependent Variable: Dry matter feed intake

Analysis of Variance

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

Model	4	77.30388	19.32597	5.92	0.0072
Error	12	39.16082	3.26340		
Corrected Total	16	116.46471			

Root MSE	1.80649	R-Square	0.6638
Dependent Mean	15.91765	Adj R-Sq	0.5517
Coeff Var	11.34897		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	24.50469	2.49069	9.84	<.0001
Region	1	-0.69631	0.66322	-1.05	0.3145
Intervention	1	-1.28253	0.35196	-3.64	0.0034
Farmsize	1	-0.55021	1.04945	-0.52	0.6096
GrazingSystem	1	-2.40059	1.05863	-2.27	0.0426

C(p) Selection Method

Number in Model	C(p)	R-Square	AIC	BIC	SSE	Variables in Model
2	2.9978	0.6078	22.8037	25.9986	45.68033	Intervention GrazingSystem
3	3.2749	0.6561	22.5709	27.3541	40.05784	Region Intervention GrazingSystem
3	4.1023	0.6329	23.6798	27.8827	42.75795	Intervention Farmsize GrazingSystem

Dependent Variable: SCFA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	4.40212308	0.36684359	21.79	<.0001
Error	26	0.43766667	0.01683333		
Corrected Total	38	4.83978974			

R-Square	Coeff Var	Root MSE	degrat Mean
0.909569	27.63512	0.129743	0.469487

Least square means

Adjustment for Multiple Comparisons: Tukey

specie	degrat LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	0.94000000	0.07490735	<.0001	1
2	1.25000000	0.07490735	<.0001	2
3	0.94000000	0.07490735	<.0001	3
4	0.57333333	0.07490735	<.0001	4
5	0.28000000	0.07490735	0.0009	5
6	0.31000000	0.07490735	0.0003	6
7	0.34000000	0.07490735	0.0001	7
8	0.26000000	0.07490735	0.0018	8
9	0.27000000	0.07490735	0.0013	9
10	0.17000000	0.07490735	0.0318	10
11	0.15000000	0.07490735	0.0558	11
12	0.30000000	0.07490735	0.0005	12
13	0.32000000	0.07490735	0.0002	13

Dependent Variable: ME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	109.1000342	9.0916695	119.70	<.0001
Error	25	1.8988000	0.0759520		
Corrected Total	37	110.9988342			

R-Square	Coeff Var	Root MSE	degrat Mean
0.982894	2.400919	0.275594	11.47868

Source	DF	Type I SS	Mean Square	F Value	Pr > F
specie	12	109.1000342	9.0916695	119.70	<.0001

Least square means

specie	degrat LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	10.7700000	0.1591142	<.0001	1
2	11.9333333	0.1591142	<.0001	2
3	9.1900000	0.1591142	<.0001	3
4	14.7200000	0.1591142	<.0001	4
5	13.3700000	0.1591142	<.0001	5

6	12.2800000	0.1591142	<.0001	6
7	11.6900000	0.1591142	<.0001	7
8	10.1000000	0.1948743	<.0001	8
9	11.0700000	0.1591142	<.0001	9
10	9.6500000	0.1591142	<.0001	10
11	8.6800000	0.1591142	<.0001	11
12	13.0233333	0.1591142	<.0001	12
13	12.2866667	0.1591142	<.0001	13

Dependent Variable: *In-vitro* OMD%

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	4065.669544	338.805795	15.87	<.0001
Error	26	554.996000	21.346000		
Corrected Total	38	4620.665544			

R-Square	Coeff Var	Root MSE	degrat Mean
0.879888	14.07984	4.620173	32.81410

Source	DF	Type I SS	Mean Square	F Value	Pr > F
specie	12	4065.669544	338.805795	15.87	<.0001

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

specie	degrat LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	43.3800000	2.6674582	<.0001	1
2	56.3466667	2.6674582	<.0001	2
3	50.9333333	2.6674582	<.0001	3
4	27.4600000	2.6674582	<.0001	4
5	20.9500000	2.6674582	<.0001	5
6	31.4933333	2.6674582	<.0001	6
7	31.6533333	2.6674582	<.0001	7
8	29.7533333	2.6674582	<.0001	8
9	26.7000000	2.6674582	<.0001	9
10	25.7900000	2.6674582	<.0001	10
11	25.7300000	2.6674582	<.0001	11
12	28.0133333	2.6674582	<.0001	12
13	28.3800000	2.6674582	<.0001	13

Appendix 2 : Questionnaire

Field Study Questionnaire ; 3R Project (SNV)

Do you wish to participate in this survey? (*If respondent agrees to participate proceed with questionnaire*)

Yes ☐

No ☐

General Farm Information

A.1 Enumerator's Name…………………..

A.2 Date…………………………………

A.3 Farm name…………………………..

A.4 Name of respondent…………………

A.5 County of respondent

Trans Nzoia ☐

Uasin Gishu ☐

Nyeri ☐

Baringo ☐

Machakos ☐

Kajiado ☐

Kirinyaga ☐

Nakuru ☐

Kericho ☐

Kiambu ☐

Murang'a ☐

Meru ☐

Other ☐

A.6 Specify if County of respondent is other…………………………….

A.7 Village of respondent…………………………….

Farm Characterization

A.8 Farm size (*less than 100 litres (Small*); *100-599 litres (Medium) and Above 600 (Large*)

Small Scale ☐

Medium Scale ☐

Large Scale ☐

A.9 Farm Category

Zero-grazing System ☐

Semi zero-grazing System ☐

Grazing System ☐

A.10 Intervention

Maize-silage (SPEs) ☐

Control (SPEs) ☐

Maize-silage (maize train/baled) ☐

Control (maize train/baled) ☐

Feed-rationing (*Rumen8*) ☐

Control (*Rumen8*) ☐

A.11 What was the amount of milk production yesterday L/farm/day?………….

A.12 How many cows were milked yesterday?………………..

Herd data

B.1 In total, how many cows are in this farm (lactating and dry)?………………..

B.2 How many lactating cows are in this farm?……………………..

B.3 In total how many dry cows are in this farm?…………………….

B.4 How many heifers not calved do you have in the farm?……………..

B.5 How many Calves pre weaning do you have in the farm?……………….

B.6 How many Bulls are there in this farm?…………………….

B.7 How many Breeding bulls are there in the farm?……………………..

C.1 How many times do you feed your dairy cattle per day?

Once ☐

Twice ☐

Thrice ☐

More than three ☐

C.2 Types of roughages fed

Roughages ☐

Straw ☐

Stover ☐

Fresh grass ☐

Hay ☐

Maize silage ☐

Grass silage ☐

Specify if any other roughage ☐

C.3 Specify if roughage fed is other……………..

C.4 Specify if straw fed

Rice straw ☐

Barley straw ☐

Wheat straw ☐

Other straw (please specify) ☐

C.5 Type of stovers fed

Maize Stover ☐

Millet Stover ☐

Sorghum Stover ☐

Other Stover (please specify) ☐

C.6 Types of concentrates fed

Dairy meal (specify manufacturer) ☐

Soya ☐

Rapeseed ☐

Corn Gluten Meal ☐

Cotton ☐

Sunflower ☐

Fish Meal ☐

Maize grain ☐

Maize Germ ☐

Maize Bran ☐

Rice Polish Bran ☐

Wheat Bran ☐

Wheat Pollard ☐

Poultry waste dry ☐

Brewer’s grain ☐

C.7 Specify the manufacturer if you feed dairy meal………………..

Feeding

E.1 Feeding of dairy cattle (*To be replicated for early, mid and late lactation*)

E.2 Which grazing system do you practice with the lactating cow?

Grazing ☐

Semi-zero-grazing ☐

Zero-grazing ☐

E.3 How many hours do you graze your lactating cows?……………..

E.4 Select the type of grass the lactating cows are grazed on

Kikuyu grass ☐

Boma Rhodes grass ☐

Couch grass ☐

Other grass ☐

E.5 If cows are grazed on other grass please specify……………..

E.6 Do you feed your cows differently based on the stage of lactation (*e.g. early, mid and late lactation?*)

(***Note:*** *Use early lactation in place of high yielders and late lactation in place of low yielders. If enumerator include mid it will imply farmer differentiate feeding in three lactation stages. If the response of whether respondent differentiate feeding is yes, enumerator should select at least two lactation stages*)

Yes ☐

No ☐

F.1 Select the lactating stage

Early ☐

Mid ☐

Late ☐

G.1 What is the total amount of roughage in kgs that you feed to all your dairy cows per day?.............

G.2 What is the total amount (kgs) of grass that you feed to your dairy cattle per day?..........………

G.3 Quality assessment for Fresh cut grass

Harder yellow brown (HYB)(Poor grain Stover) ☐

Softer yellow green (SYG) (Poor tropical grass) ☐

Harder light green (HLG) (Legume Stover) ☐

Soft hard light green (SHLG) (Medium quality tropical grass) ☐

Soft light green (SLG) (Medium/high quality tropical grass) ☐

Harder green (SHG) (Grass/legume mixtures) ☐

Softer green (SG) (High quality tropical grass) ☐

Soft dark green (SDG) (High quality legumes) ☐

G.4 Quantity as fed in kg/cow/day for Fresh cut grass……………………….

G.5 Price in KES per kg for Fresh cut grass…………………….

G.6 What is the total amount (in Kgs) of hay that you feed to all your dairy cattle per day?………

G.7 Quantity in kg/cow/day for Hay…………………..

G.8 Price in KES per kg for Hay……………………..

G.9 What is the total amount (kgs) of maize silage that you feed to all of your dairy cattle per day?....

G.10 Quantity in kg/cow/day for Maize silage………………..

G.11 Price in KES per kg for Maize silage……………………….

G.12 What is the total amount (kgs) of grass silage that you feed to all of your dairy cattle per day?...

G.13 Quantity in kg/cow/day for Grass silage………………….

G.14 Price in KES per kg for Grass silage……………………….

H.15 Specify other type of roughage not specified above?………………...

I.16 What is the total amount (kgs) of other roughages that you feed to all of your dairy cattle/day?

I.17 Quantity in kg/cow/day for the other roughages………………………

I.18 Price in KES per kg for the other roughages……………….

J.1 What is the total amount (kgs) of straw that you feed to all of your dairy cattle per day?..….

J.2 Quantity in kg/cow/day for straw…………………

J.2 Price in KES per kg for straw……………………

K.1 Which concentrates are fed to your lactating cows?……………

K.2 Specify the manufacturer of dairy meal……………..

K.3 What is the total amount in Kgs of dairy meal that you feed your cows per day?………….

K.4 Quantity in kg/cow/day for Dairy meal……………

K.5 Price in KES per kg for Dairy meal……………

Herd data

D.1 Total number of cows…………………

D.2 Number of lactating cows…………………

D.3 Average weight of lactating cows in Kgs…………………

D.4 Total number of dry cows…………………

D.5 Average weight of dry cows in Kgs…………………

D.6 Number of Heifers…………………

D.7 Average weight of heifers in Kgs…………………

D.10 Number of Calves of age 0 to 3 months……………......

F.1 Average Heifer value in KES/heifer…………………

F.2 Average Cull cow value in KES/Cow…………………

F.3 Average male Calf value in KES/male calf…………………

F.3 Average female Calf value in KES/female calf…………………

Detailed characterization of mature cows

Detailed characterization of mature cows Data to be collected for all cows for herd with up to 10 cows, 5 cows each from (dry, early lactation, mid lactation, late lactation)

J.1 Number of cows to be characterized………………………

K.1 Cow Identification………………

K.2 Date of birth of this cow……………….

K.3 Is this cow in-calf? Yes/No…………………

K.4 Is this cow lactating or Dry………………..

K.5 What is the lactation number (Parity?)………………….

K.6 In what stage of lactation is this cow in? (*Early, Mid, Late*)…………………..

K.7 What is the heart girth of this cow in cm?…………………..

K.8 What is the average milk production of this cow in kg?………………………

K.9 Indicate body condition score of this cow?……………………….

K.10 What is the breed of this cow?………………………..

K.11 What is the date of calving of this cow?………………………

Milk Utilization

EC.1 Amount of milk in litres fed to calves…………………..

EC.2 Amount of milk in litres given to workers for free…………………..

EC.4 Which channels did you sell your milk through in the last month?

- Cooperative society ☐
- Hawkers at Farm gate ☐
- Own milk bar/ATMs ☐
- To other milk bars/ATMs ☐
- Hotels ☐
- School ☐
- Neighbours ☐
- Processor ☐
- Other specify ☐

EC.5 If you sell milk through cooperative which cooperative?…………………….

EC.6 If you sell milk through processor, which processor?………………………….

EC.7 If you sell your milk through other channels please specify……………………………

EC.8 What amount of milk do you sell through cooperative in litres per day?……………….

EC.9 What amount of milk do you sell through hawkers in litres per day?…………………….

EC.10 What amount of milk do you sell through own milk bar in litres per day?…………….

EC.11 What amount of milk do you sell through other milk bar in litres per day?…………..

EC.12 What amount of milk do you sell through hotels in litres per day?……………………….

EC.13 What amount of milk do you sell through school in litres per day?………………………

EC.14 What amount of milk do you sell through neigbours in litres per day?…………………

EC.15 What amount of milk do you sell through processors in litres per day?………………….

EC.16 What amount of milk do you sell through other channels in litres per day?…………….

EC.17 What price does cooperative offers in Kenya shillings per litre?

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)..…....

EC.18 What price does hawkers offers in Kenya shillings per litre

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

EC.19 What price does own milk bar offers in Kenya shillings per litre?

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

EC.20 What price does other milk bar offers in Kenya shillings per litre?

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

EC.21 What price does hotel(s) offers in Kenya shillings per litre

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

EC.22 What price does school offers in Kenya shillings per litre

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

EC.23 What price does neigbours offers in Kenya shillings per litre

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

EC.24 What price does processor offers in Kenya shillings per litre?

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)…..

EC.25 What price does other milk buyers offers in Kenya shillings per litre

(*Note: The farmer should decide which price should be used in the Rumen8 calculations*)……

J.18 What is your current education level?

Primary education incomplete ☐

Primary education complete ☐

Secondary education incomplete ☐

Secondary education complete ☐

College/TVET education ☐

University education (under graduate) ☐

University education (masters) ☐

University education PhD ☐

J.19 Have you received any other training related to dairy farming?

Yes ☐

No ☐

J.20 List the subject area of dairy farming training that you were trained on?……………

J.21 List the stakeholders who trained you on dairy enterprises?

Appendix 3: Photos of the Interventions and Laboratory analysis of feed ingredients

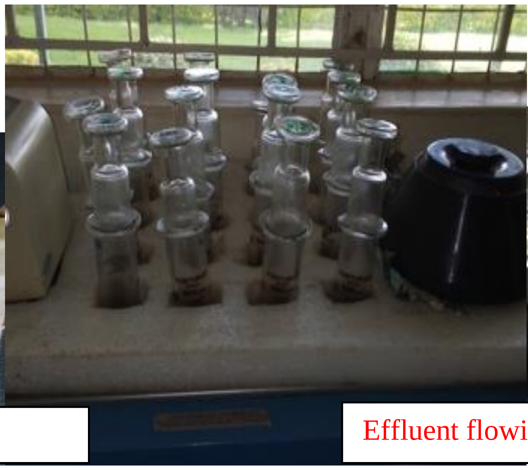
Maize train silage

Baled maize silage

SPEs maize

In-vitro degradation process

Feed samples for laboratory



Effluent flowing from SPE maize silage

APPENDIX 4: RESEARCH PERMIT

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APPENDIX 5: PUBLICATION

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Evaluation of nutritive value of feeds and feed ration ingredients from different interventions used by dairy farms in Kenya

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Abstract
Dairy cows' production potential in Kenya is affected by inadequate supply of quality feeds. Chemical analysis and *in-vitro* degradability of feed ingredients from twelve farms using each of the three interventions: maize train and bale silage, silage from Service Provider Enterprises (SPEs), and feed ingredients from farms using ration formulation (*Rumen8*) software were compared with 12 control farms for each intervention. Data from the experiments was subjected to analysis of variance using the General linear model. Mean separation was done using least significant difference at 5% level of significance. Dry matter content of maize train silage (34.4%) and baled silage (34.9%) differed from SPEs silages (32.3%) ($p<0.05$). Neutral detergent fibre ranged from 13.9% in soybean meal to 46.6% in SPEs silage. Metabolizable energy ranged from 8.7MJ/kgDM in sunflower meal to14.7MJ/kgDM in maize germ. Organic matter degradability was high in maize train silage (56.4%) and lowest in sunflower meal (25.8%). In conclusion, use of maize train and baler intervention is the best fodder conservation measure for quality silage.

Keywords: Chemical composition, *In-vitro* degradability, maize train silage, short chain fatty acids, service provider enterprises, rumen8 ration

Introduction

Livestock production in the tropical regions of Kenya is affected by the inadequate supply of quality feeds [1]. The optimal dairy cattle feeding regime should consist of 75% energy sources, 24% protein sources and 1% mineral sources [2,3]. The nutritive value of an animal feed is determined predominately by its digestibility, which affects intake. Digestibility and intake, in turn, determine the feeds' influence (such as support of milk synthesis) on productive performance [4]. The performance of animals maintained in resource-poor surroundings is usually poor due to seasonal fluctuations in the quality and supply of animal feeds. When accessible even in limited quantities, the fibrous feeds such as cereal crop residues and poor-quality mature grasses can not maintain animals during much of the year [5].

In-vitro gas methods primarily measure digestion of soluble and insoluble carbohydrates [6], and the amount of gas produced from a feed on incubation reflects production of volatile fatty acids (VFA), which are a major source of energy for ruminants. Rumen fermentation by anaerobic microbes results in production of short chain fatty acids (SCFA), gases (carbon dioxide (CO_2) and methane (CH4)) and microbial mass [7].

The 3R Project Kenya documentation of KMDP fodder interventions (Maize train/baled silage, service provider enterprises (SPEs) silage, and dairy ration formulation using *Rumen8* software) reported that with good quality (maize, sorghum, grass) silage to replace hay in the total mixed rations, the farmer can reduce the share of dairy meal in the ration and cost price of milk. Use of SPE silage-making services was most frequent among farmers in Central and Eastern regions, where the majority (75%) of farmers used the services at least four times per year [8]. Scarcity and low quality of feed resources constitute one of the major constraints to improved dairy productivity. Therefore, improving the efficiency of feed conversion to milk can have a significant impact on the productivity and profitability of dairy farms.